Mitigation Measure M-GCC-7
Attachment “A”

Part 3 of 3: Verra

PREFACE

During the Village 13 Project's implementation phase and prior to the County's issuance of Project-related grading and building permits, the County shall reference and use Mitigation Measure M-GCC-7 Attachment "A" to determine whether the Project is proposing to use eligible carbon offset project types to meet its CEQA mitigation obligations under mitigation measures M-GCC-7 and M-GCC-8. This Preface describes the contents of Attachment "A."

Mitigation Measure M-GCC-7 Attachment "A" contains copies of the manuals used by the Climate Action Reserve, American Carbon Registry and Verra to administer their carbon offset programs. Each manual contains the foundational principles and standards deployed by the registries to ensure that their carbon offset programs achieve high standards of environmental integrity. As such, the manuals contain generally applicable GHG reduction accounting guidelines; rules and procedures for carbon offset project registration, implementation, and verification; and, standards for the development of protocols and methodologies. The registries' program manuals are updated from time to time; reference should be made to the current iteration of each manual, as needed.

Mitigation Measure M-GCC-7 Attachment "A" also contains all of the carbon offset protocols and methodologies of these three registries that the County has determined to be eligible for use when reducing GHG emissions pursuant to mitigation measures M-GCC-7 and M-GCC-8 of the Village 13 Project's EIR. While the following bulleted summary is not an exhaustive listing of the types of information contained in protocols and methodologies, each of the Attachment "A" protocols and methodologies routinely provide the following type of information:

- A description of the specific carbon offset project type, and associated definitional parameters;
- Eligibility rules pertaining to project location, start date, the crediting period, the additionality tests, and regulatory compliance;
- A description of the GHG assessment boundary and rules for quantifying both baseline and project emissions; and,
- Project monitoring and reporting requirements, including related verification standards.

The County of San Diego has reviewed and determined that the protocols and methodologies included in Attachment "A" establish and require carbon offset projects to comply with standards designed to achieve additional, real, permanent, quantifiable, verifiable and enforceable reductions. In making this determination, the County reviewed the registries' program manuals, the registries' websites (which provide additional background information on each protocol and methodology, including comments from interested members of the public and experts in the field), and the registries' protocols and methodologies included herein. As such, when implementing mitigation measures M-GCC-7 and M-GCC-8, the Village 13 Project shall procure offsets only from the carbon offset project types authorized by the Attachment "A" protocols and methodologies.

The Attachment "A" protocols and methodologies are periodically updated by the registries, pursuant to their established processes, in response to public comments, on-the-ground experience, and technological, scientific and regulatory developments. Updates ensure no reduction in efficacy and environmental integrity, in accordance with the registries' program manuals. Related iterations of the protocols and methodologies for the carbon offset project types listed herein may be used. However, protocols and methodologies for carbon offset project types that are not listed herein cannot be utilized by the Village 13 Project, absent additional evaluation and action by the County of San Diego.

MITIGATION MEASURE M-GCC-7
ATTACHMENT "A"

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** As provided in mitigation measures M-GCC-7 and M-GCC-8, the protocols and methodologies, and other related documents contained in this Attachment are periodically updated by the registries, pursuant to their established processes, in response to public comments, on-the-ground experience, and technological, scientific and regulatory developments. Related iterations of the protocols and methodologies for the carbon offset project types listed herein may be used during the mitigation implementation phase. However, protocols and methodologies for carbon offset project types that are not listed herein cannot be utilized, absent additional County evaluation and action.*

Program Guide

19 September 2019

v4.0

ABOUT VERRA

Verra supports climate action and sustainable development through the development and management of standards, tools and programs that credibly, transparently and robustly assess environmental and social impacts, and drive funding for sustaining and scaling up these benefits. As a mission-driven, non-profit (NGO) organization, Verra works in any arena where we see a need for clear standards, a role for market-driven mechanisms and an opportunity to achieve environmental and social good.

Verra manages a number of global standards frameworks designed to drive finance towards activities that mitigate climate change and promote sustainable development, including the Verified Carbon Standard (VCS) Program and its Jurisdictional and Nested REDD+ framework (JNR), the Verra California Offset Project Registry (OPR), the Climate, Community & Biodiversity (CCB) Standards and the Sustainable Development Verified Impact Standard (SD VISta). Verra is also developing new standards frameworks, including LandScale, which will promote and measure sustainability outcomes across landscapes. Finally, Verra is one of the implementing partners of the Initiative for Climate Action Transparency (ICAT), which helps countries assess the impacts of their climate actions and supports greater transparency, effectiveness, trust and ambition in climate policies worldwide.

Intellectual Property Rights, Copyright and Disclaimer

CONTENTS

1 INTRODUCTION

The Verified Carbon Standard (VCS) Program provides a global program and standard for GHG emission reduction and removal projects and programs. It uses as its core the requirements set out in *ISO 14064-2:2006, ISO 14064-3:2006 and ISO 14065:2013*. The *VCS Program Guide* (this document) is the overarching program document and provides the rules and requirements governing the VCS Program, and describes the constituent parts of the program such as the project and program registration process, the Verra registry system, the methodology approval process, and the accreditation requirements for validation/verification bodies.

1.1 Version

VCS Program editions are labeled with a version number and program documents are correspondingly version controlled. *VCS Version 4* is the fourth working version of the VCS, having been preceded by *VCS Version 1* (the initial version), *VCS 2007* and *VCS 2007.1* (which were two releases of the same version, but with the latter version incorporating the agriculture, forestry and other land use (AFOLU) specifications), and *VCS Version 3*.

VCS Version 4 was released on 19 September 2019 and becomes the applicable version with immediate effect, except where grace periods were set out for particular requirements.

VCS Version 4 is comprised of all the program documents labeled v4.x, where x is a running number starting at zero. Individual program documents may be updated from time-to-time, as developments require, and their version numbers will be incremented using the v4.x format. Such updated documents still form part of version 4 and the VCS Program edition should be referred to as *VCS Version 4* regardless of the version numbers of the individual program documents. Where documents are updated, an appendix to the document will clearly state the updates made and their effective date. VCS Program stakeholders will be informed of the updates and the updates will also be catalogued on the Verra website. Readers shall ensure that they are using the most current version of this and all other program documents.

Note that errata documents may also be issued on a periodic basis to correct typographical errors in text, equations or figures in VCS Program documents or methodologies. In addition, clarification documents may be issued to provide additional guidance on the VCS Program rules or methodological requirements. Errata and clarification documents are posted to the Verra website alongside the relevant program document or methodology, and are effective on their issuance date. Project proponents and validation/verification bodies shall apply and interpret the VCS Program rules and methodological requirements consistent with any errata and clarifications. Errata and clarifications will be incorporated into the next issued version of the relevant program document or methodology.

New versions of the VCS Program will be issued on a periodic basis when major edition updates are required. Development of new versions of the program will include public stakeholder consultation and will be announced on the Verra website and to VCS Program stakeholders.

The VCS Program documents for previous versions of the VCS Program are available on the Verra website and these should be referred to for the rules and requirements under such previous versions of the VCS Program.

Note that projects, programs and verified carbon units (VCUs) are not labeled in the Verra registry with a specific version of the VCS Program (i.e., projects are not “Version 3 projects” or “Version 4 projects”, and likewise with VCUs). The VCS Program documentation is merely labeled with a version in order to provide version control over the program documents.

1.2 Language

The operating language of the VCS Program is English. The VCS Program documents may be translated into other languages to facilitate local use. However, the English versions of VCS Program documents, and the interpretation of same, shall take precedence over any other language translations.

1.3 Definitions

Definitions as set out in the VCS Program document *Program Definitions*, *ISO 14064-2:2006*, *ISO 14064-3:2006* and *ISO 14065:2013* shall apply to all VCS Program documentation. Note that defined terms in the VCS Program documents, in common with ISO convention, are used without capital first letters.

2 OVERVIEW OF THE VCS PROGRAM

2.1 Program Objectives

The VCS Program establishes the rules and requirements that operationalize the *VCS Standard* to enable the validation of GHG projects and programs, and the verification of GHG emission reductions and removals that can be used both in voluntary and compliance markets. The VCS Program aims to:

1) Establish clear rules and procedures to enable the successful development of GHG projects and programs, and the creation of high quality GHG credits;
2) Create a trusted and fungible GHG credit, the VCU;
3) Stimulate innovation in GHG mitigation technologies and measures as well as procedures for validation, verification and registration, all within a context of quality, credibility and transparency;
4) Provide a secure registry system for all VCUs that offers assurance against double counting and provides transparency to the public;
5) Demonstrate workable frameworks and offer lessons that can be incorporated into other GHG programs and climate change regulation;
6) Provide oversight to ensure that investors, buyers and the market recognizes VCUs as being real, additional and permanent; and
7) Link carbon markets worldwide through a coherent and robust framework.

2.2 Program History

The Climate Group, the International Emissions Trading Association and the World Business Council for Sustainable Development are the partner organizations that founded the VCS Program. The World Economic Forum also partnered in the development of the VCS Program for part of the process. *VCS Version 1* was released on 28 March 2006 as both a consultation document and a standard for use by the market. *VCS Version 2* was released in October 2006 as a consultation document and did not replace *VCS Version 1* as the applicable version. After two years of work, two rounds of public consultation and the work of the 19-member steering committee[1] and seven technical working groups, *VCS 2007* was released on 19 November 2007. *VCS 2007.1*, which incorporated requirements for agriculture, forestry and other land use projects, was released on 18 November 2008. *VCS Version 3* was issued on 8 March 2011. *VCS Version 4* was released on 19 September 2019.

[1] The members of the steering committee were Jan-Willem Bode, Derik Broekhoff, Mike Burnett, Robert Dornau, Steve Drummond, Mitchell Feierstein, Yoshito Izumi, Mark Kenber, Adam Kirkman, Andrei Marcu, Erin Meezan, Ken Newcombe, Mark Proegler, Robert Routliffe, Richard Samans, Marc Stuart, Einar Telnes, Bill Townsend and Diane Wittenberg.

2.3 Program Scope

The VCS Program provides the standard and framework for independent validation of projects and programs, and verification of GHG emission reductions and removals, based on *ISO 14064-2:2006* and *ISO 14064-3:2006*. The scope of the VCS Program covers all those activities related to the generation of GHG emission reductions and removals, including jurisdictional programs and nested REDD+ projects. The scope does not include carbon footprint assessments or carbon neutrality claims.

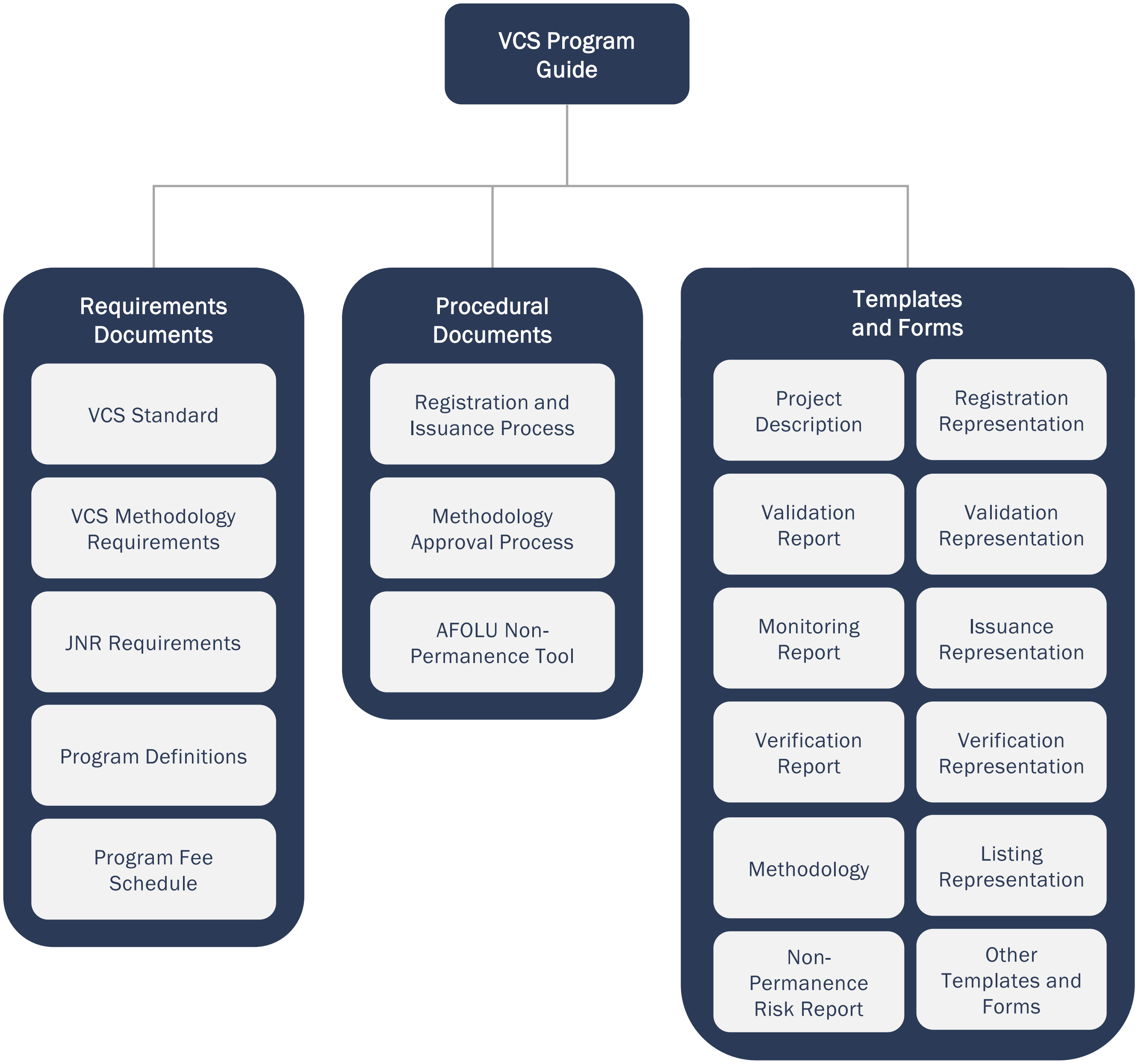
Participation is voluntary and based on objective criteria. The VCS Program is not discriminatory to project proponents, jurisdictional proponents, methodology element developers, validation/verification bodies, or VCU buyers, sellers or brokers.

2.4 Program Documents

The rules and requirements for the VCS Program are set out in the program documents. Projects, programs and methodologies shall meet with all the applicable rules and requirements set out in these documents.

The structure of the program documents is summarized in Diagram 1. The *VCS Program Guide* is the overarching program document, providing the rules and requirements governing the VCS Program and further describing the constituent parts of the program such as the project and program registration process, the Verra registry system, the methodology approval process, and the accreditation requirements for validation/verification bodies. Complementing the *VCS Program Guide* are requirements documents, procedural documents and templates and forms. Verra may issue new documents, as developments in the VCS Program require, and the complete and current list of the program documents is available on the Verra website.

Diagram 1: Program Documents



In addition to the *VCS Program Guide*, the program documents currently include the following:

1) Requirements Documents

   a) *VCS Standard*. Provides the requirements for developing projects and for the validation and verification process.

   b) *Methodology Requirements*. Provides the requirements for developing new methodology elements.

   c) *JNR Requirements*. Provides further requirements for developing jurisdictional REDD+ programs and nested REDD+ projects.

   d) *Program Definitions*. Provides the definitions for terms used in the VCS Program documents.

   e) *Program Fee Schedule*. Provides the fees related to the various parts of the VCS Program.

2) Procedural Documents

   a) *Registration and Issuance Process.* Provides the procedures and rules for registering projects and issuing VCUs.

   b) *JNR Registration and Issuance Process.* Provides the procedures and rules for registering jurisdictional baselines and jurisdictional REDD+ programs, as well as projects nested in jurisdictional programs and standalone projects operating under Scenario 1.

   c) *JNR Validation and Verification Process.* Provides the process and requirements for the validation and verification of jurisdictional baselines and jurisdictional REDD+ programs.

   d) *Methodology Approval Process.* Provides the procedures and rules for approval of VCS Program methodology elements.

   e) *AFOLU Non-Permanence Risk Tool.* Provides the procedure for conducting non-permanence risk analysis and buffer determination for AFOLU projects.

3) Templates and Forms

   a) *VCS Program Templates.* Templates for project descriptions, validation reports, monitoring reports, verification reports and methodologies.

   b) *Representations Templates.* Templates for deeds of representation made by project proponents and validation/verification bodies.

   c) *Forms.* Forms such as for submitting methodology elements under the methodology approval process and for applying to be an AFOLU expert.

The following are normative (referenced) documents for the VCS Program:

1) *ISO 14064-2:2006*, Greenhouse gases – Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements, ISO, 2006.

2) *ISO 14064-3:2006*, Greenhouse gases – Part 3: Specification with guidance for the validation and verification of greenhouse gas assertions, ISO 2006.

3) *ISO 14065:2013*, Greenhouse gases – Requirements for greenhouse gas validation and verification bodies for use in accreditation or other forms of recognition, BSI, 2007.

4) *The GHG Protocol for Project Accounting* (Chapter 7, guidance related to additionality and common practice), WRI, 2005.

The four standards above are part of the requirements of the VCS Program and their requirements shall be met either by the project proponent (*ISO 14064-2:2006*) or validation/verification body (*ISO 14064-3:2006* and *ISO 14065:2013*). Where there is any conflict between VCS Program documentation and the above normative references, the VCS Program documentation shall take precedence.

The program documents are also complemented by a number of guidance documents. These guidance documents do not set out VCS Program rules and requirements, but they provide additional information to assist with the interpretation of the rules and requirements. It is strongly encouraged that such guidance is followed.

2.5 Roles and Responsibilities

2.5.1 Project and Jurisdictional Proponents

Project and jurisdictional proponents are the entities with overall control and responsibility for projects or programs. A project may have one project or jurisdictional proponent, or there may be a number of project or jurisdictional proponents who collectively have overall control and responsibility for a project or program. Project and jurisdictional proponents establish and operate projects and programs in accordance with the VCS Program rules. They are responsible for providing the project or program description, monitoring report and supporting documentation (including evidence of project ownership or program ownership) to facilitate validation and verification.

Project and jurisdictional proponents sign unilateral representations with respect to their projects or programs and VCUs, and these are made available on the Verra registry. Project proponents assume limited liability for replacement of excess VCUs, as set out in Section 4.2.

Note – In order to aid the readability of the VCS Program documentation, the documents use project and jurisdictional proponent in the singular. For projects and programs with multiple project or jurisdictional proponents, "project proponents" or "jurisdictional proponents" should be substituted in place of "project proponent" or "jurisdictional proponent", as appropriate.

2.5.2 Methodology Element Developers

Methodology element developers are entities that develop methodologies, methodology revisions, modules and tools that are subject to the methodology approval process.

2.5.3 Validation/Verification Bodies

Validation/verification bodies are accredited to:

1) Validate projects and verify GHG emission reductions and removals.

2) Assess methodology elements under the methodology approval process.

Validation/verification bodies are only eligible to carry out work for the sectoral scopes for validation and verification for which they hold accreditation and must sign the required agreement with Verra before they can perform validation or verification in connection with the VCS Program. The list of validation/verification bodies is available on the Verra website.

2.5.4 Verra Registry

The Verra registry is responsible for ensuring that all required project and program documents have been submitted to Verra; issuing and maintaining accounts of VCUs for accountholders; ensuring the seamless flow of VCUs throughout the entire Verra registry system; tracking and reporting the deposit/withdrawal of buffer credits to/from the centrally managed AFOLU pooled buffer account and jurisdictional pooled buffer account; and maintaining custody and records of VCU legal ownership.

2.5.5 VCU Buyers, Sellers and Brokers

Buyers, sellers and brokers are companies, organizations or individuals who transact VCUs or facilitate the transaction of VCUs.

2.5.6 Verra

The VCS Program is managed by Verra, which is an independent, non-profit organization incorporated under the laws of the District of Columbia in the United States. Verra is responsible for managing, overseeing and developing the program. It maintains an impartial position in the market and does not develop projects, programs or methodologies, nor does it provide validation, verification or consulting services.

One of Verra's roles is in respect of overseeing and ensuring the integrity of projects, programs and VCUs in the Verra registry system. Verra conducts reviews of project and program registration and VCU issuance requests. Verra is also responsible for overseeing the validation/verification bodies operating under the VCS Program. Where Verra identifies shortcomings in a validation/verification body's performance, it may provide feedback and require the validation/verification body to address non-conformities.

Verra reserves the right not to register projects and programs, or issue VCUs where it deems that they are not in compliance with the VCS Program rules or may otherwise impact the integrity of the VCS Program or the functioning of the broader carbon market, and to delist projects, programs and VCUs where it deems that they have not been registered or issued in accordance with the VCS Program rules. Verra also reserves the right to take action against validation/verification bodies in accordance with the provisions set out in the agreements signed with Verra. The rights and obligations for validation/verification bodies are set out in such agreements.

Verra is also responsible for managing the methodology approval process, and it reserves the right to not accept methodology elements into the process, not approve methodology elements, or review and update, put on hold or withdraw approved methodology elements where it deems that they are not in compliance with the VCS Program rules, would sanction politically or ethically contentious project activities, or may otherwise impact the integrity of the VCS Program or the functioning of the broader carbon market.

Verra may convene steering committees, advisory committees or working groups to support its work in specific areas. These groups draw in expertise from outside the organization to develop and support specific elements of the VCS Program. A full list of steering committees and working groups is available on the Verra website.

3 VCS PROGRAM CRITERIA FOR GHG PROJECTS AND PROGRAMS

All projects and programs shall meet the requirements set out in the *VCS Version 4* program documents.

GHG emission reductions and removals verified under the VCS Program and issued as VCUs shall meet the following principles:

Real
All GHG emission reductions and removals and the projects or programs that generate them must be proven to have genuinely taken place.

Measurable
All GHG emission reductions and removals must be quantifiable using recognized measurement tools (including adjustments for uncertainty and leakage) against a credible emissions baseline.

Permanent
Where GHG emission reductions or removals are generated by projects or programs that carry a risk of reversibility, adequate safeguards must be in place to ensure that the risk of reversal is minimized and that, should any reversal occur, a mechanism is in place that guarantees the reductions or removals will be replaced or compensated.

Additional
GHG emission reductions and removals must be additional to what would have happened under a business-as-usual scenario if the project had not been carried out.

Independently Audited
All GHG emission reductions and removals must be verified to a reasonable level of assurance by an accredited validation/verification body with the expertise necessary in both the country and sector in which the project is taking place.

Unique
Each VCU must be unique and must only be associated with a single GHG emission reduction or removal activity. There must be no double counting, or double claiming of the environmental benefit, in respect of the GHG emission reductions or removals.

Transparent
There must be sufficient and appropriate public disclosure of GHG-related information to allow intended users to make decisions with reasonable confidence.

Conservative
Conservative assumptions, values and procedures must be used to ensure that the GHG emission reductions or removals are not over-estimated.

4 VERRA REGISTRY

The Verra registry provides the public interface to all project, program and VCU information. VCU serial numbers are generated by the registry, which ensures uniqueness of projects, programs and VCUs. In addition, the Verra registry provides full transparency on project and program documentation, together with information on project and jurisdictional proponents, VCU issuance and retirement, the AFOLU pooled buffer account and the jurisdictional pooled buffer account.

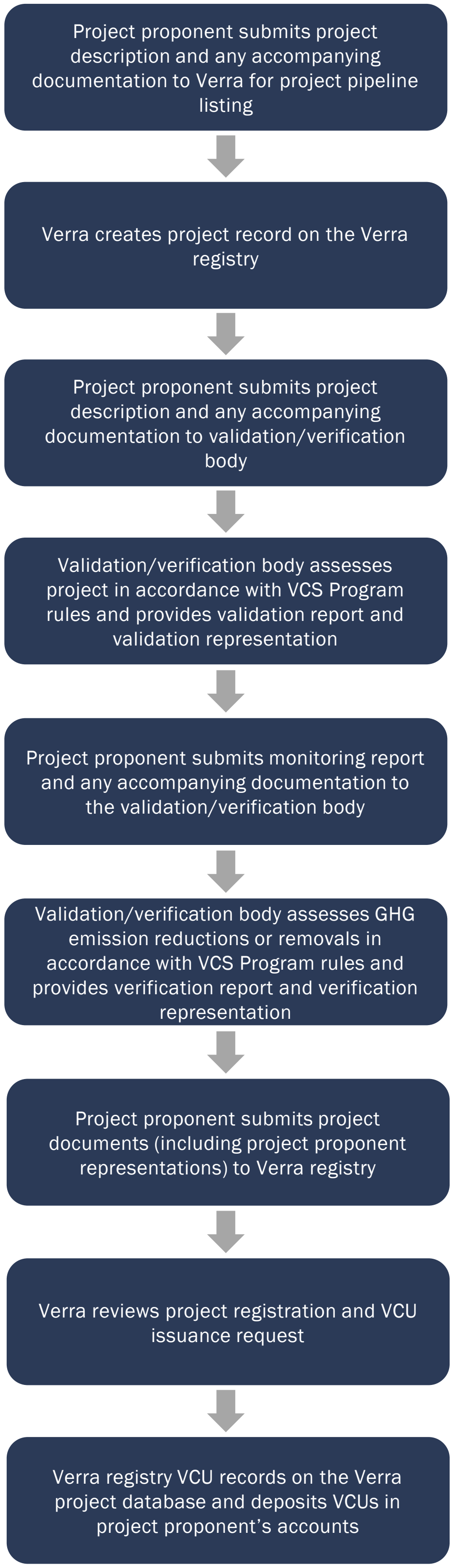
The AFOLU pooled buffer account holds non-tradable buffer credits to cover the non-permanence risk associated with AFOLU projects. It is a single account that holds the buffer credits for all projects. The account is subject to a periodic reconciliation, as set out in the VCS Program document *VCS Standard*. Likewise, the jurisdictional pooled buffer account holds the non-tradable buffer credits to cover the non-permanence risk associated with jurisdictional REDD+ programs and nested projects.

The Verra registry provides accountholder services and is the entry point into the registry system for project and jurisdictional proponents, and VCU buyers and sellers. Such market participants open an account with the Verra registry and project and program registration and VCU issuance is initiated with the Verra registry.

The Verra registry is responsible for ensuring that projects and programs are registered and VCUs are issued in accordance with the VCS Program rules; providing services for holding, transferring and retiring VCUs; managing AFOLU and jurisdictional buffer credits; and providing custodial services for VCUs and maintaining records of VCU legal ownership.

Project and jurisdictional proponents (or other eligible entities, as set out in the VCS Program documents *Registration and Issuance Process* and *JNR Registration and Issuance Process*) request listing and registration of projects and programs, and VCU issuance, with the Verra registry. Diagram 2 outlines the project life cycle and registration process, which is similar to the program life cycle and registration process. Once the project or program has been validated and the GHG emission reductions or removals verified, the project or jurisdictional proponent submits the relevant documents to the Verra registry. Verra conducts a completeness review of the documents, and may conduct a further accuracy review to assess compliance with the VCS Program rules. Where it is determined that the project or program complies with the VCS Program rules, Verra uploads the documents to the public Verra registry and issues VCUs into the project or jurisdictional proponent's account. Note that validation and verification may be undertaken simultaneously, with registration and issuance of the VCUs occurring at the same time, or validation may occur before verification, with registration occurring before any subsequent issuance of VCUs.

Diagram 2: Project Life Cycle and Registration Process



The process and detailed rules and requirements for project pipeline listing, program listing, project and program registration, and VCU issuance are set out in the VCS Program documents *Registration and Issuance Process* and *JNR Registration and Issuance Process*.

4.1 VCS Program Fees

Verra charges fees to cover administration costs, at the rates set out in the VCS Program document *Program Fee Schedule*.

4.2 VCU Liability And Statute Of Limitations

Registered projects and issued VCUs are subject to review by Verra, as set out in the VCS Program document *Registration and Issuance Process*. Project proponents are responsible for compensating for excess VCU issuance where Verra deems, acting reasonably, that there has been a material erroneous issuance of VCUs in respect of a project, as a result of the fraudulent conduct, negligence, intentional act, recklessness, misrepresentation or mistake of the project proponent. A statute of limitations applies, whereby Verra can only require such compensation in relation to any verification completed after 8 April 2014 and up to the later of:

1) 6 years after the date of issuance of the relevant VCU; or
2) 12 months after the date upon which any second verification report with respect to the relevant VCU is accepted on the Verra registry.[2]

[2] The relevant VCU will be issued following acceptance of a verification report for a project. For some types of AFOLU projects in particular, verification cycles may be longer than 6 years. In this regard, if the second verification report shows a VCU has been erroneously issued, Verra will have an additional 12 months to deal with that issue. Note also that where a VCU is erroneously issued from the last verification report of a project, Section 4.2(1) applies.

5 VCS PROGRAM ACCREDITATION

Validation/verification bodies are eligible to provide validation and verification services under the VCS Program if they have signed the required agreement with Verra and are:

1) Accredited under a VCS-approved GHG program[3]; or
2) Accredited under *ISO 14065:2013* for scope VCS by an accreditation body that is a member of the International Accreditation Forum;

The validation/verification body shall hold such accreditation or approval for validation or verification (as applicable) for the sectoral scope(s) applicable to the methodology applied to the project. Where the methodology falls under more than one sectoral scope, the validation/verification body shall hold accreditation or approval for validation or verification (as applicable) for all relevant sectoral scopes.

Where the validation/verification body holds accreditation or approval for the verification for the relevant sectoral scope(s) but does not hold accreditation or approval for validation, it may validate project description deviations and inclusion of new project activity instances in grouped projects at the time of verification, under the following circumstances:

1) It holds accreditation or approval for validation in at least one other sectoral scope.
2) It has completed validation of at least five projects under the VCS Program or an approved GHG program, and such projects have been registered under the relevant program.
3) The validation activity does not entail the validation of a project description deviation that impacts the applicability of the methodology, additionality or the appropriateness of the baseline scenario (see the *VCS Standard* for further information on such deviations).

Validation/verification bodies are also eligible to conduct assessments (validation) of methodology elements under the methodology approval process. The validation/verification body shall hold accreditation for validation for the sectoral scope(s) applicable to the methodology. Where the methodology falls under more than one sectoral scope, the validation/verification body shall hold accreditation for validation for all relevant sectoral scopes.

To apply to become an approved validation/verification body with the VCS Program, organizations must complete a *Verra Validation/Verification Body Application Form* and submit the signed application, along with any supporting evidence (as required by the application) to secretariat@verra.org.

A list of validation/verification bodies approved to undertake validation and verification services under the VCS Program is available on the Verra website.

[3] Note that accreditation under an approved GHG program shall be recognized only until such time as Verra determines that a sufficient number of validation/verification bodies are accredited under other recognized accreditation pathways, or two years from the date of release of VCS Version 4, whichever is earlier. After such date, all validation/verification bodies must be accredited through another approved accreditation pathway.

6 METHODOLOGY APPROVAL PROCESS

The methodology approval process is the process by which methodologies, methodology revisions, modules and tools (including additionality tools, performance benchmarks and technology benchmarks), are approved under the VCS Program. Such methodology elements are subject to review by Verra, a global stakeholder consultation hosted on the Verra website and independent assessment by one validation/verification body, before final approval by Verra.

The full rules and requirements for methodology elements with respect to the methodology approval process are set out in the VCS Program document *Methodology Approval Process*.

6.1 Review of Approved VCS Methodology Elements

Verra may periodically review methodology elements approved under the VCS Program to ensure they continue to reflect best practice and scientific consensus. This includes ensuring that methodology elements approved under the program are consistent with any new requirements issued by Verra and that methodology elements have appropriate criteria and procedures for addressing all VCS Program requirements and are consistent with emerging best practice and scientific consensus. As a result, Verra may need to update, put on hold or withdraw a methodology element. The procedure through which Verra may review approved VCS Program methodology elements and take appropriate action is set out in the VCS Program document *Methodology Approval Process*.

6.2 Compensation for Methodology Developers

Methodology developers are eligible to receive compensation for methodologies approved under the VCS Program.

Compensation will be paid according to the number of VCUs issued to projects using the methodology or a revision of the methodology, at the rate and in accordance with the payment terms set out in the VCS Program document *Program Fee Schedule*. Compensation is payable with respect to VCUs issued on or after 15 June 2010. Methodology developers may elect not to receive compensation by notifying Verra at any time.

Where Verra sanctions the consolidation of a number of methodologies, the compensation due to the developer of the consolidated methodology and the underlying methodologies respectively will be determined on a case-by-case basis by Verra.

Where an eligible methodology is withdrawn or put on hold, compensation remains payable in respect of continuing issuance of VCUs to registered projects that have applied the methodology or a revision of the methodology.

Only methodologies developed under the VCS Program methodology approval process are eligible for the compensation mechanism. Developers of methodology revisions, modules and tools are not compensated under the mechanism.

Note – Project proponents pay the same VCU issuance levy regardless of the methodology applied to the project. Verra pays any compensation to the methodology developer out of the VCU issuance levy it receives.

7 LINKING TO OTHER GHG PROGRAMS

To recognize work that has gone into developing other credible GHG programs, the VCS Program has a process for approving GHG programs that meet VCS Program criteria. A GHG program shall demonstrate compliance with VCS Program principles and requirements through a gap analysis and the Verra Board will make the final decision on whether to approve the GHG program. Approval of a GHG program under the VCS Program has three implications:

1) GHG credits under the approved GHG program may be cancelled and issued as VCUs (converted into VCUs).
2) Validation/verification bodies under the approved GHG program are approved for validation and verification under the VCS Program (for the corresponding sectoral scopes for validation and verification respectively, and provided they have signed the required agreement with Verra).
3) Methodology elements under the approved GHG program may be used for developing projects under the VCS Program.

The list of approved GHG programs is available on the Verra website, together with any specific conditions or further clarifications with respect to the scope of approval.

7.1 Gap Analysis Methodology and Process

The approval of other GHG programs is based on the principle of full compatibility with the VCS Program. A gap analysis process is applied on a case-by-case basis to determine the other GHG program's compliance with VCS Program principles and requirements and to assess whether the GHG emission reductions or removals issued under the GHG Program are fully compatible with VCUs issued under the VCS Program.

Any party may initiate a gap analysis of another GHG program with the VCS Program. All relevant documentation in relation to the GHG program shall be provided to Verra, with appropriate authorization secured.

The onus is on the GHG program to demonstrate that it meets the VCS Program criteria. The costs of the assessment are borne by the GHG program or whoever initiates the gap analysis.

Based on the gap analysis report, the Verra Board will make a decision on whether to approve the full GHG program or elements of the program.

7.2 Review of VCS Program-Approved GHG Programs

Approved GHG programs are reviewed periodically by Verra. Any changes made by an approved GHG program which may affect its compatibility with the VCS Program shall be communicated immediately to Verra. In the event that it is considered that the changes lead to non-conformity with the VCS Program, the Verra Board may decide to suspend or terminate its recognition of the approved GHG program. Any projects approved under the GHG program prior to such Verra Board decision will not be affected by the suspension or termination.

8 COMPLAINTS AND APPEALS PROCEDURE

Project proponents, validation/verification bodies, methodology element developers and other stakeholders (including interested stakeholders) may submit enquiries to Verra at any time. In addition, the VCS Program provides a complaints and appeals procedure as set out in the Verra *Appeals, Complaints and Conduct Policy* available on the Verra website.

APPENDIX 1: DOCUMENT HISTORY

Version	Date	Comment
v4.0	19 Sep 2019	Initial version released under VCS Version 4.

VERRA

Standards for a Sustainable Future

Verified Carbon Standard

Climate, Community & Biodiversity Standards

Sustainable Development Verified Impact Standard

Verified Carbon Standard
A VERRA STANDARD

VCS Standard

19 September 2019

v4.0

ABOUT VERRA

Verra supports climate action and sustainable development through the development and management of standards, tools and programs that credibly, transparently and robustly assess environmental and social impacts, and drive funding for sustaining and scaling up these benefits. As a mission-driven, non-profit (NGO) organization, Verra works in any arena where we see a need for clear standards, a role for market-driven mechanisms and an opportunity to achieve environmental and social good.

Verra manages a number of global standards frameworks designed to drive finance towards activities that mitigate climate change and promote sustainable development, including the Verified Carbon Standard (VCS) Program and its Jurisdictional and Nested REDD+ framework (JNR), the Verra California Offset Project Registry (OPR), the Climate, Community & Biodiversity (CCB) Standards and the Sustainable Development Verified Impact Standard (SD VISta). Verra is also developing new standards frameworks, including LandScale, which will promote and measure sustainability outcomes across landscapes. Finally, Verra is one of the implementing partners of the Initiative for Climate Action Transparency (ICAT), which helps countries assess the impacts of their climate actions and supports greater transparency, effectiveness, trust and ambition in climate policies worldwide.

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CONTENTS

1 INTRODUCTION

The *VCS Standard* provides a global standard for GHG emission reduction and removal projects and programs. It uses as its core the requirements set out in *ISO 14064-2:2006*, *ISO 14064-3:2006* and *ISO 14065:2013*. The three principal documents of the program are the *VCS Program Guide,* the *VCS Standard,* and the *VCS Methodology Requirements*. The *VCS Program Guide* describes the rules and requirements governing the VCS Program and further describes the constituent parts of the program such as the project and program registration process, the Verra registry system, the methodology approval process and the accreditation requirements for validation/verification bodies. The *VCS Standard* provides the requirements for developing projects and programs, as well as the requirements for validation, monitoring and verification of projects, programs and GHG emission reductions and removals. The *VCS Methodology Requirements* provides the rules and requirements for developing new VCS methodologies. The *VCS Program Guide* should be read before using the *VCS Standard* or the *VCS Methodology Requirements*.

Verra recognizes the kind agreement of the International Organization for Standardization (ISO, www.iso.org) to allow inclusion of critical clauses of *ISO 14064-2:2006* and *ISO 14064-3:2006* in the VCS Program documentation to facilitate comprehension. In particular, the sections in this document on project and methodology requirements include text drawn from *ISO 14064-2:2006* clause 5 and *ISO 14064-3:2006* clause 4.9, amended where necessary to fit the context of the VCS Program.

1.1 Version

All information about version control under the VCS Program is contained in the *VCS Program Guide*.

This document will be updated from time-to-time and readers shall ensure that they are using the most current version of the document. Where external documents are referenced, such as the *IPCC 2006 Guidelines for National GHG Inventories*, and such documents are updated, the most recent version of the document shall be used.

Previous versions of the VCS Program may have included different rules and requirements than those set out in this version. Previous versions of the *VCS Standard* and other VCS Program documents are archived and available on the Verra website.

1.2 Language

The operating language of the VCS Program is English. The project and program description, validation report, monitoring report, verification report and all other documentation (including all and any appendices) required under the VCS Program shall be in English.

2 VCS PROGRAM SPECIFIC ISSUES

2.1 Scope of VCS Program

2.1.1 The scope of the VCS Program includes:

1) The six Kyoto Protocol greenhouse gases.
2) Ozone-depleting substances.
3) Project activities supported by a methodology approved under the VCS Program through the methodology approval process.
4) Project activities supported by a methodology approved under a VCS approved GHG program, unless explicitly excluded under the terms of Verra approval.
5) Jurisdictional REDD+ programs and nested REDD+ projects as set out in the VCS Program document *Jurisdictional and Nested REDD+ (JNR) Requirements*.

The scope of the VCS Program excludes projects that can reasonably be assumed to have generated GHG emissions primarily for the purpose of their subsequent reduction, removal or destruction. The VCS Program also excludes the following project activities under the circumstances indicated in Table 1, below.

Table 1: Excluded Project Activities

Activity	Non-LDC[1]		LDC	
	Large scale[2]	Small scale[2]	Large scale	Small scale
Activities that reduce hydrofluorocarbon-23 (HFC-23) emissions	Excluded	Excluded	Excluded	Excluded
Grid-connected electricity generation[3]	Excluded	Excluded	Excluded	

[1] Least Developed Country, as designated by the United Nations.
[2] Small-scale and large-scale designations are as per CDM definitions for same.
[3] "Grid-connected electricity generation" means the generation of electricity primarily for delivery to a national or regional grid. Generation of electricity primarily for delivery to a micro-grid (i.e., a localized grid that facilitates the delivery of electricity to discrete and often remote sets of infrastructure that do not otherwise have reliable access to electricity) is not included in this definition, and such project activities are eligible under the scope of the VCS Program.

using hydro power plants/units				
Grid-connected electricity generation using wind, geothermal, or solar power plants/units	Excluded	Excluded		
Utilization of recovered waste heat for, *inter alia*, combined cycle electricity generation and the provision of heat for residential, commercial or industrial use	Excluded	Excluded		
Generation of electricity and/or thermal energy using biomass. This does not include efficiency improvements in thermal applications (e.g., cook stoves).	Excluded	Excluded		
Generation of electricity and/or thermal energy using fossil fuels, including activities that involve switching from a higher carbon content fuel to a lower carbon content fuel	Excluded	Excluded		
Replacement of electric lighting with more energy efficient electric lighting, such as the replacement of incandescent electrical bulbs with CFLs or LEDs	Excluded			
Installation and/or replacement of electricity transmission lines and/or energy efficient transformers	Excluded			

For example, and to illustrate the mechanics of this table, large-scale grid-connected hydroelectric projects are excluded in all cases. However, a small-scale grid-connected hydroelectric project would be eligible where located within an LDC.

2.2 Principles

2.2.1 The application of principles is fundamental in ensuring that GHG-related information is a true and fair account. The principles below shall provide the basis for, and shall guide the application of, the VCS Program rules and requirements.

Principles taken from ISO 14064-2:2006, clause 3.

Relevance
Select the GHG sources, GHG sinks, GHG reservoirs, data and methodologies appropriate to the needs of the intended user.

Completeness
Include all relevant GHG emissions and removals. Include all relevant information to support criteria and procedures.

Consistency
Enable meaningful comparisons in GHG-related information.

Accuracy
Reduce bias and uncertainties as far as is practical.

Transparency
Disclose sufficient and appropriate GHG-related information to allow intended users to make decisions with reasonable confidence.

Conservativeness
Use conservative assumptions, values and procedures to ensure that net GHG emission reductions or removals are not overestimated.

Note – Accuracy should be pursued as far as possible, but the hypothetical nature of baselines, the high cost of monitoring of some types of GHG emissions and removals, and other limitations make accuracy difficult to attain in many cases. In these cases, conservativeness may serve as a moderator to accuracy in order to maintain the credibility of project and program GHG quantification.

2.3 Timing of Crediting

2.3.1 VCUs shall not be issued under the VCS Program for GHG emission reductions or removals that have not been verified.

2.3.2 Project activities are eligible for immediate crediting of future avoided emissions under the conditions set out below, which shall be addressed at the level of the methodology:

1) The project immediately avoids future streams of GHG emissions as a result of an upfront intervention that permanently precludes further emissions from the source. VCUs shall be issued only after such an intervention has occurred and the GHG emission reductions have been verified. Examples of such activities include projects that destroy chlorofluorocarbons recovered from refrigeration equipment thereby immediately precluding their future release into the atmosphere, and composting projects that divert organic waste from landfill sites thereby immediately precluding future methane emissions. A REDD project would not qualify for immediate crediting because future streams of GHG emissions are not permanently precluded.

2) The physical processes that would generate GHG emissions in the absence of an intervention are well-understood, stable and quantifiable. Models used to simulate such processes shall meet the requirements for such models set out in the VCS Program document *VCS Methodology Requirements*. Any default factors associated with input parameters shall meet the requirements set out for such default factors in the VCS Program document *VCS Methodology Requirements*.

3) VCUs may be issued only for GHG emissions avoided over a ten-year period, even if such GHG emissions are likely to have continued over a longer period of time under the baseline scenario. For example, a composting project that diverts organic waste from a landfill site would be eligible for crediting (in relation to a specific amount of composted organic waste) for the GHG emissions that would have occurred at the landfill site over a ten-year period, and any emissions that would have occurred beyond the ten year period (in relation to the specific amount of composted organic waste) are not eligible. Note that in this particular example the ten-year rule applies to the specific amount of composted organic waste and the usual rules on duration of the project and project crediting period still apply.

2.3.3 ODS projects are eligible for immediate crediting of future avoided emissions and methodology elements may use such a crediting model.

Note – Crediting of ODS projects shall still be in relation to the baseline scenario. In many cases, methodology elements will credit projects for all of the ODS destroyed by the project (minus any project emissions and leakage). However, it is possible that projects could destroy ODS from existing stockpiles and only a portion of the ODS would have been emitted under the baseline scenario. For example, if the baseline scenario includes use of the ODS to service existing equipment and a certain proportion of such ODS would be recovered and destroyed at the end of that equipment's life (whether voluntarily or due to regulation), then the volume of credits granted to the project shall reflect this.

2.4 AFOLU Non-Permanence Risk and Pooled Buffer Account

2.4.1 Non-permanence risk in Agriculture, Forestry, and Other Land Use (AFOLU) projects is addressed through the use of a project risk analysis, using the *AFOLU Non-Permanence Risk Tool*, which determines a number of credits to be deposited in the AFOLU pooled buffer account. The pooled buffer account holds non-tradable buffer credits to cover the non-permanence risk associated with AFOLU projects. It is a single account that holds the buffer credits for all projects.

Buffer credits are cancelled to cover carbon known, or believed, to be lost. As such, the VCUs already issued to projects that subsequently fail are not cancelled and do not have to be "paid back". All VCUs issued to AFOLU projects (as with all projects) are permanent. The VCS approach provides atmospheric integrity because the AFOLU pooled buffer account will always maintain an adequate surplus to cover unanticipated losses from individual project failures and the net GHG benefits across the entire pool of AFOLU projects will be greater than the total number of VCUs issued.

The full rules and procedures for AFOLU projects with respect to non-permanence risk are set out in Section 3.2.

2.4.2 The AFOLU pooled buffer account is subject to periodic reconciliation. Reconciliation is based on a review of existing AFOLU verification reports and an assessment of project performance. This process will identify the projects that have failed or underperformed and seek to identify their common characteristics. The risk analysis criteria and buffer withholding percentages, set out in the VCS Program document *AFOLU Non-Permanence Risk Tool*, will be adjusted accordingly to ensure that there are always sufficient buffer credits in the AFOLU pooled buffer account to cover project losses. Any changes to the tool will not be retroactive (i.e., they will apply only to future non-permanence risk assessments).

2.4.3 Project risk analyses will be subject to periodic review by Verra. This process consists of a review of a sample of AFOLU project risk reports to identify any inconsistencies in the process and application of the *AFOLU Non-Permanence Risk Tool* and assessment of same by validation/verification bodies. The risk analysis criteria and risk ratings set out in the tool may be adjusted, to ensure consistent and accurate application of the tool. Any changes to the tool will not be retroactive (i.e., they will apply only to subsequent non-permanence risk analyses).

2.5 AFOLU Leakage Assessments

2.5.1 Project market leakage assessments will be subject to periodic review by Verra. This process consists of a review of a sample of AFOLU projects' leakage assessments to identify any inconsistencies in the process and application of the leakage requirements in Sections 3.14.7–3.14.9 and the VCS Program document *VCS Methodology Requirements,* and assessment of same by validation/verification bodies. The leakage requirements set out in the *VCS Methodology Requirements* may be adjusted to ensure consistent and accurate application. Any changes to the leakage requirements will not be retroactive (i.e., they will apply only to subsequent leakage assessments).

3 PROJECT REQUIREMENTS

This section sets out the rules and requirements for projects under the VCS Program. Specific requirements for AFOLU and ODS projects are set out throughout this section, as these project types may encounter unique circumstances related to project implementation, monitoring and other matters, which must be addressed.

In order to complete the VCS Program certification process, projects must demonstrate how they meet the rules and requirements set out below. Projects must also demonstrate how they have applied an eligible methodology in full. Projects demonstrate their compliance with the VCS Program rules and the applied methodology through the validation and verification processes, which are defined in Section 4 below. Once projects complete the validation and verification processes, they become eligible to request registration and VCU issuance. Note that the full process for requesting project registration and VCU issuance is set out in the VCS Program document *Registration and Issuance Process*.

3.1 General Requirements

Concept

Establishing a consistent and standardized certification process is critical to ensuring the integrity of VCS projects. Accordingly, certain high-level requirements must be met by all projects, as set out below.

Requirements

3.1.1 Projects shall meet all applicable rules and requirements set out under the VCS Program, including this document. Projects shall be guided by the principles set out in Section 2.2.1.

3.1.2 Projects shall apply methodologies eligible under the VCS Program. Methodologies shall be applied in full, including the full application of any tools or modules referred to by a methodology, noting the exception set out in Section 3.13.1. The list of methodologies and their validity periods is available on the Verra website.

3.1.3 Projects and the implementation of project activities shall not lead to the violation of any applicable law, regardless of whether or not the law is enforced.

3.1.4 Where projects apply methodologies that permit the project proponent its own choice of model (see the VCS Program document *Program Definitions* for definition of model), such model shall meet with the requirements set out in the VCS Program document *VCS Methodology Requirements* and it shall be demonstrated at validation that the model is appropriate to the project circumstances (i.e., use of the model will lead to an appropriate quantification of GHG emission reductions or removals).

3.1.5 Where projects apply methodologies that permit the project proponent its own choice of third party default factor or standard to ascertain GHG emission data and any supporting data for establishing baseline scenarios and demonstrating additionality, such default factor or standard shall meet with the requirements set out in the VCS Program document *VCS Methodology Requirements*.

3.1.6 Projects shall preferentially apply methodologies that use performance methods (see the VCS Program document *VCS Methodology Requirements* for further information on performance methods) where a methodology is applicable to the project that uses a performance method for determining both additionality and the crediting baseline (i.e., a project shall not apply a methodology that uses a project method where such a performance method is applicable to the project). Methodologies approved under the VCS Program that use performance methods provide a list of similar methodologies that use project methods (that were approved under the VCS Program or an approved GHG program at the time the performance method was developed). Such lists are not necessarily exhaustive but can serve as the starting point for determining whether a performance method is applicable to the project. Following the approval of a methodology that uses a performance method, projects may use any applicable pre-existing methodology that uses a project method for a six-month grace period.

3.1.7 Where the rules and requirements under an approved GHG program conflict with the rules and requirements of the VCS Program, the rules and requirements of the VCS Program shall take precedence.

3.1.8 Where projects apply methodologies from approved GHG programs, they shall comply with any specified capacity limits (see the VCS Program document *Program Definitions* for definition of capacity limit) and any other relevant requirements set out with respect to the application of the methodology and/or tools referenced by the methodology under those programs.

3.1.9 Where Verra issues new requirements relating to projects, registered projects do not need to adhere to the new requirements for the remainder of their project crediting periods (i.e., such projects remain eligible to issue VCUs through to the end of their project crediting period without revalidation against the new requirements). The new requirements shall be adhered to at project crediting period renewal, as set out in Section 3.8.9.

3.2 AFOLU-Specific Matters

Concept

AFOLU projects may encounter unique circumstances related to project implementation, monitoring and other matters. This section sets out high-level requirements related to such AFOLU-specific matters. Note that additional AFOLU-specific requirements are also set out throughout this document.

Requirements

General

3.2.1 There are currently six AFOLU project categories eligible under the VCS Program, as defined in *Appendix 1 Eligible AFOLU Project Categories* below: afforestation, reforestation and revegetation (ARR), agricultural land management (ALM), improved forest management (IFM), reduced emissions from deforestation and degradation (REDD), avoided conversion of grasslands and shrublands (ACoGS), and wetland restoration and conservation (WRC). Further specification with respect to eligible activities which may be included within methodologies approved under the VCS Program can be found in the VCS Program document *VCS Methodology Requirements.*

3.2.2 Where projects are located within a jurisdiction covered by a jurisdictional REDD+ program, project proponents shall follow the requirements in this document and the requirements related to nested projects set out in the VCS Program document *Jurisdictional and Nested REDD+ Requirements*.

3.2.3 Where an implementation partner is acting in partnership with the project proponent, the implementation partner shall be identified in the project description. The implementation partner shall identify its roles and responsibilities with respect to the project, including but not limited to, implementation, management and monitoring of the project, over the project crediting period.

3.2.4 Activities that convert native ecosystems to generate GHG credits are not eligible under the VCS Program. Evidence shall be provided in the project description that any ARR, ALM, WRC or ACoGS project areas were not cleared of native ecosystems to create GHG credits (e.g., evidence indicating that clearing occurred due to natural disasters such as hurricanes or floods). Such proof is not required where such clearing or conversion took place at least 10 years prior to the proposed project start date. The onus is upon the project proponent to demonstrate this, failing which the project shall not be eligible.

3.2.5 Activities that drain native ecosystems or degrade hydrological functions to generate GHG credits are not eligible under the VCS Program. Evidence shall be provided in the project description that any AFOLU project area was not drained or converted to create GHG credits. Such proof is not required where such draining or conversion took place prior to 1 January 2008. The onus is upon the project proponent to demonstrate this, failing which the project shall not be eligible.

3.2.6 The project proponent shall demonstrate that project activities that lead to the intended GHG benefit have been implemented during each verification period in accordance with the project design. Where no new project activities have been implemented during a verification period, project proponents shall demonstrate that previously implemented project activities continued to be implemented during the verification period (e.g., forest patrols or improved agricultural practices of community members).

3.2.7 For all IFM, REDD, WRC and ACoGS project types, the project proponent shall, for the duration of the project, reassess the baseline every 10 years and have this validated at the same time as the subsequent verification. Baseline projections for deforestation and/or degradation, land conversion, forest management plans and wetland hydrological changes beyond a 10-year period are not likely to be realistic because rates of change in land-use and/or land or water management practices are subject to many factors that are difficult to predict over the long term, hence the need for periodic reassessment of the baseline. The following shall apply with respect to the baseline reassessment:

1) The reassessment will capture changes in the drivers and/or behavior of agents that cause the change in land use, hydrology, sediment supply and/or land or water management practices and changes in carbon stocks, all of which shall then be incorporated into revised estimates of the rates and patterns of land-use change and estimates of baseline emissions.[4]

2) The latest approved version of the methodology or its replacement shall be applied at the time of baseline reassessment.

3) The project description shall be updated at the time of baseline reassessment following the requirements set out in Section 3.8.9(2)(d).

4) Ex-ante baseline projections beyond a 10-year period are not required.

3.2.8 Where ARR, ALM, IFM or REDD project activities occur on wetlands, the project shall adhere to both the respective project category requirements and the WRC requirements, unless the expected emissions from the soil organic carbon pool or change in the soil organic carbon pool in the project scenario is deemed below *de minimis* or can be conservatively excluded as set out in the VCS Program document *VCS Methodology Requirements*, in which case the project shall not be subject to the WRC requirements.

Non-Permanence Risk

3.2.9 Projects shall prepare a non-permanence risk report in accordance with the VCS Program document *AFOLU Non-Permanence Risk Tool* at both validation and verification. In the case of projects that are not validated and verified simultaneously, having their initial risk assessments validated at the time of VCS project validation will assist VCU buyers and sellers by providing a more accurate early indication of the number of VCUs projects are expected to generate. The non-permanence risk report shall be prepared using the *VCS Non-Permanence Risk Report Template*, which may be included as an annex to the project description or monitoring report, as applicable, or provided as a stand-alone document.

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[4] Brown, S., M. Hall, K. Andrasko, F. Ruiz, W. Marzoli, G. Guerrero, O. Masera, A. Dushku, B. DeJong, and J. Cornell, 2007. Baselines for land-use change in the tropics: application to avoided deforestation projects. Mitigation and Adaptation Strategies for Global Change, 12 (6):1001-1026.

3.2.10 Projects with tree harvesting shall demonstrate that the permanence of their carbon stock is maintained and shall put in place management systems to ensure the carbon against which VCUs are issued is not lost during a final cut with no subsequent replanting or regeneration.

3.2.11 WRC projects shall demonstrate that the permanence of their soil carbon stock will be maintained. The maximum quantity of GHG emission reductions that may be claimed by the project is limited to the difference between project and baseline scenario after a 100-year time frame, as further described in the VCS Program document *VCS Methodology Requirements*.

3.2.12 Buffer credits shall be deposited in the AFOLU pooled buffer account based upon the non-permanence risk report assessed by the validation/verification body(s). Buffer credits are not VCUs and cannot be traded. The full rules and procedures with respect to the deposit of buffer credits are set out in the VCS Program document *Registration and Issuance Process*.

3.2.13 Projects shall perform the non-permanence risk analysis at every verification event because the non-permanence risk rating may change. Projects that demonstrate their longevity, sustainability and ability to mitigate risks are eligible for release of buffer credits from the AFOLU pooled buffer account. The full rules and procedures with respect to the release of buffer credits are set out in the VCS Program document *Registration and Issuance Process*.

3.2.14 Assessment of non-permanence risk analyses may be conducted by the same validation/verification body that is conducting validation or verification of the project and at the same time as the validation or verification of the project, as applicable. The rules and requirements for the process of assessment by validation/verification body(s) are set out in Section 4 below.

3.2.15 Where an event occurs that is likely to qualify as a loss event (see the VCS Program document *Program Definitions* for definition of loss event), the project proponent shall notify Verra within 30 days of discovering the likely loss event. Where VCUs have been previously issued, a loss event report shall be prepared and submitted to the Verra registry, as follows:

1) The loss event report shall be prepared using the *VCS Loss Event Report Template*. It shall include a conservative estimate of the loss of previously verified emission reductions and removals due to losses in carbon stocks from the project, based on monitoring of the full area affected by the loss event.
2) The loss event report shall be accompanied by a loss event representation signed by the project proponent and representing that the loss estimate is true and accurate in all material respects. The template for the loss event representation is available on the Verra website.
3) The loss event report shall be submitted to the Verra registry within two years of the date of discovery of the loss event. Where a loss event report is not submitted within two years of the date of discovery of the loss event, the project shall no longer be eligible to issue VCUs.

4) The Verra registry shall put buffer credits from the AFOLU pooled buffer account on hold, in an amount equivalent to the estimated loss stated in the loss event report.

3.2.16 At the verification event subsequent to the loss event, the monitoring report shall restate the loss from the loss event and calculate the net GHG benefit for the monitoring period in accordance with the requirements set out in the methodology applied. In addition, the following applies:

1) Where the net GHG benefit of the project, compared to the baseline, for the monitoring period is negative, taking into account project emissions, removals and leakage, a reversal has occurred (see the VCS Program document *Program Definitions* for definition of reversal) and buffer credits equivalent to the reversal shall be cancelled from the AFOLU pooled buffer account, as follows:

a) Where the total reversal is less than the number of credits put on hold after the submission of the loss event report, Verra shall cancel buffer credits equivalent to the reversal. Any remaining buffer credits shall be released from their hold status (though remain in the AFOLU pooled buffer account).

b) Where the reversal is greater than stated by the loss event report, the full amount of buffer credits put on hold with respect to the submission of the loss event report shall be cancelled, and additional buffer credits from the AFOLU pooled buffer account shall be cancelled to fully account for the reversal.

2) Where the net GHG benefit for the monitoring period is positive, taking into account project emissions, removals and leakage (i.e., all losses have been made up over the monitoring period), a reversal has not occurred and buffer credits put on hold after the submission of the loss event report shall be released from their hold status (but shall remain in the AFOLU pooled buffer account).

3.2.17 At a verification event, where a reversal has occurred, the following applies:

1) Where the reversal is a catastrophic reversal (see the VCS Program document *Program Definitions* for the definition of catastrophic reversal), the following applies:

a) The baseline may be reassessed, including any relevant changes to baseline carbon stocks and, where reassessed, shall be validated at the time of the verification event subsequent to the reversal. Note that allowing baseline revisions after catastrophic reversal supersedes any methodological requirements for a fixed baseline.

b) The same geographic boundary shall be maintained. The entire project area, including areas degraded or disturbed by the catastrophic event, shall continue to be a part of project monitoring. GHG credits may not be claimed from any increased rate of sequestration from natural regeneration after a catastrophic reversal until the loss from catastrophic reversals is recovered. At the subsequent VCU issuance, GHG credits from the project equal to the additional number of buffer credits cancelled after the reversal from the AFOLU pooled buffer account on behalf of the project (i.e., above what has been previously contributed by the project) shall be deposited in the AFOLU pooled buffer account. For example, if the project previously contributed 100 buffer credits and 150 credits were cancelled from the AFOLU pooled buffer account after a reversal, the project would deposit an additional 50 buffer credits (to replenish the pool at large) in addition to the amount required by the risk analysis at the current verification event. Buffer credits deposited to replenish the pool after a reversal (50 in the example above) shall never be eligible for release back to the project, as set out in Section 3.2.12. In addition, buffer credits shall be deposited in the AFOLU pooled buffer account based upon the non-permanence risk analysis determined in accordance with the VCS Program document *AFOLU Non-Permanence Risk Tool*, as assessed by the validation/verification body(s).

2) Where the reversal is a non-catastrophic reversal (e.g., due to poor management, removal of a portion of the project area from participation in the project or over-harvesting), the following applies:

   a) No further VCUs shall be issued to the project until the deficit is remedied. The deficit is equivalent to the full amount of the reversal, including GHG emissions from losses to project and baseline carbon stocks.

   b) The same geographic boundary shall be maintained. The entire project area, including areas degraded or disturbed by the non-catastrophic event, shall continue to be a part of project monitoring. Projects may not claim GHG credits from any increased rate of sequestration from natural regeneration after a reversal until the loss from catastrophic reversals is recovered.

   Note – Notwithstanding the rules set out in (b) above, where a portion of the project area is removed from participation in the project, it is not expected that the project proponent maintain the same geographic boundary of the project, nor is it expected that the area that is removed from the project continue to be monitored.

3.2.18 As set out in the VCS Program document *Registration and Issuance Process*, where projects fail to submit a verification report within five or ten years from the previous verification event, a percentage of buffer credits is put on hold under the conservative assumption that the carbon benefits represented by buffer credits held in the AFOLU pooled buffer account may have been reversed or lost in the field. Where projects fail to submit a verification report within 15 years from the previous verification event, buffer credits are cancelled under the same assumption. The full rules and requirements with respect to the cancellation and holding of buffer credits are set out in the VCS Program document *Registration and Issuance Process*.

3.2.19 The remaining balance of buffer credits is cancelled at the end of the project crediting period.

Long-term Average GHG Benefit

3.2.20 ARR and IFM projects with harvesting activities shall not be issued GHG credits above the long-term average GHG benefit maintained by the project.

3.2.21 Where ARR or IFM projects include harvesting, the loss of carbon due to harvesting shall be included in the quantification of project emissions. The maximum number of GHG credits available to projects shall not exceed the long-term average GHG benefit. The GHG benefit of a project is the difference between the project scenario and the baseline scenario of carbon stocks stored in the selected carbon pools and adjusted for any project emissions of N_2O, CH_4 and fossil-derived CO_2, and leakage emissions. The long-term average GHG benefit shall be calculated using the following procedure:

1) Establish the period over which the long-term average GHG benefit shall be calculated, noting the following:

   a) For ARR or IFM projects undertaking even-aged management, the time period over which the long-term GHG benefit is calculated shall include at minimum one full harvest/cutting cycle, including the last harvest/cut in the cycle. For example, where a project crediting period is 40 years and has a harvest cycle of 12 years, the long-term average GHG benefit will be determined for a period of 48 years.

   b) For ARR projects under conservation easements with no intention to harvest after the project crediting period, or for selectively-cut IFM projects, the time period over which the long-term average is calculated shall be the length of the project crediting period.

2) Determine the expected total GHG benefit of the project for each year of the established time period. For each year, the total GHG benefit is the to-date GHG emission reductions or removals from the project scenario minus baseline scenario.

3) Sum the total GHG benefit of each year over the established time period.

4) Calculate the average GHG benefit of the project over the established time period.

5) Use the following equation to calculate the long-term average GHG benefit:

$$LA = \frac{\sum_{t=0}^{n} PE_t - BE_t}{n}$$

Where:

LA = The long-term average GHG benefit

PE_t = The total to-date GHG emission reductions and removals generated in the project scenario (tCO_2e). Project scenario emission reductions and removals shall also consider project emissions of CO_2, N_2O, CH_4 and leakage.

BE_t = The total to-date GHG emission reductions and removals projected for the baseline scenario (tCO_2e)

t = Year

n = Total number of years in the established time period

6) A project may claim GHG credits during each verification event until the long-term average GHG benefit is reached. Once the total number of GHG credits issued has reached this average, the project can no longer issue further GHG credits. The long-term average GHG benefit shall be calculated at each verification event, meaning the long-term average GHG benefit may change over time based on monitored data. For an example of determining the long-term average GHG benefit, see the Verra website.

   Buffer credits are withheld only when GHG credits are issued. the number of buffer credits to withhold is based on the change in carbon stocks only (not the net GHG benefit), as such the buffer credits will be based on the long-term average change in carbon stock. Use the following equation to calculate the long-term average change in carbon stock.

   Where:

$$LC = \frac{\sum_{t=0}^{n} PC_t - BC_t}{n}$$

LC = The long-term average change in carbon stock

PC_t = The total to-date carbon stock in the project scenario (tCO_2e)

BC_t = The total to-date carbon stock projected for the baseline scenario (tCO_2e)

t = Year

n = Total number of years in the established time period

Note – The VCS Program guidance document AFOLU Guidance: Example for Calculating the Long-Term Average Carbon Stock for ARR Projects with Harvesting*, available on the Verra website, provides examples for calculating the long-term average carbon stock for a variety of ARR project scenarios with harvesting. The same examples can be applied to IFM projects with harvesting.*

3.3 ODS-Specific Matters

Concept

ODS projects may encounter unique circumstances related to project implementation, avoidance of perverse incentives and other matters. This section sets out high-level requirements related to such ODS-specific matters. Note that additional ODS-specific requirements are also set out throughout this document.

Requirements

Eligible ODS

3.3.1 ODS residing in stockpiles or ODS recovered directly from any of the products set out in Section 3.3.2 are eligible. The following ODS controlled by the Montreal Protocol for which the IPCC publishes a global warming potential (100-year time horizon) are eligible:

1) Annex A, Group I
2) Annex B, Group I
3) Annex C, Group I

3.3.2 The destruction of ODS recovered from the following products are eligible:

1) Refrigeration equipment, systems or appliances;
2) Air conditioning equipment, systems or appliances;
3) Fire suppression equipment or systems; and
4) Thermal insulation foams.

3.3.3 The destruction of ODS recovered from pre-polymers, aerosol products or other products is not eligible.

ODS Origin

3.3.4 Where ODS is recovered from products that have been imported specifically for their disassembly (i.e., the products have not been collected in the host country), the following shall apply:

1) The products shall not originate from any country in which any law, statute or other regulatory framework requires the recovery and destruction of the relevant ODS from such products.
2) The project proponent shall provide documentary evidence, such as shipping manifests, bills of lading and evidence of collection of the products in the originating country, to demonstrate the origin of such products.

3.3.5 Documentary evidence shall be provided to verify the origin of all ODS destroyed by the project. Evidence may include, inter alia, shipping manifests, bills of lading, other commercial documentation, and addresses of households, commercial premises and other evidence of collection of the products. Such evidence shall be appropriate to the nature and scale of the project.

Destruction Technology

3.3.6 The project shall use a destruction technology that meets the screening criteria for destruction technologies set out in the *UNEP April 2002 Report of the Technology and Economic Assessment Panel (TEAP), Volume 3b, Report of the Task Force on Destruction Technologies*[5], as may be updated from time to time. The report sets out, inter alia, requirements for Destruction and Removal Efficiency (DRE).

3.3.7 For concentrated sources (e.g., refrigerants), projects shall use a destruction technology with a minimum verified DRE of 99.99 percent.

3.3.8 For dilute sources (i.e., foams), projects shall use a destruction technology with a minimum verified DRE of 95 percent. In addition, a minimum Recovery and Destruction Efficiency (RDE) of 85 percent shall be achieved. RDE describes the proportion of blowing agent (ODS) remaining in the foam immediately prior to decommissioning that is recovered in the overall end-of-life management step, including ultimate destruction. For a full specification of RDE, see the *UNEP May 2005 Report of the Technology and Economic Assessment Panel, Volume 3, Report of the Task Force on Foam End-of-Life Issues*.[6]

Note – The May 2005 TEAP report *provides a theoretical model for calculating RDE and methodology elements will need to specify a practical approach for determining RDE, such as those provided in* RAL GZ 728 (Quality Assurance and Test Specifications for the Demanufacture of Refrigeration Equipment, 2007)*, the* WEEE Forum standard (Requirements for the Collection, Transportation, Storage, Handling and Treatment of Household Cooling and Freezing Appliances containing CFC, HCFC or HFC, 2007) *or another appropriate approach.*

3.4 Project Documentation

Concept

In order to complete the project validation process, project proponents shall prepare a project description, which describes the project's GHG emission reduction or removal activities. In order to complete the project verification process, project proponents shall prepare a monitoring report, which describes the data and information related to the monitoring of GHG emission reductions or removals.

[5] UNEP, 2002, UNEP April 2002 Report of the Technology and Economic Assessment Panel, Volume 3b, Report of the Task Force on Destruction Technologies. (http://ozone.unep.org/teap/Reports/Other_Task_Force/TEAP02V3b.pdf)
[6] UNEP, 2005, UNEP May 2005 Report of the Technology and Economic Assessment Panel, Volume 3, Report of the Task Force on Foam End-of-Life Issues. (http://ozone.unep.org/teap/Reports/TEAP_Reports/TEAP-May-2005-Vol-2-Forms-End-of-Life.pdf)

Requirements

Project Description

3.4.1 The project proponent shall use the *VCS Project Description Template*, an approved combined project description template available on the Verra website or an approved GHG program project description template where the project is registered under an approved GHG program, as appropriate. The project proponent shall adhere to all instructional text within the template.

3.4.2 All information in the project description shall be presumed to be available for public review, though commercially sensitive information may be protected, as set out in the VCS Program document *Registration and Issuance Process*, where it can be demonstrated that such information is commercially sensitive. The validation/verification body shall check that any information designated by the project proponent as commercially sensitive meets the VCS Program definition of commercially sensitive information. Information in the project description related to the determination of the baseline scenario, demonstration of additionality, and estimation and monitoring of GHG emission reductions and removals shall not be considered to be commercially sensitive and shall be provided in the public versions of the project description.

Monitoring Report

3.4.3 The project proponent shall use the *VCS Monitoring Report Template* or an approved combined monitoring report template available on the Verra website, as appropriate, and adhere to all instructional text within the template.

3.4.4 The monitoring period of the monitoring report shall be a distinct time period that does not overlap with previous monitoring periods. Projects shall not be eligible for crediting of GHG emission reductions generated in previous monitoring periods. In addition, monitoring periods shall be contiguous with no time gaps between monitoring periods.

3.4.5 Where a monitoring report and associated verification report divide a monitoring period into vintages, separate VCU issuance records in accordance with vintage periods may be issued, as set out in the VCS Program document *Registration and Issuance Process*.

3.5 Project Design

Concept

The VCS Program allows for different approaches to project design. Projects may be designed as a single installation of an activity. Projects may also be designed to include more than one project activity, such as an AFOLU project that includes REDD and ALM components. In addition, projects may be designed to include more than one project activity instance, such as a clean cookstove project that distributes cookstoves to a number of different communities. Finally, projects may be designed as grouped projects, which are projects structured to allow the expansion of a project activity subsequent to project validation.

Note – Project activity and project activity instance both have the specific meanings that are set out in the VCS Program document Program Definitions*.*

Requirements

Multiple Project Activities

3.5.1 Projects may include multiple project activities where the methodology applied to the project allows more than one project activity and/or where projects apply more than one methodology.

3.5.2 Where more than one methodology has been applied to a project with multiple project activities, the following applies:

1) Each project activity shall be specified separately in the project description, referencing the relevant methodology.

2) All criteria and procedures set out in the applied methodologies in relation to applicability conditions, demonstration of additionality, determination of baseline scenario and GHG emission reduction and removal quantification shall be applied separately to each project activity, noting the following:

   a) A single set of criteria and procedures for the demonstration of additionality may be applied where the applied methodologies reference the same additionality tool and/or procedures, and where separate demonstration of additionality for each project activity is not practicable.

      For example, separate demonstration of additionality may not be practicable in project activities that are implemented at a single facility and therefore represent a single investment. The onus is upon the project proponent to demonstrate to the validation/verification body that separate demonstration of additionality is not practicable, failing which separate demonstration of additionality shall be provided. Where a methodology specifies requirements for demonstrating additionality in addition to those specified in the referenced additionality tool and/or procedures, such requirements shall be adhered to.

   b) The criteria and procedures for identifying the baseline scenario may be combined where the relevant methodologies or the referenced additionality tool and/or procedures specify criteria and procedures for combining baseline scenarios.

3) The criteria and procedures relating to all other aspects of the methodologies may be combined.

4) Where AFOLU projects are required to undertake non-permanence risk assessment and buffer withholding determination, this shall be done separately for each project activity.

Note – Where a single methodology is applicable to more than one project activity and where the methodology does not provide clear procedures for the application of more than one project activity, the above requirements shall be adhered to.

3.5.3 AFOLU projects that include multiple project activities shall comply with the respective project requirements of each included AFOLU category.

For example, projects that combine agroforestry or enrichment planting with community forestry in a single project, where farmers integrate these activities within a single landscape, shall follow an ARR methodology for planting activities and an IFM methodology for community forestry activities (except where the activities have been combined in a single methodology). Similarly, projects that integrate avoided grassland and shrubland conversion and improved grazing practices shall follow an ACoGS methodology for grassland or shrubland protection activities and an ALM methodology for improved grazing practices (except where both activities have been combined into a single methodology). Avoided conversion projects in landscapes that contain both forest and non-forest shall follow a REDD methodology for forested lands and an ACoGS methodology for non-forested lands. For each activity covered by a different methodology, the geographic extent of the area to which the methodology is applied shall be clearly delineated.

Multiple Instances of Project Activities

3.5.4 Inclusion of further project activity instances subsequent to initial validation of a non-grouped project is not permitted (see Sections 3.5.8 – 3.5.16 for information on grouped projects).

3.5.5 The baseline determination and additionality demonstration for all project activity instances shall be combined (e.g., multiple wind turbines shall be assessed in combination rather than individually).

3.5.6 Where a project includes multiple project activity instances from multiple project activities, the project activity instances from each project activity shall be assessed in accordance with Sections 3.5.1 – 3.5.3.

3.5.7 Non-grouped projects with multiple project activity instances shall not exceed any capacity limits to which a project activity is subject.

Grouped Projects

Baseline Scenario and Additionality

3.5.8 Grouped projects shall have one or more clearly defined geographic areas within which project activity instances may be developed. Such geographic areas shall be defined using geodetic polygons as set out in Section 3.10 below.

3.5.9 Determination of baseline scenario and demonstration of additionality are based upon the initial project activity instances. The initial project activity instances are those that are included in the project description at validation and shall include all project activity instances currently implemented on the issue date of the project description. The initial project activity instances may also include any planned instances of the project activity that have been planned and developed to a sufficient level of detail to enable their assessment at validation. Geographic areas with no initial project activity instances shall not be included in the project unless it can be demonstrated that such areas are subject to the same (or at least as conservative) baseline scenario and rationale for the demonstration of additionality as a geographic area that does include initial project activity instances.

3.5.10 As with non-grouped projects, grouped projects may incorporate multiple project activities (see Section 3.5.1 – 3.5.3 for more information on multiple project activities). Where a grouped project includes multiple project activities, the project description shall designate which project activities may occur in each geographic area.

3.5.11 The baseline scenario for a project activity shall be determined for each designated geographic area, in accordance with the methodology applied to the project. Where a single baseline scenario cannot be determined for a project activity over the entirety of a geographic area, the geographic area shall be redefined or divided such that a single baseline scenario can be determined for the revised geographic area or areas.

3.5.12 The additionality of the initial project activity instances shall be demonstrated for each designated geographic area, in accordance with the methodology applied to the project. Where the additionality of the initial project activity instances within a particular geographic area cannot be demonstrated for the entirety of that geographic area, the geographic area shall be redefined or divided such that the additionality of the instances occurring in the revised geographic area or areas can be demonstrated.

3.5.13 Where factors relevant to the determination of the baseline scenario or demonstration of additionality require assessment across a given area, the area shall be, at a minimum, the grouped project geographic area. Examples of such factors include, inter alia, common practice; laws, statutes, regulatory frameworks or policies relevant to demonstration of regulatory surplus; determination of regional grid emission factors; and historical deforestation and degradation rates.

Capacity Limits

3.5.14 Where a capacity limit applies to a project activity included in the project, no project activity instance shall exceed such limit. Further, no single cluster of project activity instances shall exceed the capacity limit, determined as follows:

1) Each project activity instance that exceeds one percent of the capacity limit shall be identified.
2) Such instances shall be divided into clusters, whereby each cluster is comprised of any system of instances such that each instance is within one kilometer of at least one other instance in the cluster. Instances that are not within one kilometer of any other instance shall not be assigned to clusters.

3) None of the clusters shall exceed the capacity limit and no further project activity instances shall be added to the project that would cause any of the clusters to exceed the capacity limit.

Eligibility Criteria

3.5.15 Grouped projects shall include one or more sets of eligibility criteria for the inclusion of new project activity instances. At least one set of eligibility criteria for the inclusion of new project activity instances shall be provided for each combination of project activity and geographic area specified in the project description. A set of eligibility criteria shall ensure that new project activity instances:

1) Meet the applicability conditions set out in the methodology applied to the project.
2) Use the technologies or measures specified in the project description.
3) Apply the technologies or measures in the same manner as specified in the project description.
4) Are subject to the baseline scenario determined in the project description for the specified project activity and geographic area.
5) Have characteristics with respect to additionality that are consistent with the initial instances for the specified project activity and geographic area. For example, the new project activity instances have financial, technical and/or other parameters (such as the size/scale of the instances) consistent with the initial instances, or face the same investment, technological and/or other barriers as the initial instances.

Note – Where grouped projects include multiple baseline scenarios or demonstrations of additionality, such projects will require at least one set of eligibility criteria for each combination of baseline scenario and demonstration of additionality specified in the project description.

Inclusion of New Project Activity Instances

3.5.16 Grouped projects provide for the inclusion of new project activity instances subsequent to the initial validation of the project. New project activity instances shall:

1) Occur within one of the designated geographic areas specified in the project description.
2) Comply with at least one complete set of eligibility criteria for the inclusion of new project activity instances. Partial compliance with multiple sets of eligibility criteria is insufficient.
3) Be included in the monitoring report with sufficient technical, financial, geographic and other relevant information to demonstrate compliance with the applicable set of eligibility criteria and enable sampling by the validation/verification body.

4) Be validated at the time of verification against the applicable set of eligibility criteria.

5) Have evidence of project ownership, in respect of each project activity instance, held by the project proponent from the respective start date of each project activity instance (i.e., the date upon which the project activity instance began reducing or removing GHG emissions).

6) Have a start date that is the same as or later than the grouped project start date.

7) Be eligible for crediting from the start date of the instance through to the end of the project crediting period (only). Note that where a new project activity instance starts in a previous verification period, no credit may be claimed for GHG emission reductions or removals generated during a previous verification period (as set out in Section 3.4.4) and new instances are eligible for crediting from the start of the next verification period.

Where inclusion of a new project activity instance necessitates the addition of a new project proponent to the project, such instances shall be included in the grouped project within two years of the project activity instance start date or, where the project activity is an AFOLU activity, within five years of the project activity instance start date. The procedure for adding new project proponents is set out in the VCS Program document *Registration and Issuance Process*.

AFOLU Projects

3.5.17 AFOLU non-permanence risk analyses, where required, shall be assessed for each geographic area specified in the project description (for requirements related to geographic areas of grouped projects see the VCS Standard). Where risks are relevant to only a portion of each geographic area, the geographic area shall be further divided such that a single total risk rating can be determined for each geographic area. Where a project is divided into more than one geographic area for the purpose of risk analysis, the project's monitoring and verification reports shall list the total risk rating for each area and the corresponding net change in the project's carbon stocks in the same area, and the risk rating for each area applies only to the GHG emissions reductions generated by project activity instances within the area.

3.5.18 Activity-shifting, market leakage and ecological leakage assessments, where required, shall be undertaken as set out in Section 3.14.5 – 3.14.15, and the methodology applied, on the initial group of instances of each project activity and reassessed where new instances of the project activity are included in the project.

Project Description for Grouped Projects

3.5.19 A grouped project shall be described in a single project description, which shall contain the following (in addition to the content required for non-grouped projects):

1) A delineation of the geographic area(s) within which all project activity instances shall occur. Such area(s) shall be defined by geodetic polygons as set out in Section 3.10 below.

2) One or more determinations of the baseline for the project activity in accordance with the requirements of the methodology applied to the project.

3) One or more demonstrations of additionality for the project activity in accordance with the requirements of the methodology applied to the project.

4) One or more sets of eligibility criteria for the inclusion of new project activity instances at subsequent verification events.

5) A description of the central GHG information system and controls associated with the project and its monitoring.

Note – Where the project includes more than one project activity, the above requirements shall be addressed separately for each project activity, except for the delineation of geographic areas and the description of the central GHG information system and controls, which shall be addressed for the project as a whole.

3.6 Ownership

Concept

Project and jurisdictional proponents shall demonstrate that they have the legal right to control and operate project or program activities.

Requirements

3.6.1 The project description shall be accompanied by one or more of the following types of evidence establishing project ownership accorded to the project proponent(s), or program ownership accorded to the jurisdictional proponent(s), as the case may be (see the VCS Program document *Program Definitions* for definitions of project ownership and program ownership). To aid the readability of this section, the term project ownership is used below, but should be substituted by the term program ownership, as appropriate:

1) Project ownership arising or granted under statute, regulation or decree by a competent authority.

2) Project ownership arising under law.

3) Project ownership arising by virtue of a statutory, property or contractual right in the plant, equipment or process that generates GHG emission reductions and/or removals (where the project proponent has not been divested of such project ownership).

4) Project ownership arising by virtue of a statutory, property or contractual right in the land, vegetation or conservational or management process that generates GHG emission reductions and/or removals (where the project proponent has not been divested of such project ownership).

5) An enforceable and irrevocable agreement with the holder of the statutory, property or contractual right in the plant, equipment or process that generates GHG emission reductions and/or removals which vests project ownership in the project proponent.

6) An enforceable and irrevocable agreement with the holder of the statutory, property or contractual right in the land, vegetation or conservational or management process that generates GHG emission reductions or removals which vests project ownership in the project proponent.

7) Project ownership arising from the implementation[7] or enforcement of laws, statutes or regulatory frameworks that require activities be undertaken or incentivize activities that generate GHG emission reductions or removals.

3.7 Project Start Date

Concept

The project start date of a non-AFOLU project is the date on which the project began generating GHG emission reductions or removals. The project start date of an AFOLU project is the date on which activities that led to the generation of GHG emission reductions or removals are implemented (e.g., preparing land for seeding, planting, changing agricultural or forestry practices, rewetting, restoring hydrological functions, or implementing management or protection plans). Projects shall complete validation within specific timeframes from the project start date.

Requirements

Non-AFOLU Projects

3.7.1 Non-AFOLU projects shall complete validation within two years of the project start date. Additional time is granted for non-AFOLU projects to complete validation where they are applying a new VCS methodology. Specifically, projects using a new VCS methodology and completing validation within two years of the approval of the methodology by Verra may complete validation within four years of the project start date.

3.7.2 Note that new VCS methodology in this context refers to both newly issued VCS methodologies and newly issued VCS revisions to approved GHG program methodologies. The grace period does not apply in relation to any subsequent versions of such new methodologies and new methodology revisions that may be issued.

AFOLU Projects

3.7.3 AFOLU projects shall complete validation within five years of the project start date.

[7] Implemented in the context of this paragraph means enacted or introduced, consistent with use of the term under the CDM rules on so-called Type E+ and Type E- policies.

ODS Projects

3.7.4 ODS projects shall comply with at least one of the following in relation to project start date:

1) The project start date shall not be before the Montreal Protocol production phase-out deadline (except for critical/essential uses) for the relevant ODS as it applies to the host country and/or any country from which ODS destroyed by the project is imported (as applicable); or

2) The project start date shall not be before the date the host country and/or any country from which ODS destroyed by the project is imported (as applicable) implements the production phase-out, or consumption phase-out where such country does not produce the relevant ODS, of the relevant ODS (critical/essential uses exempted). Such phase-outs shall be implemented in combination with an import ban on the relevant ODS (critical/essential uses exempted). This project start date requirement accounts for countries that phase-out the relevant ODS in advance of their Montreal Protocol production phase-out deadline.

Note – The project can destroy ODS that has not been phased out under either of the two options in above (e.g., if one ODS has contaminated another), but it shall receive no credit for the destruction of such ODS. Note also that the relevant production phase-out deadlines are those of the individual substances and not the substance groups.

Note – The relevant production phase-out deadlines are those of the individual substances and not the substance groups.

3.7.5 Where the project imports ODS, it shall provide documentary evidence, such as shipping manifests and bills of lading, to demonstrate that the ODS originates from a country meeting with the above.

Standardized Methods

3.7.6 Notwithstanding the requirements set out in Sections 3.7.1 – 3.7.5 above, projects applying a standardized method for determining additionality shall initiate the project pipeline listing process set out in the VCS Program document *Registration and Issuance Process* within the project validation timelines set out above. Validation may be completed any time thereafter.

For example, a non-AFOLU project applying a standardized method for determining additionality shall initiate the project pipeline listing process within two years of the project start date, and may complete validation any time thereafter.

Projects Registered with Other GHG Programs

3.7.7 For projects registered under an approved GHG program which are seeking registration with the VCS Program, further specification with respect to the validation deadline is set out in Sections 3.19.5 and 3.19.6.

3.8 Project Crediting Period

Concept

The project crediting period is the time period for which GHG emission reductions or removals generated by the project are eligible for issuance as VCUs. Project crediting periods shall be renewed periodically in order to ensure that changes to a project's baseline scenario and regulatory surplus are taken into consideration throughout the lifetime of the project.

Requirements

Project Crediting Period Length

Non-AFOLU Projects

3.8.1 For non-AFOLU projects, the project crediting period shall be either seven years, twice renewable for a total of 21 years, or ten years fixed.

AFOLU Projects

3.8.2 For ALM projects focusing exclusively on reducing N_2O, CH_4 and/or fossil-derived CO_2 emissions, the project crediting period shall be either seven years, twice renewable for a total of 21 years, or ten years fixed.

3.8.3 For all other AFOLU projects other than such ALM projects described above, the project crediting period shall be a minimum of 20 years up to a maximum of 100 years, which may be renewed at most four times with a total project crediting period not to exceed 100 years.

3.8.4 AFOLU projects shall have a credible and robust plan for managing and implementing the project over the project crediting period.

3.8.5 For ARR or IFM extension of rotation age or low-productive to high-productive projects with harvesting, the length of the project crediting period shall be set to include at least one complete harvest/cutting cycle. In the case of selectively cut IFM projects, where trees are individually selected for harvest, the harvest/cutting cycle is the allowable re-entry period into the harvest area as determined by legal and regulatory requirements, and/or common practice.

3.8.6 The earliest project crediting period start date for AFOLU projects shall be 1 January 2002.

Projects Registered under Other GHG Programs

3.8.7 Projects registered under other GHG programs are not eligible for VCU issuance beyond the end of the total project crediting period under those programs. For example, a CDM project with a seven year twice renewable project crediting period is not eligible for VCU issuance beyond the end of those 21 years. Where projects have been registered under more than one other GHG program, they are not eligible for VCU issuance after the date that is the earliest end date of all applicable project crediting periods.

Note – Since the total project crediting period under the Joint Implementation (JI) program is not defined ex-ante, the total project crediting period shall be deemed as 21 years for non-AFOLU JI projects and as 60 years for AFOLU JI projects[8].

Renewal of Project Crediting Period

3.8.8 Where projects fail to renew the project crediting period, the project crediting period shall end and the project shall be ineligible for further crediting.

3.8.9 The following shall apply with respect to the renewal of the project crediting period under the VCS Program:

1) A full reassessment of additionality is not required when renewing the project crediting period. However, regulatory surplus shall be demonstrated in accordance with the requirements set out in the VCS Program rules and the project description shall be updated accordingly.
2) The validity of the original baseline scenario shall be demonstrated, or where invalid a new baseline scenario shall be determined, when renewing the project crediting period, as follows:
    a) The validity of the original baseline scenario shall be assessed. Such assessment shall include an evaluation of the impact of new relevant national and/or sectoral policies and circumstances on the validity of the baseline scenario.
    b) Where it is determined that the original baseline scenario is still valid, the GHG emissions associated with the original baseline scenario shall be reassessed using the latest version of the *CDM Tool to assess the validity of the original/current baseline and to update the baseline at the renewal of a crediting period*.
    c) Where it is determined that the original baseline scenario is no longer valid, the current baseline scenario shall be established in accordance with the VCS Program rules.
    d) The project description, containing updated information with respect to the baseline, the estimated GHG emission reductions or removals and the monitoring plan, shall be submitted for validation. Such updates shall be based upon the latest approved version of the methodology or its replacement. Where the project does not meet the requirements of the latest approved version of the methodology or its replacement, the project proponent shall select another applicable approved methodology (which may be a new methodology or methodology revision it has had approved via the methodology approval process), or shall apply a methodology deviation (where a methodology deviation is appropriate). Failing this, the project shall not be eligible for renewal of its project crediting period.

[8] Consistent with the UNFCCC's other project-based mechanism, CDM.

3) The updated project description shall be validated in accordance with the VCS Program rules. In addition, the project shall be validated against the (current) scope of the VCS. Such validation report shall be issued after the end of the (previous) project crediting period but within two years after the end of the (previous) project crediting period.

Additional time is granted for projects to complete such validation where they are switching to a new VCS methodology (*new VCS methodology* in this context has the same meaning as set out in Section 3.7.1) when renewing the project crediting period. Specifically, projects switching to a new VCS methodology and completing such validation within one year of the approval of the methodology by Verra may complete such validation within three years of the end of the (previous) project crediting period.

3.9 Project Scale

Concept

Projects are categorized by size according to their estimated average annual GHG emission reductions or removals. Materiality thresholds differ for projects of different sizes.

Requirements

3.9.1 Project size categorizations are as follows:

1) *Projects*: Less than or equal to 300,000 tonnes of CO_2e per year.
2) *Large projects*: Greater than 300,000 tonnes of CO_2e per year.

3.9.2 Materiality requirements for validation and verification differ according to project size, as set out in Section 4.1.8 below.

3.9.3 Where applying a methodology with scale and/or capacity limits, it shall be demonstrated that the project is not a fragmented part of a larger project or activity that would otherwise exceed such limits. The project shall be considered a fragmented part of a larger project if within one kilometer of the project boundary there exists another project where:

1) The project proponents for both projects are the same.
2) The sectoral scope and project activity for both projects are the same.
3) The other project has been registered under the VCS Program or another GHG program within the previous two years.

3.10 Project Location

Concept

The project location shall be provided in order to accurately describe project characteristics and to demonstrate a project's conformance with other requirements, such as project ownership and regulatory compliance.

Requirements

General

3.10.1 Project location shall be specified in the project description as follows:

1) Project location for non-AFOLU projects shall be specified by a single geodetic coordinate.
2) Where there are multiple project activity instances (see Sections 3.5.4 – 3.5.7 for more information on multiple project activities), project location shall be specified according to the following:
    a) Where it is reasonable to do so, a geodetic coordinate shall be provided for each instance and provided in a KML file; or
    b) Where there are a large number project activity instances (e.g., cookstoves or energy efficient light bulbs), at least one geodetic coordinate shall be provided, together with sufficient additional geographic information (with respect to the location of the instances) to enable sampling by the validation/verification body.
3) Project location for grouped projects shall be specified using geodetic polygons to delineate the project's geographic area or areas (see Section 3.5.8 for further information on geographic areas for grouped projects) and provided in a KML file.

AFOLU Projects

3.10.2 The project location for AFOLU projects shall be specified in the project description in terms of its project area. The spatial extent of the project shall be clearly specified to facilitate accurate monitoring, reporting and verification of GHG emission reductions and removals and to demonstrate that the project meets the eligibility criteria of the relevant project category. The description of the project location shall include the following information:

1) Name of the project area (e.g., compartment number, allotment number and local name).
2) Maps of the project area.
3) Geodetic polygons that delineate the geographic area of each AFOLU project activity, provided in a KML file.
4) Total size of the project area.
5) Details of ownership.

Where the project area is comprised of multiple polygons (parcels), the project location details of each polygon/parcel shall be included in the project description.

3.10.3 The project proponent shall demonstrate control over the entire project area with documentary evidence establishing project ownership, noting the following:

1) For non-grouped projects, the entire project area shall be under the control of the project proponent at the time of validation, or shall come to be under the control of the project proponent by the first verification event.

2) Where the project proponent does not yet have control over the entire area at validation, the entire project area (that shall be specified in accordance with Section 3.10.2) is to be validated as if it were under control and the project is ready to be implemented.

3) Where less than 80 percent of the total proposed area of the project is under current control at validation, the following applies:

   a) It shall be demonstrated that the result of the additionality test is applicable to the project area at the time of validation and to the entire project area to come under control in the future.

   b) The monitoring plan shall be designed such that it is flexible enough to deal with changes in the size of the project.

   c) The project shall be verified within five years of validation. At verification, the size of the project becomes fixed.

   d) Where the area fixed at verification is smaller than intended at validation, areas that at verification have not come under control of the project shall be considered in the leakage management, mitigation and accounting. This requires the selection, at validation, of a methodology with appropriate leakage methods that may be used in the event the entire area does not come under control of the project.

3.10.4 WRC projects shall demonstrate that:

1) There is no hydrological connectivity to adjacent (non-project) areas; or

2) It is not possible for hydrologically connected areas to have a negative impact on the hydrology within the project area that could cause a significant increase in GHG emissions; or

3) Where projects are hydrologically connected to adjacent areas that may have a negative impact on the hydrology within the project area, projects shall demonstrate that such impacts will not result in a significant increase in GHG emissions, as follows:

   a) Peatland projects shall establish a buffer zone to ensure that potential negative impacts to the hydrology in the project area, such as causing the water table in the project area to drop or otherwise negatively impacting the hydrology, are mitigated. The buffer zone may be inside or outside the geographic boundary of the project area.

Where it is outside of the project area, the buffer zone shall be adjacent to the project geographic boundary and binding water management agreements with land holders in the buffer zone shall be in place by the time of the first verification. The size and shape of the buffer zone shall be sufficient to avoid such negative impacts on the project area, which may be demonstrated through peer reviewed literature or expert judgment.

b) All other wetland projects shall establish a buffer zone as set out in Section 3.10.4(3)(a) above, or implement project activities or establish a mitigation plan to ensure that impacts to the hydrology (e.g., interrupted water or sediment supply) do not result in a significant increase in GHG emissions. Emphasis shall be placed on hydrological connectivity that is immediately adjacent to the project area. Coastal wetlands shall consider hydrological connectivity originating from adjacent lands and shall follow the applied methodology with respect to oceanic impacts.

Where a project activity to mitigate impacts from hydrological connectivity causes an increase in GHG emissions in the project area or buffer zone, such emissions shall be included in GHG accounting where above *de minimis.*

3.11 Project Boundary

Concept

The project boundary includes the GHG sources, sinks and reservoirs that are relevant to the project and baseline scenarios. The relevant GHG sources, sinks and reservoirs that shall be included or excluded, or are optional, are set out in the methodology(s) applied by the project.

Requirements

3.11.1 The project boundary shall be described (using diagrams, as required) and GHG sources, sinks and reservoirs shall be identified and assessed in accordance with the methodology applied to the project. The project shall justify not selecting any relevant GHG source, sink and reservoir.

3.12 Baseline Scenario

Concept

The baseline scenario represents the activities and GHG emissions that would occur in the absence of the project activity. The baseline scenario shall be accurately determined so that an accurate comparison can be made between the GHG emissions that would have occurred under the baseline scenario and the GHG emission reductions and/or removals that were achieved by project activities.

Requirements

3.12.1 The baseline scenario for the project shall be determined in accordance with the requirements set out in the methodology applied to the project, and the choice of baseline scenario shall be justified.

3.12.2 Equivalence in type and level of activity of products or services provided by the project and the baseline scenario shall be demonstrated and, where appropriate, any significant differences between the project and the baseline scenario shall be explained.

3.12.3 In developing the baseline scenario, assumptions, values and procedures shall be selected that help ensure that net GHG emission reductions and removals are not overestimated.

3.13 Additionality

Concept

A project activity is additional if it can be demonstrated that the activity results in emission reductions or removals that are in excess of what would be achieved under a “business as usual” scenario and the activity would not have occurred in the absence of the incentive provided by the carbon markets. Additionality is an important characteristic of GHG credits, including VCUs, because it indicates that they represent a net environmental benefit and a real reduction of GHG emissions, and can thus be used to offset emissions.

Requirements

3.13.1 Additionality shall be demonstrated and assessed in accordance with the requirements set out in the methodology applied to the project, noting the following exceptions:

1) Where a VCS module using an activity method (see the *VCS Methodology Requirements* for further information on activity methods) is applicable to the project, additionality may be demonstrated using the module in substitution of the additionality requirements set out in the methodology.

   For example, if a module uses an activity method (i.e., positive list) to deem a project activity additional, the project proponent does not have to follow the additionality requirements in the methodology applied to the project and may instead demonstrate additionality by demonstrating that it meets the applicability conditions and any other criteria of the activity method.

   Note that only modules may be used in this way. Where a methodology contains an activity method for additionality, the additionality procedures may not be applied in conjunction with a different methodology.

2) Where the applied methodology was developed under an approved GHG program and uses an activity method or other simplified procedure for demonstrating additionality, the project proponent shall demonstrate to the validation/verification body that the simplified procedure is appropriate to apply to the project considering the project characteristics, including the context in which the project activity takes place. Failing this demonstration, the project proponent shall not use the simplified procedure for demonstrating additionality, and shall instead use an appropriate additionality assessment method in substitution.

For example, where a project is developed in the United States and applies a CDM methodology which uses a simplified procedure for demonstrating additionality, the project proponent shall demonstrate to the validation/verification body that the simplified procedure is appropriate to apply given that the simplified procedure was originally developed for application in a developing country context.

ODS Projects

3.13.2 The project shall not be mandated by any law, statute or other regulatory framework applying in the host country that was implemented on or before 11 November 2001, or the compliance rate of any such law, statute or other regulatory framework during (part of) the project crediting period shall be below 50 percent.

3.14 Quantification of GHG Emission Reductions and Removals

Concept

GHG emission reductions and removals achieved by projects are the basis for the volume of VCUs that can be issued. GHG emissions reductions and removals shall be quantified in accordance with the applied methodology(s).

Requirements

3.14.1 GHG emission and/or removals shall be estimated for each GHG source, sink and/or reservoir relevant for the project (including leakage) and the baseline scenarios.

3.14.2 The net GHG emission reductions and removals generated by the project shall be quantified.

3.14.3 Metric tonnes shall be used as the unit of measure and the quantity of each type of GHG shall be converted to tonnes of CO_2e.

3.14.4 The six Kyoto Protocol greenhouse gases and ozone-depleting substances shall be converted using 100-year global warming potentials derived from the IPCC's *Fourth Assessment Report*.

AFOLU Projects

3.14.5 The potential for leakage shall be identified for AFOLU projects, and projects are encouraged to include leakage management zones as part of the overall project design. Leakage management zones can minimize the displacement of land use activities to areas outside the project area by maintaining the production of goods and services, such as agricultural products, within areas under the control of the project proponent or by addressing the socio-economic factors that drive land use change. Activities to mitigate ecological leakage in WRC projects may include the establishment of a leakage management zone inside the project boundary.

3.14.6 Activities to mitigate leakage and sustainably reduce deforestation and/or forest or wetland degradation are encouraged and may include the establishment of agricultural intensification practices on non-wetlands, lengthened fallow periods, agroforestry and fast-growing woodlots on degraded land, forest under-story farming, ecotourism and other sustainable livelihood activities, sustainable production of non-timber forest products, and/or sustainable aquaculture. Leakage mitigation activities may be supplemented by providing economic opportunities for local communities that encourage forest or wetland protection, such as employment as protected-area guards, training in sustainable forest use or assisting communities in securing markets for sustainable forest products, such as rattan, vanilla, cacao, coffee and natural medicines, or wetland products, such as rattan, fish and shellfish.

3.14.7 Where projects are required to account for leakage, such leakage evaluation shall be documented in the appropriate section of the project description and/or monitoring report, as applicable.

3.14.8 Market leakage assessments shall occur per the requirements set out in the applied methodology(s) at validation and verification.

3.14.9 Notwithstanding the requirement set out in Section 3.14.8 above, IFM projects may apply the appropriate market leakage discount factor identified in Table 2 to the net change in carbon stock associated with the activity that reduces timber harvest to determine market leakage.

Table 2: Market Leakage Discount Factors

Project Action	Leakage Risk	Market Leakage Discount Factor
IFM activity with no effect or minimal effect on total timber harvest volumes (e.g., RIL with less than 25% reduction)	None	0%
IFM activity that leads to a shift in harvests across time periods but minimal change in total timber harvest over time (e.g., ERA with rotation extension of 5-10 years)	Low	10%
IFM activity that substantially reduces harvest levels permanently (e.g., RIL activity that reduces timber harvest across the project area, or project that halts logging by at least 25%)	Moderate to High	Conditional upon where timber harvest is likely to be shifted, as follows: • Where the ratio of merchantable biomass to total biomass is higher within the area to which harvesting is displaced compared to the project area, 20% • Where the ratio of merchantable biomass to total biomass is similar within the area to which harvesting is displaced compared to the project area, 40% • Where the ratio of merchantable biomass to total biomass is lower within the area to which harvesting is displaced compared to the project area, 70% • Where the leakage is out of country, 0%

3.14.10 Leakage occurring outside the host country (international leakage) does not need to be quantified.

3.14.11 Projects shall not account for positive leakage (i.e., where GHG emissions decrease or removals increase outside the project area due to project activities).

3.14.12 Where the applied methodology(s) does not set out a method to determine whether leakage is *de minimis*, projects may use the process set out in the VCS Program document *VCS Methodology Requirements* or the CDM A/R methodological *Tool for testing significance of GHG Emissions in A/R CDM Project Activities.*

3.14.13 Projects may apply optional default leakage deductions at validation under the following circumstances:

1) Where the applied methodology requires the quantification of activity-shifting leakage, projects may apply the optional default activity-shifting leakage deduction of 15 percent to the gross GHG emission reductions and/or removals.

2) Where the applied methodology requires the quantification of market leakage and where a) timber is a significant[9] commodity that is driving deforestation and/or degradation in the baseline scenario and b) the project country is not a leading producer or exporter of forest products as defined by the United Nations Food and Agriculture Organization (FAO)[10], projects may apply the optional default market leakage deduction of 10 percent to the gross GHG emission reductions and/or removals.

3.14.14 Projects shall monitor and calculate leakage, per the applied methodology, for all ex-post accounting (i.e., at each verification), and leakage shall be deducted from the total GHG emission reductions and/or removals of the project. Any leakage shall be subtracted from the number of GHG emission reductions and removals eligible to be issued as VCUs.

3.14.15 The number of GHG credits issued to projects is determined by subtracting out the buffer credits from the net GHG emission reductions or removals (including leakage) associated with the project. The buffer credits are calculated by multiplying the non-permanence risk rating (as determined by the *AFOLU Non-Permanence Risk Tool*) times the change in carbon stocks only. The full rules and procedures with respect to assignment of buffer credits are set out in the VCS Program document *Registration and Issuance Process*.

3.15 Monitoring

Concept

The impacts of project activities on relevant emission sources, sinks and reservoirs shall be monitored in order to determine the net GHG benefit. Projects shall be monitored in accordance with the applied methodology(s).

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[9] Defined as contributing to 20 percent or more of baseline emissions.

[10] The FAO releases annual listings of countries that are Major Producers of Forest Products (http://www.fao.org/forestry/statistics/80938@180723/en/) and Major Exporters of Forest Products (http://www.fao.org/forestry/statistics/80938@180724/en/).

Requirements

Data and Parameters

3.15.1 Data and parameters used for the quantification of GHG emission reductions and/or removals shall be provided in accordance with the methodology.

3.15.2 Quality management procedures to manage data and information shall be applied and established. Where applicable, procedures to account for uncertainty in data and parameters shall be applied in accordance with the requirements set out in the methodology.

Monitoring Plan

3.15.3 The project proponent shall establish a GHG information system for obtaining, recording, compiling and analyzing data and information important for quantifying and reporting GHG emissions and/or removals relevant for the project (including leakage) and baseline scenario.

3.15.4 A monitoring plan for the project that includes roles and responsibilities shall be established.

3.15.5 Where measurement and monitoring equipment is used, the project proponent shall ensure the equipment is calibrated according to the equipment's specifications and/or relevant national or international standards.

3.16 Safeguards

Concept

Project activities shall not negatively impact the natural environment or local communities. Project proponents shall identify and address any negative environmental and socio-economic impacts of project activities, and shall engage with local stakeholders during the project development and implementation processes.

Requirements

General

No Net Harm

3.16.1 The project proponent shall identify potential negative environmental and socio-economic impacts, and shall take steps to mitigate them. Additional certification standards may be applied to demonstrate social and environmental benefits beyond GHG emission reductions or removals.

Note that VCUs may be labeled with additional standards and certifications on the Verra registry where both the VCS Program and another standard are applied. The Verra website provides the list of standards that are accepted as VCU labels and the procedure for attaining such VCU labels.

Local Stakeholder Consultation

3.16.2 The project proponent shall conduct a local stakeholder consultation prior to validation as a way to inform the design of the project and maximize participation from stakeholders. Such consultations allow stakeholders to evaluate impacts, raise concerns about potential negative impacts and provide input on the project design.

3.16.3 The project proponent shall establish mechanisms for ongoing communication with local stakeholders to allow stakeholders to raise concerns about potential negative impacts during project implementation.

3.16.4 The project proponent shall take due account of all and any input received during the local stakeholder consultation and through ongoing communications, which means it will need to either update the project design or justify why updates are not appropriate. The project proponent shall demonstrate to the validation/verification body what action it has taken in respect of the local stakeholder consultation as part of validation, and in respect of ongoing communications as part of each subsequent verification.

Public Comment Period

3.16.5 All projects are subject to a 30-day public comment period. The date on which the project is listed on the project pipeline marks the beginning of the project's 30-day public comment period (see the VCS Program document *Registration and Issuance Process* for more information on the VCS project pipeline).

3.16.6 Projects shall remain on the project pipeline for the entirety of their 30-day public comment period.

3.16.7 Any comments shall be submitted to Verra at secretariat@verra.org and respondents shall provide their name, organization, country and email address. At the end of the public comment period, Verra provides all and any comments received to the project proponent.

3.16.8 The project proponent shall take due account of any and all comments received during the consultation, which means it will need to either update the project design or demonstrate the insignificance or irrelevance of the comment. It shall demonstrate to the validation/verification body what action it has taken.

AFOLU Projects

3.16.9 Where AFOLU project activities do not impact local stakeholders, projects are not required to meet the requirements set out in Sections 3.16.11– 3.16.18 below. The project proponent shall provide evidence that project activities do not impact local stakeholders at validation and each verification.

3.16.10 Where AFOLU projects complete a validation or verification to the Climate, Community & Biodiversity (CCB) Program at the same time as a VCS Program validation or verification, they are not required to conduct a separate demonstration of compliance with the requirements set out in this Section 3.16.

Note – Where an AFOLU project has previously certified to the Climate, Community & Biodiversity (CCB) Program, but is completing a VCS Program verification without also completing a CCB Program verification for the same verification period, the project proponent shall demonstrate compliance with the requirements set out in Sections 3.16.11 – 3.16.18 below.

Local Stakeholder Identification and Background

3.16.11 The project proponent shall conduct a thorough assessment of the local stakeholders that will be impacted by the project. The project description shall include information on local stakeholders at the start of the project, including:

1) The process(es) used to identify local stakeholders likely impacted by the project and a list of such stakeholders;
2) Identification of any legal or customary tenure/access rights to territories and resources, including collective and/or conflicting rights, held by local stakeholders;
3) A description of the social, economic and cultural diversity within local stakeholder groups and the differences and interactions between the stakeholder groups;
4) Any significant changes in the makeup of local stakeholders over time;
5) The expected changes in well-being and other stakeholder characteristics under the baseline scenario, including changes to ecosystem services identified as important to local stakeholders;
6) The location of communities, local stakeholders and areas outside the project area that are predicted to be impacted by the project; and
7) The location of territories and resources which local stakeholders own or to which they have customary access.

Risks to Local Stakeholders

3.16.12 The project proponent shall identify likely natural and human-induced risks to local stakeholder well-being expected during the project lifetime and outline measures needed to mitigate these risks.

3.16.13 The project proponent shall identify the risks for local stakeholders to participate in the project, including project design and consultation. Risks should include trade-offs with food security, land loss, loss of yields and climate change adaptation. The project shall be designed and implemented to avoid trade-offs and manage the identified risks to local stakeholders.

3.16.14 The project proponent or any other entity involved in project design or implementation shall not be involved in any form of discrimination or sexual harassment.

3.16.15 The management teams involved in the project shall have expertise and prior experience implementing land management and carbon projects with community engagement at the project scale. Where relevant experience is lacking, the project proponent shall either demonstrate how they have partnered with other organizations to support the project or have a recruitment strategy to fill the identified gaps.

Respect for Local Stakeholder Resources

3.16.16 The project proponent shall avoid negative impacts of project implementation and mitigate impacts when unavoidable, including the following:

1) The project proponent shall recognize, respect and support local stakeholders' property rights and where feasible, take measures to help secure rights. The project shall not encroach on private, stakeholder or government property or relocate people off their lands without consent. The project may affect property rights if free, prior and informed consent is obtained from those concerned and a transparent agreement is reached that includes provisions for just and fair compensation. In the event there are any ongoing or unresolved conflicts over property rights, usage or resources, the project shall undertake no activity that could exacerbate the conflict or influence the outcome of an unresolved dispute.
2) To reduce damage to the ecosystems on which the local stakeholders rely:
    a) The project shall not introduce any invasive species or allow an invasive species to thrive through project implementation.
    b) The project shall justify the use of non-native species over native species, explaining the possible adverse effects of non-native species.
    c) The project shall justify the use of fertilizers, chemical pesticides, biological control agents and other inputs used by the project and their possible adverse effects.

Communication and Consultation

3.16.17 The project proponent shall take all appropriate measures to communicate and consult with local stakeholders in an ongoing process for the life of the project. The project proponent shall communicate:

1) The project design and implementation, including the results of monitoring.
2) The risks, costs and benefits the project may bring to local stakeholders.
3) All relevant laws and regulations covering workers' rights in the host country.
4) The process of VCS Program validation and verification and the validation/verification body's site visit.

3.16.18 The project proponent shall develop a grievance redress procedure to address disputes with local stakeholders that may arise during project planning and implementation, including with regard to benefit sharing. The procedure shall include processes for receiving, hearing, responding and attempting to resolve grievances within a reasonable time period, taking into account culturally-appropriate conflict resolution methods. The procedure and documentation of disputes resolved through the procedure shall be made publicly available. The procedure shall have three stages:

1) The project proponent shall attempt to amicably resolve all grievances and provide a written response to the grievances in a manner that is culturally appropriate.

2) Any grievances that are not resolved by amicable negotiations shall be referred to mediation by a neutral third party.

3) Any grievances that are not resolved through mediation shall be referred either to a) arbitration, to the extent allowed by the laws of the relevant jurisdiction or b) competent courts in the relevant jurisdiction, without prejudice to a party's ability to submit the grievance to a competent supranational adjudicatory body, if any.

3.16.19 All communication and consultation shall be performed in a culturally appropriate manner, including language and gender sensitivity, directly with local stakeholders or their legitimate representatives when appropriate. The results of implementation shall be provided in a timely manner and consultation shall be performed prior to design decisions or implementation to allow stakeholders adequate time to respond to the proposed design or action.

3.17 Methodology Deviations

Concept

Projects may deviate from the procedures set out in methodologies in certain cases, where alternative methods may be more efficient for project-specific circumstances, and where the deviation will achieve the same level of accuracy or is more conservative than what is set out in the methodology.

Requirements

3.17.1 Deviations from the applied methodology are permitted where they represent a deviation from the criteria and procedures relating to monitoring or measurement set out in the methodology (i.e., deviations are permitted where they relate to data and parameters available at validation, data and parameters monitored, or the monitoring plan).

3.17.2 Methodology deviations shall not negatively impact the conservativeness of the quantification of GHG emission reductions or removals, except where they result in increased accuracy of such quantification. Deviations relating to any other part of the methodology shall not be permitted.

3.17.3 Methodology deviations shall be permitted at validation or verification and their consequences shall be reported in the validation or verification report, as applicable, and all subsequent verification reports. Methodology deviations are not considered to be precedent setting.

3.18 Project Description Deviations

Concept

Projects may deviate from the validated project description in certain cases in order to accommodate changing circumstances post-validation. Such deviations shall be described and assessed by a validation/verification body during the next project verification.

Requirements

3.18.1 Deviations from the project description are permitted at verification.

3.18.2 The procedures for documenting a project description deviation depend on whether the deviation impacts the applicability of the methodology, additionality or the appropriateness of the baseline scenario. Interpretation of whether the deviation impacts any of these shall be determined consistent with the *CDM Guidelines on assessment of different types of changes from the project activity as described in the registered PDD,* mutatis mutandis. The procedures are as follows:

1) Where the deviation impacts the applicability of the methodology, additionality or the appropriateness of the baseline scenario, the deviation shall be described and justified in a revised version of the project description. This shall include a description of when the changes occurred, the reasons for the changes and how the changes impact the applicability of the methodology, additionality and/or the appropriateness of the baseline scenario.

   An example of such a deviation is a change in project capacity where a different baseline scenario would be more plausible, the applied methodology would no longer be applicable, or there would be a significant impact on the investment analysis used by the project to demonstrate additionality. Other examples include changes to the project that might have similar impacts such as the addition of new carbon pools or new types of project activities.

2) Where the deviation does not impact the applicability of the methodology, additionality or the appropriateness of the baseline scenario, and the project remains in compliance with the applied methodology, the deviation shall be described and justified in the monitoring report. This shall include a description of when the changes occurred and the reasons for the changes. The deviation shall also be described in all subsequent monitoring reports.

   Examples of such deviations include changes in the procedures for measurement and monitoring, or project design changes that do not have an impact on the applicability of the methodology, additionality or the appropriateness of the baseline scenario.

Note that project proponents may apply project description deviations for the purpose of switching to the latest version of the methodology, or switching to a different methodology. For example, a project proponent may want to switch to the latest version of a methodology where such version includes additional types of carbon pools or project activities.

3.18.3 The deviation shall be assessed by a validation/verification body and the process, findings and conclusions shall be reported in the verification report. The assessment shall determine whether the deviation is appropriately described and justified, and whether the project remains in compliance with the VCS Program rules. The deviation shall also be reported on in all subsequent verification reports. Project description deviations are not considered to be precedent-setting.

3.18.4 The validation/verification body assessing the project description deviation shall be accredited for the validation, recognizing that assessment of project description deviations is a validation activity, as further set out in the VCS Program Guide.

3.19 Participation under Other GHG Programs

Concept

Projects may be registered under both the VCS Program and either an approved GHG program or a GHG program that is not an approved GHG program.

Requirements

General

3.19.1 Project proponents shall not claim credit for the same GHG emission reduction or removal under the VCS Program and another GHG program. Projects issuing GHG credits under both the VCS Program and another GHG program shall also comply with the rules and requirements set out in the VCS Program document *Registration and Issuance Process*.

3.19.2 Projects registered under other GHG programs are not eligible for VCU issuance beyond the end of the total project crediting period under those programs (see Section 3.8.7 for further information).

3.19.3 For projects registered under the CDM as a program of activities (PoA), the following applies:

1) Each component project activity (CPA) shall be registered with the VCS Program as a separate project accompanied by its associated program of activities design document.

2) Each such project shall be validated in accordance with Section 3.19.5(1) below.

3) The project start date for such projects is the date on which the first activity under the program of activities began reducing or removing GHG emissions.

4) Validation shall be completed within the relevant project start date deadline, as set out in Section 3.19(in this case, validation refers to validation of the first CPA under the associated PoA).

AFOLU Projects

3.19.4 In addition to the above, AFOLU projects registered under both the VCS Program and another GHG program shall comply with the following:

1) All and any (VCS) monitoring and verification reports shall state the total amount of credits (GHG credits and, where applicable, buffer credits) issued under the other GHG program.

2) The project shall prepare a non-permanence risk report in accordance with the VCS Program document *AFOLU Non-Permanence Risk Tool* and a validation/verification body shall undertake a full validation of same in accordance with the VCS Program rules. The non-permanence risk analysis shall be based upon the project as a whole, though the buffer withholding shall apply to the net change in carbon stocks for which credits are sought under the VCS Program.

3) Where temporary GHG credits (e.g., tCERs or lCERs) have been issued to the project, VCUs may be issued to the project only in accordance with the rules and requirements set out in the VCS Program document *Registration and Issuance Process*.

4) Where a loss event or a reversal occurs, the project shall comply with the rules for reporting a loss event and holding/cancelling credits set out in Section 3.2.15 and the VCS Program document *Registration and Issuance Process*. Such reporting, holding and cancelling shall apply to the proportion of credits (GHG credits and buffer credits) granted to date under the VCS Program.

   For example, if 50 percent of the total credits (GHG credits and, where applicable, buffer credits) related to the project have been issued under the VCS Program and a loss event results in a reversal of GHG emission reductions or removals achieved, buffer credits would be cancelled to cover 50 percent of the reversal. An example calculation is available on the Verra website.

Approved GHG Programs

3.19.5 The following applies with respect to projects registered under an approved GHG program which are seeking registration with the VCS Program:

1) For projects registered under the CDM, the cover page and sections 1.1, 1.2, 1.3, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.12, 1.13, 1.14, 1.15.1, 1.16, 1.17 and 2.6 of the *VCS Project Description Template* shall be completed. A validation/verification body shall undertake a validation of same, which shall be accompanied by a validation representation, to provide a gap validation for the project's compliance with the VCS Program rules.

2) For projects registered under the JI program, a new *VCS Project Description Template* shall be completed (applying a methodology eligible under the VCS Program). A validation/verification body shall undertake a full validation of same in accordance with the VCS Program rules. The validation report shall be accompanied by a validation representation.

3) For projects registered under the Climate Action Reserve, the cover page and sections 1.1, 1.2, 1.3, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.12, 1.13, 1.15.1, 1.16, 1.17, 2.1, 2.2, 2.3, 2.4 and 3.6 of the *VCS Project Description Template* shall be completed. A validation/verification body shall undertake a validation of same, which shall be accompanied by a validation representation, to provide a gap validation for the project's compliance with VCS Program rules.

4) The approved GHG program validation (or verification, where the approved GHG program does not have a validation step) or VCS validation shall be completed within the relevant validation deadline as set out in Section 3.7. Validation (or verification) is deemed to have been completed when the validation (or verification) report that is submitted to the relevant program to request registration has been issued.

Other GHG Programs

3.19.6 Projects registered under a GHG program that is not an approved GHG program may also register with the VCS Program where a validation or verification report has been issued under such program (by an entity approved under the program to issue such reports). For such projects, the following applies:

1) The project start date shall be on or after 19 November 2007.

2) A new *VCS Project Description Template* shall be completed (using a methodology eligible under the VCS Program) and a validation/verification body shall undertake a full validation of same in accordance with the VCS Program rules. The validation report shall be accompanied by a validation representation.

3) The validation or verification that is submitted to request registration under the other GHG program shall be completed within the relevant validation deadline set out in Section 3.7. Validation or verification is deemed to have been completed when the validation or verification report that is submitted to the other GHG program to request registration has been issued.

Projects Rejected by Other GHG Programs

3.19.7 Projects rejected by other GHG programs due to procedural or eligibility requirements can be considered under the VCS Program, but the following conditions shall be met:

1) The project description (where the other GHG program has rejected the project before VCS validation) or monitoring report (where the other GHG program has rejected the project after VCS validation) shall clearly state all GHG programs to which the project has applied

for registration and the reason(s) for rejection. Such information shall not be deemed as commercially sensitive information.

2) The validation/verification body shall be provided with the rejection document(s), including any additional explanations.

3) The project shall be validated against the VCS Program rules. For projects where the other GHG program has rejected the project after VCS validation, this means a complete revalidation of the project against the VCS Program rules.

3.20 Other Forms of Credit

Concept

In order to maintain atmospheric integrity, GHG emission reductions/removals that are issued as VCUs cannot also be issued as other types of GHG credits or claimed as other forms of environmental credit. Project proponents shall demonstrate that project emission reductions or removals are not also used under emission trading programs, other mechanisms that include GHG allowance trading, or as other forms of environmental credit.

Requirements

Emission Trading Programs and Other Binding Limits

3.20.1 Where projects reduce GHG emissions from activities that are included in an emissions trading program or any other mechanism that includes GHG allowance trading, evidence shall be provided that the GHG emission reductions or removals generated by the project have not and will not be otherwise counted or used under the program or mechanism. Such evidence may include:

1) A letter from the program operator, designated national authority or other relevant regulatory authority that emissions allowances (or other GHG credits used in the program) equivalent to the reductions or removals generated by the project have been cancelled from the program or national cap, as applicable.

2) Evidence of the purchase and cancellation of GHG allowances equivalent to the GHG emissions reductions or removals generated by the project related to the program or national cap.

3) Evidence from the program operator, designated national authority or other relevant regulatory authority stating that the specific GHG emission reductions or removals generated by the project or type of project are not within the scope of the program or national cap.

Other Forms of Environmental Credit

3.20.2 Projects may generate other forms of GHG-related environmental credits, such as renewable energy certificates (RECs), though GHG emission reductions and removals presented for VCU issuance shall not also be recognized as another form of GHG-related environmental credit. The requirements set out in Sections 3.20.2 and 3.20.3 below assist Verra in confirming that this requirement has been met at the point of the issuance request (i.e., Verra uses the information disclosed in the project documents to perform its checks).

Therefore, project proponents interested in issuing (sequentially) both VCUs and another GHG-related environmental credit should consider which periods of time they wish to issue one credit or the other. Project proponents should also investigate whether such other GHG-related environmental credits can be cancelled from the relevant program, in case such credits have already been issued for periods where the project proponent wishes to issue VCUs. Note that additional requirements regarding evidence that no double issuance has occurred are set out in the VCS Program document *Registration and Issuance Process*.

3.20.3 Where projects have sought or received another form of GHG-related environmental credit, the following information shall be provided to the validation/verification body:

1) Name and contact information of the relevant environmental credit program.
2) Details of the project as registered under the environmental credit program (e.g., project title and identification number as listed under the program).
3) Monitoring periods for which GHG-related environmental credits were sought or received under the environmental credit program.
4) Details of all GHG-related environmental credits sought or received under the environmental credit program (e.g., volumes and serial numbers).

3.20.4 Where projects are eligible to participate under one or more programs to create another form of GHG-related environmental credit, but are not currently doing so, a list of such programs shall be provided to the validation/verification body.

Note – The requirements set out in Section 3.20.3 above and this Section 3.20.4 do not apply to non-GHG related environmental credits, such as water or biodiversity credits.

3.21 Records and Information

Concept

The project proponent shall make relevant information available to the validation/verification body during validation and each verification and retain documents and records related to the project for future reference.

Requirements

Records Relating to the Project

3.21.1 The project proponent shall ensure that all documents and records are kept in a secure and retrievable manner for at least two years after the end of the project crediting period.

Information for the Validation/Verification Body

3.21.2 For validation, the project proponent shall make available to the validation/verification body the project description, evidence of project ownership and any requested supporting information and data needed to support statements and data in the project description and evidence of project ownership.

3.21.3 For verification, the project proponent shall make available to the validation/verification body the project description, validation report, monitoring report applicable to the monitoring period and any requested supporting information and data needed to evidence statements and data in the monitoring report.

4 VALIDATION AND VERIFICATION REQUIREMENTS

This section sets out the rules and requirements for validation and verification of projects under the VCS Program. Validation/verification bodies must assess projects' compliance with VCS Program rules and requirements and the applied methodology(s) in accordance with the sections below. Validation/verification bodies must be approved under the VCS Program, and meet the eligibility criteria set out in the *VCS Program Guide*.

4.1 Introduction and General Requirements

Concept

Validation is the independent assessment of the project by a validation/verification body that determines whether the project complies with the VCS Program rules. Verification is the periodic ex-post independent assessment by a validation/verification body of the GHG emission reductions and removals that have occurred as a result of the project during the monitoring period, conducted in accordance with the VCS Program rules.

Requirements

General

4.1.1 Validation and verification is a risk-based process and shall be carried out in conformance with *ISO 14064-3:2006* and *ISO 14065:2013*. Additional requirements with respect to validation and verification are set out in this Section 4 and shall be adhered to.

4.1.2 The validation/verification body shall select samples of data and information to be validated or verified to provide a reasonable level of assurance and to meet the materiality requirements of the specific project.

4.1.3 The project shall be validated and GHG emission reductions or removals verified by a validation/verification body that meets with the eligibility requirements set out in the *VCS Program Guide*.

4.1.4 Validation and verification of the project may be undertaken by the same validation/verification body, noting the rules on rotation of validation/verification bodies set out in Section 4.1.20 below. Validation may occur before the first verification or at the same time as the first verification.

4.1.5 The project shall be listed on the project pipeline before the opening meeting between the validation/verification body and the project proponent (such opening meeting representing the beginning of the validation process). The validation/verification body is responsible for checking that the project is listed on the project pipeline and shall not conduct the opening meeting or otherwise begin validation until such time as the project is listed.

4.1.6 Where the project applies a methodology from an approved GHG program that does not have an independent validation step, the VCS Program rules still require validation of the project.

4.1.7 Validation/verification bodies are expected to follow the guidance provided in the *VCS Validation and Verification Manual* when validating or verifying projects and conducting methodology assessments under the VCS Program.

Validation and Verification Process

4.1.8 In addition to the requirements set out in *ISO 14064-3:2006*, the following shall apply:

1) The level of assurance shall be reasonable, with respect to material errors, omissions and misrepresentations, for both validation and verification.
2) The criteria for validation shall be the *VCS Version 4*, or approved GHG program where the validation is performed under an approved GHG program (as in cases of participation under the VCS Program and an approved GHG program). The criteria for verification shall be the *VCS Version 4* (regardless of the VCS version or GHG program under which the project was validated). This means the validation or verification shall ensure conformance of the project with the VCS Program rules, or rules and requirements of the approved GHG program, as applicable.
3) The objective of validation or verification shall be in conformance with the VCS Program rules and the methodology applied to the project.
4) The threshold for materiality with respect to the aggregate of errors, omissions and misrepresentations relative to the total reported GHG emission reductions and/or removals shall be five percent for projects and one percent for large projects.

4.1.9 Where the project does not fully comply with the methodology, the validation/verification body shall determine whether this represents a methodology deviation or a methodology revision (in accordance with the specifications for each), and the case shall be handled accordingly.

4.1.10 Where the project applies a revision to an approved GHG program methodology and the version of the (underlying) methodology referenced by the methodology revision is no longer current, the validation/verification body shall determine whether material changes have occurred to the underlying methodology that affect the integrity of the methodology revision. Where such material changes have occurred, the project shall not be approved.

4.1.11 Where the project does not meet the criteria for validation or verification, the validation/verification body shall produce a negative validation conclusion and provide the validation or verification report and project description, or monitoring report, to Verra. The project shall be ineligible for registration until such time as corrective action is taken and the (same) validation/verification body has provided a positive validation or verification.

Competence

4.1.12 The validation/verification body and validation and verification team shall meet the competence requirements set out in *ISO 14065:2013*, mutatis mutandis.

Validation and Verification Reporting

4.1.13 The validation report describes the validation process, any findings raised during validation and their resolutions, and the conclusions reached by the validation/verification body. The validation/verification body shall use the *VCS Validation Report Template,* an approved combined validation report template available on the Verra website, or an approved GHG program validation report template where the project is registered under an approved GHG program, as appropriate, and adhere to all instructional text within the template. The validation report shall be accompanied by a validation representation, which shall be prepared using the *VCS Validation Deed of Representation Template*.

4.1.14 The verification report describes the verification process, any findings raised during verification and their resolutions, and the conclusions reached by the validation/verification body. The validation/verification body shall use the *VCS Verification Report Template* or an approved combined verification report template available on the Verra website, and adhere to all instructional text within the template. The verification report shall be accompanied by a verification representation, which shall be prepared using the *VCS Verification Deed of Representation Template*.

4.1.15 Where a monitoring report and associated verification report divide a verification period into vintages, separate VCU issuance records in accordance with vintage periods may be issued, as set out in the VCS Program document *Registration and Issuance Process*.

Validation and Verification Statement

4.1.16 The validation report and the verification report shall contain a validation statement and a verification statement, respectively.

4.1.17 Validation and verification statements shall:

1) Describe the level of assurance of the validation or verification.
2) Describe the objectives, scope and criteria of the validation or verification.
3) Describe whether the data and information supporting the GHG assertion were hypothetical, projected and/or historical in nature.

4) Include the validation/verification body's conclusion on the GHG assertion, including any qualifications or limitations.

5) For AFOLU projects, state the version number of the non-permanence risk report or market leakage evaluation documentation upon which the statement is based.

4.1.18 The verification statement shall state the volume of GHG emission reductions or removals generated during the monitoring period that have been verified. For AFOLU projects, the verification statement shall also include the non-permanence risk rating, leakage emissions and number of GHG emission reductions or removals eligible to be issued as VCUs.

Records of Validation and Verification

4.1.19 The validation/verification body shall keep all documents and records in a secure and retrievable manner for at least two years after the end of the project crediting period, even where they do not conduct verification for the whole project crediting period.

Rotation of Validation/Verification Bodies

4.1.20 Rotation of validation/verification bodies is required in respect of validation and verification, as follows:

1) Validation (including project crediting period renewal validation) and the first verification of a project (in a given project crediting period) may be undertaken by the same validation/verification body. However, the subsequent verification shall be undertaken by a different validation/verification body. For example, if validation and verification were undertaken at the same time, the subsequent verification would have to be undertaken by a different validation/verification body. If validation were undertaken first (i.e., separately), the first verification could be undertaken by the same validation/verification body, but the subsequent verification would have to be undertaken by a different validation/verification body.

Note – The gap validation of a project registered under an approved GHG program may be disregarded when assessing adherence to these requirements.

2) A validation/verification body may not verify more than six consecutive years of a project's GHG emission reductions or removals. The validation/verification body may undertake further verification for the project only when at least three years of the project's GHG emission reductions or removals have been verified by a different validation/verification body. Additionally, where a validation/verification body verifies the final six consecutive years of a project crediting period, the project crediting period renewal validation shall be undertaken by a different validation/verification body. Notwithstanding these rules, where AFOLU projects have verification periods longer than six years, a validation/verification body is permitted to verify more than six consecutive years of a project's GHG emission reductions or removals, and the subsequent verification shall be undertaken by a different validation/verification body.

Note – Validations and verifications performed under other GHG programs shall be counted when assessing adherence to these requirements.

Validation and Verification Requirements for Grouped Projects

4.1.21 Validation and verification of grouped projects shall assess conformance of the project with the requirements for grouped projects set out in the VCS Program rules.

4.1.22 New project activity instances shall be validated, based on the information reported in the monitoring report, against the applicable set of eligibility criteria. The validation/verification body shall specify which instances meet the eligibility criteria for inclusion in the project. Such validation may be reported in the verification report or a separate validation report.

4.1.23 Where, due to the number of project activity instances, it is unreasonable to undertake an individual assessment of each initial or new instance, the validation/verification body shall document and explain the sampling methods employed for the validation of such instances. Such sampling methods shall be statistically sound. The number of instances included in the project, eligible for monitoring and generation of VCUs shall be proportional to the percentage of sampled instances found to be in compliance by the validation/verification body.

4.1.24 The verification report for grouped projects shall document and explain the sampling methods employed by the validation/verification body for the verification of GHG emission reductions or removals generated by the project. Such methods shall be statistically sound. Any subsequent changes to the sampling method(s) required as a result of the verification findings shall be documented.

Non-Permanence Risk Analysis and Market Leakage Evaluations for AFOLU Projects

4.1.25 Non-Permanence risk analysis and market leakage evaluations shall be assessed by the validation/verification body in accordance with the VCS Program rules.

4.1.26 The validation/verification body shall assess the risk analysis carried out by the project proponent in accordance with the VCS Program document A*FOLU Non-Permanence Risk Tool*. The project proponent shall respond to all and any of the validation/verification body's findings. As a result of any such findings, the project proponent shall amend the documentation as necessary and update the risk rating accordingly.

APPENDIX 1 ELIGIBLE AFOLU PROJECT CATEGORIES

This appendix defines the types of activities that are included within each AFOLU project category, and is intended to aid project proponents in determining which type of methodology may be applicable to their AFOLU project activity(s). As set out in Section 3.2 above, AFOLU projects must apply a methodology eligible under the VCS Program.

Additional information about the eligible activities and specific GHG sources, sinks and reservoirs that must be included in methodologies developed under the VCS Program for each eligible AFOLU project category is available in the VCS Program document *VCS Methodology Requirements*.

Afforestation, Reforestation and Revegetation (ARR)

A1.1 Eligible ARR activities are those that increase carbon sequestration and/or reduce GHG emissions by establishing, increasing or restoring vegetative cover (forest or non-forest) through the planting, sowing or human-assisted natural regeneration of woody vegetation. Eligible ARR projects may include timber harvesting in their management plan. The project area shall not be cleared of native ecosystems within the 10 year period prior to the project start date, as set out in Section 3.2.4.

Note – Activities which improve forest management practices such as enrichment planting and liberation thinning are categorized as IFM project activities.

Agricultural Land Management (ALM)

A1.2 Eligible ALM activities are those that reduce net GHG emissions on croplands and grasslands by increasing carbon stocks in soils and woody biomass and/or decreasing CO_2, N_2O and/or CH_4 emissions from soils. The project area shall not be cleared of native ecosystems within the 10-year period prior to the project start date. Eligible ALM activities include:

1) Improved Cropland Management (ICM): This category includes practices that demonstrably reduce net GHG emissions of cropland systems by increasing soil carbon stocks, reducing soil N_2O emissions, and/or reducing CH_4 emissions.

2) Improved Grassland Management (IGM): This category includes practices that demonstrably reduce net GHG emissions of grassland ecosystems by increasing soil carbon stocks, reducing N_2O emissions and/or reducing CH_4 emissions.

3) Cropland and Grassland Land-use Conversions (CGLC): This category includes practices that convert cropland to grassland or grassland to cropland and reduce net GHG emissions by increasing carbon stocks, reducing N_2O emissions, and/or reducing CH_4 emissions.

Note – Project activities relating to manure management are eligible under sectoral scope 15 (livestock, enteric fermentation, and manure management), not sectoral scope 14 (AFOLU).

Improved Forest Management (IFM)

A1.3 Eligible IFM activities are those that increase carbon sequestration and/or reduce GHG emissions on forest lands managed for wood products such as sawtimber, pulpwood and fuelwood by increasing biomass carbon stocks through improving forest management practices. The baseline and project scenarios for the project area shall qualify as forests remaining as forests, such as set out in the *IPCC 2006 Guidelines on National GHG Inventories*, and the project area shall be designated, sanctioned or approved for wood product management by a national or local regulatory body (e.g., as logging concessions or plantations).

A1.4 Various sanctioned forest management activities may be changed to increase carbon stocks and/or reduce emissions, but only a subset of these activities make a measurable difference to the long-term increase in net GHG emissions compared to the baseline scenario. Eligible IFM activities include:

1) Reduced Impact Logging (RIL): This category includes practices that reduce net GHG emissions by switching from conventional logging to RIL during timber harvesting.
2) Logged to Protected Forest (LtPF): This category includes practices that reduce net GHG emissions by converting logged forests to protected forests. By eliminating harvesting for timber, biomass carbon stocks are protected and can increase as the forest re-grows and/or continues to grow. Harvesting of trees to advance conservation purposes (e.g., the removal of diseased trees) may continue in the project scenario.
3) Extended Rotation Age / Cutting Cycle (ERA): This category includes practices that reduce net GHG emissions of evenly aged managed forests by extending the rotation age or cutting cycle and increasing carbon stocks.
4) Low-Productive to High-Productive Forest (LtHP): This category includes practices that increase carbon sequestration by converting low-productivity forests to high-productivity forests. Note - Activities that reduce GHG emissions from unsanctioned forest degradation (e.g., illegal logging) are considered REDD activities. Projects focusing solely on the reduction of forest fires are not eligible under IFM. Activities that degrade wetlands to increase forest production are not eligible.

Reduced Emissions from Deforestation and Degradation (REDD)

A1.5 Eligible REDD activities are those that reduce net GHG emissions by reducing deforestation and/or degradation of forests. Deforestation is the direct, human-induced conversion of forest land to non-forest land. Degradation is the persistent reduction of canopy cover and/or carbon stocks in a forest due to human activities such as animal grazing, fuelwood extraction, timber removal or other such activities, but which does not result in the conversion of forest to non-forest land (which would be classified as deforestation), and qualifies as *forests remaining as forests*, such as set out under the *IPCC 2003 Good Practice Guidance*. The project area shall meet an internationally accepted definition of forest, such as those based on UNFCCC host-country thresholds or FAO definitions, and shall qualify as forest for a minimum of 10 years before the project start date. The definition of forest may include mature forests, secondary forests, and degraded forests. Under the VCS Program, secondary forests are considered to be forests that have been cleared and have recovered naturally and that are at least 10-years-old and meet the lower bound of the forest threshold parameters at the start of the project. Forested wetlands, such as floodplain forests, peatland forests and mangrove forests, are also eligible provided they meet the forest definition requirements mentioned above.

A1.6 Activities covered under the REDD project category are those that are designed to stop planned (designated and sanctioned) deforestation or unplanned (unsanctioned) deforestation and/or degradation. Avoided planned degradation is classified as IFM.

A1.7 Activities that stop unsanctioned deforestation and/or illegal degradation (such as removal of fuelwood or timber extracted by non-concessionaires) on lands that are legally sanctioned for timber production are eligible as REDD activities. However, activities that reduce or stop logging only, followed by protection, on forest lands legally designated or sanctioned for forestry activities are included within IFM. Projects that include both avoided unplanned deforestation and/or degradation as well as stopping sanctioned logging activities, shall follow the REDD guidelines for the unplanned deforestation and/or degradation and the IFM guidelines for the sanctioned logging activities, and shall follow the requirements set out in Section 3.5.2.

A1.8 Eligible REDD activities include:

1) Avoiding Planned Deforestation and/or Degradation (APDD): This category includes activities that reduce net GHG emissions by stopping or reducing deforestation or degradation on forest lands that are legally authorized and documented for conversion.

2) Avoiding Unplanned Deforestation and/or Degradation (AUDD): This category includes activities that reduce net GHG emissions by stopping deforestation and/or degradation of degraded to mature forests that would have occurred in any forest configuration.

Avoided Conversion of Grasslands and Shrublands (ACoGS)

A1.9 Eligible ACoGS activities are those that reduce net GHG emissions by reducing the conversion of grassland and shrubland ecosystems to other land uses with lower carbon densities. Eligible avoided conversion activities include avoiding, at a minimum, the removal/replacement of vegetation and may also include avoiding soil disturbance.

A1.10 The project area shall be native grasslands (including savanna) and/or shrublands (including chaparral). Non-forested wetlands, including peatlands, are not eligible under ACoGS and are covered under other AFOLU project categories.

A1.11 Activities covered under the ACoGS project category are those that are designed to stop planned (designated and sanctioned) conversion or unplanned (unsanctioned) conversion on public or private lands. This category type only includes avoided conversion of non-forested lands, noting that other management activities on non-forested land may qualify under ALM or ARR project categories.

A1.12 Eligible ACoGS activities include:

1) Avoiding Planned Conversion (APC): This category includes activities that reduce net GHG emissions by stopping conversion of grasslands or shrublands that are legally authorized and documented for conversion.

2) Avoiding Unplanned Conversion (AUC): This category includes activities that reduce net GHG emissions by stopping unplanned conversion of grasslands or shrublands.

Wetlands Restoration and Conservation (WRC)

A1.13 Eligible WRC activities are those that increase net GHG removals by restoring wetland ecosystems or that reduce GHG emissions by rewetting or avoiding the degradation of wetlands. The project area shall meet an internationally accepted definition of wetland, such as from the IPCC, Ramsar Convention on Wetlands, those established by law or national policy, or those with broad agreement in the peer-reviewed scientific literature for specific countries or types of wetlands. Common wetland types include peatland, salt marsh, tidal freshwater marsh, mangroves, wet floodplain forests, prairie potholes and seagrass meadows. WRC activities may be combined with other AFOLU project categories, as further explained in Section 59.

A1.14 A peatland is an area with a layer of naturally accumulated organic material (peat) at the surface (excluding the plant layer). Common peatland types include peat swamp forest, mire, bog, fen, moor, muskeg and pocosin. Rewetting of drained peatland and the conservation of undrained or partially drained peatland are sub-categories of restoring wetland ecosystems and conservation of intact wetlands, respectively[11].

A1.15 Activities that generate net reductions of GHG emissions from wetlands are eligible as WRC projects or combined category projects (such as REDD on peatland). Activities that actively lower the water table depth in wetlands are not eligible. Eligible WRC activities include:

1) Restoring Wetland Ecosystems (RWE): This category includes activities that reduce GHG emissions or increase carbon sequestration in a degraded wetland through restoration activities. Such activities include enhancing, creating and/or managing hydrological conditions, sediment supply, salinity characteristics, water quality and/or native plant communities. For the purpose of these requirements, restoration activities are those that

[11] These categories existed as rewetting drained peatlands (RDP) and conservation of undrained and partially drained peatlands (CUPP) in the *AFOLU Requirements* v3.2.

result in the reestablishment of ecological processes, functions, and biotic and/or abiotic linkages that lead to persistent, resilient systems integrated within the landscape.

2) Conservation of Intact Wetlands (CIW): This category includes activities that reduce GHG emissions by avoiding degradation and/or the conversion of wetlands that are intact or partially altered while still maintaining their natural functions, including hydrological conditions, sediment supply, salinity characteristics, water quality and/or native plant communities.

   Wetland degradation or conversion can be planned (designated and sanctioned) or unplanned (unsanctioned). Planned and unplanned degradation or conversion of wetlands can therefore encompass a wide variety of activities such as those listed under REDD while adding a wetland component. Activities covered under the CIW project category are those that are designed to stop or reduce planned or unplanned degradation or conversion in the project area to other land uses. The following CIW activities are eligible:

   a) Avoiding Planned Wetland Degradation (APWD): This activity reduces GHG emissions by avoiding degradation of wetlands, or further degradation in partially drained wetlands that are legally authorized and documented for conversion.

   b) Avoiding Unplanned Wetland Degradation (AUWD): This activity reduces GHG emissions by avoiding unplanned degradation of wetlands, or by avoiding further degradation in partially degraded wetlands.

Note – Activities where drainage is continued or maintained are not eligible. This includes, for example, projects that require the maintenance of drainage channels to maintain the pre-project drainage level on a partially drained peatland (e.g., where periodic deepening may be needed to counteract peat subsidence). Projects that allow selective harvesting that results in a lowering of the water table depth (e.g., by extracting timber using drainage canals) or affects the ability of vegetation to act as a major hydrological regulation device (e.g., extracting trees which support the peat body) are also not eligible. Project activities may include selective harvesting where harvesting does not lower the water table, for example by extracting timber using wooden rails instead of drainage canals.

A1.16 Activities that generate net GHG emission reductions by combining other AFOLU project activities with wetlands restoration or conservation activities are eligible as WRC combined projects. RWE may be implemented without further conversion of land use or it may be combined with ARR, ALM, IFM, REDD or ACoGS activities, referred to as ARR+RWE, ALM+RWE, IFM+RWE, REDD+RWE or ACoGS+RWE, respectively. CIW may be implemented on non-forest land or combined with IFM, REDD or ACoGS activities, referred to as IFM+CIW, REDD+CIW or ACoGS+CIW, respectively.

Table 3 illustrates the types of WRC activities that may be combined with other AFOLU project categories. The table identifies the applicable AFOLU requirements that shall be followed for combined category projects, based on the condition of the wetland in the baseline scenario, the land use in the baseline scenario and the project activity.

Table 3: Eligible WRC Combined Category Projects

Baseline Scenario		Project Activity	Applicable Guidance
Condition	Land Use		
Degraded wetland (including, drained, impounded, and with interrupted sediment supply)	Non-forest (including aquacultures, grasslands and shrublands)	Restoration of wetlands*	RWE
		Restoration of wetlands* and revegetation or conversion to forest	ARR+RWE
		Restoration of wetlands* and conversion to wetland agriculture (including paludiculture)	ALM+RWE
		Restoration of wetlands* and avoided conversion of grasslands or shrublands	ACoGS+RWE
	Forest	Restoration of wetlands*	RWE
	Forest with deforestation/ degradation	Restoration of wetlands* and avoided deforestation/degradation	REDD+RWE
	Forest managed for wood products	Restoration of wetlands* and improved forest management	IFM+RWE
Non-wetland or open water	Non-forest	Creation of wetland conditions and afforestation, reforestation or revegetation	ARR+RWE
	Open water or impounded wetland	Creation or restoration of conditions for vegetation development and afforestation, reforestation or revegetation	ARR+RWE
Intact wetland	Non-forest (including grasslands and shrublands)	Avoided drainage and/or interrupted sediment supply	CIW
		Avoided conversion to open water or impounded wetland (including excavation to create fish ponds)	CIW
		Avoided drainage and/or interrupted sediment supply and avoided conversion of grasslands and Shrublands	ACoGS+CIW
	Forest	Avoided drainage and/or interrupted sediment supply	CIW

		Avoided conversion to open water or impounded wetland	CIW
	Forest with deforestation/ degradation	Avoided drainage and/or interrupted sediment supply and avoided deforestation/degradation	REDD+CIW
		Avoided conversion to open water or impounded wetland and avoided deforestation/degradation	REDD+CIW
	Forest managed for wood products	Avoided drainage and/or interrupted sediment supply and improved forest management	IFM+CIW

* *Restoration of wetlands* includes all the activities set out in Section A1.15.

A1.17 Combined category projects shall use the relevant WRC requirements and the respective AFOLU project category requirements for quantifying GHG emissions/removals, unless the former may be deemed *de minimis* or conservatively excluded.

APPENDIX 2 DOCUMENT HISTORY

Version	Date	Comment
v4.0	Released: 19 Sep 2019 Updated: 9 Mar 2020	Initial version released under *VCS Version 4*, with immediate effect except for the following: For project activities that were eligible under *VCS Version 3*, but are now excluded from the scope of the VCS Program (Section 2.1): **Updated on 9 March 2020** to revise the effective dates for projects registered with an approved GHG Program. New text is shown in red and deleted text is shown in strikethrough, below. 1) Registered VCS projects and projects that request registration with the VCS Program on or before 31 December 2019 remain eligible under the VCS Program for the entirety of their crediting periods. 2) Grouped projects registered under the VCS Program shall be prohibited from adding new project activity instances of the newly excluded project types on or after 1 January 2020; verification reports dated on or after 1 January 2020 shall not be accepted where they include the validation of such new project activity instances. 3) Projects registered under an approved GHG program shall only be eligible to complete a gap validation and/or transfer to the VCS Program where the project has applied for registration with the VCS Program ~~approved GHG program~~ on or before 9 March 2020 ~~31 December 2019~~, unless evidence of contracting for a VCS gap validation prior to 9 March 2020 is provided. 4) GHG credits issued under an approved GHG program shall only be eligible to be converted into VCUs where a conversion request has been submitted ~~the project has applied for registration with the approved GHG program~~ on or before 9 March 2020 ~~31 December 2019~~, unless evidence of contracting for a CER conversion prior to 9 March 2020 is provided, in which case the conversion must take place on or before 9 April 2020. For projects subject to new crediting period requirements under *VCS Version 4* (i.e., non-AFOLU projects and ALM projects focusing exclusively on reducing N_2O, CH_4 and/or fossil-derived CO_2 emissions) (Section 3.8): 1) Registered projects and projects that complete validation on or before 19 March 2020 remain eligible to apply the crediting period requirements under *VCS Version 3.* 2) Projects applying a new VCS methodology (i.e., a methodology for which a concept note was submitted to Verra on or before 31 December 2018) shall be granted additional time to apply the crediting period requirements under VCS Version 3. Specifically, projects using a new VCS methodology and completing validation within two years of the approval of the methodology may apply the crediting requirements as set out under *VCS Version 3*.

VERRA

Standards for a Sustainable Future

Verified Carbon Standard

Climate, Community & Biodiversity Standards

Sustainable Development Verified Impact Standard

Verified Carbon Standard
A VERRA STANDARD

Methodology Requirements

19 September 2019

v4.0

ABOUT VERRA

Verra supports climate action and sustainable development through the development and management of standards, tools and programs that credibly, transparently and robustly assess environmental and social impacts, and drive funding for sustaining and scaling up these benefits. As a mission-driven, non-profit (NGO) organization, Verra works in any arena where we see a need for clear standards, a role for market-driven mechanisms and an opportunity to achieve environmental and social good.

Verra manages a number of global standards frameworks designed to drive finance towards activities that mitigate climate change and promote sustainable development, including the Verified Carbon Standard (VCS) Program and its Jurisdictional and Nested REDD+ framework (JNR), the Verra California Offset Project Registry (OPR), the Climate, Community & Biodiversity (CCB) Standards and the Sustainable Development Verified Impact Standard (SD VISta). Verra is also developing new standards frameworks, including LandScale, which will promote and measure sustainability outcomes across landscapes. Finally, Verra is one of the implementing partners of the Initiative for Climate Action Transparency (ICAT), which helps countries assess the impacts of their climate actions and supports greater transparency, effectiveness, trust and ambition in climate policies worldwide.

Intellectual Property Rights, Copyright and Disclaimer

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1 INTRODUCTION

This document provides the requirements for methodologies developed under the VCS Program. The purpose of this document is to assist methodology developers and validation/verification bodies in developing and assessing methodologies.

Where external documents are referenced, such as the *IPCC 2006 Guidelines for National GHG Inventories*, and such documents are updated, the most recent version of the document shall be used.

This document will be updated from time-to-time and readers shall ensure that they are using the most current version of the document.

2 GENERAL REQUIREMENTS

This section sets out the general rules and requirements for all methodologies under the VCS Program. Specific requirements for agriculture, forestry and other land use (AFOLU) and ozone depleting substances (ODS) methodologies are set out throughout this Section 2 (and Section 3) below, as these methodology types may encounter unique circumstances related to project implementation, monitoring and other matters, which must be addressed.

In order to become an approved methodology under the VCS Program, methodologies shall demonstrate how they meet the rules and requirements set out below. Methodologies shall be assessed per the process set out in the VCS Program document *Methodology Approval Process*.

2.1 Methodology Development

Concept

Establishing consistent and standardized criteria for development and assessment of methodologies is critical to ensuring their integrity. Accordingly, certain high-level requirements shall be met by all methodologies, as set out below.

Requirements

2.1.1 Methodologies shall comply with the requirements set out in this document and any other applicable requirements set out in the VCS Program rules, and be approved via the methodology approval process (as set out in the VCS Methodology Approval Process).

2.1.2 New methodologies shall not be developed where an existing methodology could reasonably be revised (i.e., developed as a methodology revision) to meet the objective of the proposed methodology.

2.1.3 Methodology elements shall be guided by the principles set out in the VCS Program document *VCS Standard*. They shall clearly state the assumptions, parameters and procedures that have significant uncertainty, and describe how such uncertainty shall be addressed.

2.1.4 Methodologies shall be informed by a comparative assessment of the project and its alternatives in order to identify the baseline scenario. Such an analysis shall include, at a minimum, a comparative assessment of the implementation barriers and net benefits faced by the project and its alternatives.

2.2 Methodology Structure

Concept

The VCS Program allows for different methodology structures, including modular approaches, and different approaches for demonstrating additionality and/or determining the crediting baseline.

Requirements

General

2.2.1 Methodologies may employ a modular approach in which a framework document provides the structure of the methodology and separate modules and/or tools are used to perform specific methodological tasks. Such methodologies shall use the *VCS Methodology Template* for the framework document and the *VCS Module Template* for the modules and tools. The framework document shall clearly state how the modules and/or tools are to be used within the context of the methodology.

Additionality and Crediting Baseline Approaches

2.2.2 Methodologies shall use a standardized method (i.e., performance method or activity method) or a project method to determine additionality and/or the crediting baseline, and shall state which type of method is used for each.

1) A project method is a methodological approach that uses a project-specific approach for the determination of additionality and/or crediting baseline.
2) Standardized methods are further described in Section 2.3.1 and additional guidance is available in VCS document *Guidance for Standardized Methods*. This guidance document provides additional information to aid the interpretation of the VCS Program rules on standardized methods and should be read before developing or assessing such methods. Although the guidance document does not form part of the VCS Program rules, interpretation of the rules shall be consistent with the guidance document.

2.2.3 Methodologies may use any combination of project, performance or activity methods for determining additionality and the crediting baseline. However, methodologies shall provide only one method (i.e., a project method or performance method) for determining the crediting baseline (i.e., methodologies shall not provide the option of using either a project method or a performance method for the crediting baseline).

2.3 Standardized Methods

Concept

Standardized methods are methodological approaches that standardize the determination of additionality and/or the crediting baseline for a given class of project activity, with the objective of streamlining the development and assessment process for individual projects. The VCS Program allows for the use of two types of standardized methods: performance methods, which establish performance benchmarks for the demonstration of additionality and/or the crediting baseline, and activity methods, which pre-determine additionality for given classes of project activities using a positive list.

Requirements

2.3.1 Additionality and/or the crediting baseline are determined for the class of project activity, and qualifying conditions and criteria are set out in the methodology. Individual projects need only meet the conditions and apply the pre-defined criteria set out in the standardized method, obviating the need for each project to determine additionality and/or the crediting baseline via project-specific approaches and analyses.

The VCS Program defines two types of standardized methods:

1) Performance methods: These methods establish performance benchmark metrics for determining additionality and/or the crediting baseline. Projects that meet or exceed a pre-determined level of the metric may be deemed as additional and a pre-determined level of the metric may serve as the crediting baseline.
2) Activity methods: These methods pre-determine additionality for given classes of project activities using a positive list. Projects that implement activities on the positive list are automatically deemed as additional and do not otherwise need to demonstrate additionality. One of three options (namely activity penetration, financial feasibility or revenue streams) is used to qualify the project activity for the positive list, as set out in Section 3.5.9.

Note – There is some overlap between performance and activity methods with respect to concepts, objectives and outcomes, and methodologies may use any combination of methods (performance, activity and project) for determining additionality and the crediting baseline as set out in Section 2.2.2. However, both performance and activity methods are sufficiently distinct, and this document sets out the rules and requirements for each method separately.

2.3.2 Methodologies shall include sufficient information and evidence to allow the reader to reach the same assessment conclusion on the appropriateness and rigor of the standardized method reached by the two validation/verification bodies in the methodology approval process, noting that the confidentiality of proprietary data may be protected as set out in Section 3.4.6(5). To aid the readability and clarity of methodologies, such information and evidence may be included in appendices to methodology documents rather than in the body of the documents themselves. Following their initial approval, methodologies are subject to periodic re-assessment, as set out in the VCS Program document *Methodology Approval Process*.

Performance Methods

2.3.3 All new performance methods shall be prepared using the *VCS Methodology Template*. A performance method is an integral part of a methodology and therefore it cannot be developed and approved as a separate module that is then applied by projects in conjunction with other methodologies.

2.3.4 Methodologies may use a performance method for determining additionality only, for determining additionality and the crediting baseline, or for determining the crediting baseline only. The level of the performance benchmark metric for determining additionality and for the crediting baseline may be the same, or each may be different. Where they are different, the level for determining additionality shall be more stringent than the level of the crediting baseline.

2.3.5 Where a methodology uses a performance method for determining both additionality and the crediting baseline, the methodology shall list all methodologies that use a project method for determining the crediting baseline that are applicable to similar project activities and are approved under the VCS Program or an approved GHG program. The purpose of this requirement is to facilitate the transition to standardized methods, as further set out in the VCS Program document *VCS Standard*.

2.3.6 The performance benchmark metric shall be specified in terms of tonnes of CO_2e per unit of output (i.e., GHG emissions per unit of product or service), tonnes of CO_2e per unit of input (e.g., GHG emissions per unit of input per unit of land area) or as a sequestration metric (e.g., carbon stock per unit of land area), as appropriate to the project activity applicable under the methodology. This may represent tonnes of CO_2e reduced or tonnes of CO_2e sequestered. An input metric shall only be used where an output metric is not practicable (e.g., the corresponding output metric is subject to influences outside the control of the project proponent) and leakage shall be addressed. The unit shall be unambiguously defined to allow a consistent comparison of project performance with the performance benchmark. The *GHG Protocol for Project Accounting,* Chapter 7 (WRI-WBCSD) provides some examples of products and services that may serve as candidates for performance benchmark metrics. Note that proxies for the performance benchmark metric may be used for determining additionality, as set out in Section 3.5.7.

2.3.7 It is recognized that an overly stringent level for the performance benchmark metric used for additionality may exclude additional projects (false negatives) while an overly lenient level may allow in non-additional projects (false positives). Similarly, an overly stringent level of the performance benchmark metric used for the crediting baseline may result in too little incentive for project proponents while an overly lenient level may allow the crediting of non-additional GHG emission reductions and removals. In order to address these considerations, the following shall apply with respect to setting the level(s) of the performance benchmark metric:

1) Methodologies shall provide a description and analysis of the current distribution of performance within the sector as such performance relates to the applicability of the methodology or each performance benchmark (see Section 3.2.5 for further information on applicability of methodologies and performance benchmarks). Methodologies shall also provide an overview of the technologies and/or measures available for improving performance within the sector, though an exhaustive list is not required recognizing that performance methods may be somewhat agnostic with respect to the technologies and/or measures implemented by projects.
2) Methodologies shall discuss and evaluate the trade-off between false negatives and false positives and shall describe objectively and transparently the evidence used (including reference to primary and secondary data sources), experts consulted, assumptions made, and analysis (including numerical analysis) and process undertaken in determining the selected level(s) of the performance benchmark metric (noting that expert consultation is a key part of this process, as set out below). The selected level(s) shall not systematically overestimate GHG emission reductions or removals.
3) The process of determining the level(s) of the performance benchmark metric shall include and be informed by an expert consultation process, undertaken by the methodology developer as follows:
    a) The objective of the expert consultation shall be to engage and solicit input from technical experts on the appropriateness of the proposed level(s) of the performance benchmark metric to ensuring environmental integrity and provision of sufficient financial incentive to potential projects. Technical experts are persons who have specific knowledge or expertise relevant to the methodology and performance benchmark metric.
    b) The methodology developer shall ensure that a representative group of experts participates in the consultation, including, but not limited to, representation from industry, environmental non-governmental organizations, and government or other regulatory bodies. Where a diverse range of views can be expected with regard to the appropriate level of the performance benchmark metric, experts representing the range of views shall participate in the consultation. Participation by experts shall be pro-actively sought and facilitated. Consultation that does not involve a representative group of experts shall be deemed insufficient.
    c) Experts shall be provided, under appropriate confidentiality agreements (as necessary), with sufficient background and technical information about the methodology and its context to allow meaningful participation in the consultation. The consultation process shall use meetings, conference calls and other appropriate methods to allow all experts to provide comments and exchange views in an open, fair and transparent manner.
    d) A report on the expert consultation process and outcome shall be prepared and submitted to Verra when a methodology is submitted under the methodology approval process. This may be included as an annex to the methodology, to be removed from

any final approved version of the methodology. The report shall provide a summary of expert views, and shall demonstrate how the above requirements have been met and how expert views were taken due account of (i.e., how expert views have affected the final level(s) of the performance benchmark metric in the draft methodology).

Note that expert consultation only needs to be undertaken by the methodology developer with respect to the level of the performance benchmark metric, since the methodology is also subject to public stakeholder consultation as part of the VCS Program methodology approval process.

2.3.8 Where there is heterogeneity of performance (measured in terms of the performance benchmark metric) that may be practicably achieved by individual projects, multiple benchmarks or correction factors may be required. Multiple benchmarks or correction factors shall be established under the following circumstances:

1) The project activity includes technologies and/or measures which may be implemented at both greenfield and brownfield sites and the performance (measured in terms of the performance benchmark metric) that may be practicably achieved at each is substantially different.
2) The methodology encompasses both larger and smaller scale project activities and the performance (measured in terms of the performance benchmark metric) that may be practicably achieved in each case is substantially different.
3) Any other circumstances related to the baseline scenario or project activity, such as plant age, raw material quality and climatic circumstances, that lead to heterogeneity of performance (measured in terms of the performance benchmark metric) that may be practicably achieved by individual projects.

Activity Methods

2.3.9 Activity methods shall be prepared using the *VCS Module Template*, or, where a new methodology is being developed, may be written directly into the methodology (i.e., a positive list may be prepared and approved as a standalone additionality test that may be used in conjunction with applicable methodologies, or may be prepared as a direct part of a new methodology, in which case it may not be used in conjunction with other methodologies). To aid the readability of this document, it is assumed that the activity method is being written directly into the methodology, so readers should take references to methodology to mean methodology or module, as appropriate.

2.3.10 Activity methods shall set out, using the specification of the project activity under the applicability conditions, a positive list of project activities that are deemed as additional under the activity method (see Section 3.2 for further information on providing specification of project activities). All such project activities are deemed as additional under the activity method.

2.4 Uncertainty

Concept

Uncertainty is a characteristic of a measurement or sample that describes the dispersion of values that could reasonably be attributed to the measured value. Certain measurements and sampled data will have inherent uncertainty. Where relevant, methodologies shall set out procedures for projects to estimate uncertainty and apply confidence deductions to account for uncertainty, according to recognized statistical approaches.

Requirements

2.4.1 Where applicable, methodology elements shall provide a means to estimate a 90 or 95 percent confidence interval. Where a methodology applies a 90 percent confidence interval and the width of the confidence interval exceeds 20 percent of the estimated value or where a methodology applies a 95 percent confidence interval and the width of the confidence interval exceeds 30 percent of the estimated value, an appropriate confidence deduction shall be applied.

2.4.2 Methods used for estimating uncertainty shall be based on recognized statistical approaches such as those described in the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. Confidence deductions shall be applied using conservative factors such as those specified in the CDM Meth Panel *guidance on addressing uncertainty in its Thirty Second Meeting Report, Annex 14*.

2.5 Models, Default Factors and Proxies

Concept

Methodologies may use models, default factors and/or proxies to streamline monitoring or measurement processes. Where methodologies use models, default factors and/or proxies, they shall follow the requirements set out below in order to ensure the integrity of the model, default factor(s) and proxy(s) used.

Requirements

2.5.1 Where methodologies mandate the use of specific models to simulate processes that generate GHG emissions (i.e., the project proponent is not permitted to use other models), the following applies, given the note below:

1) Models shall be publicly available, though not necessarily free of charge, from a reputable and recognized source (e.g., the model developer's website, IPCC or government agency).

2) Model parameters shall be determined based upon studies by appropriately qualified experts that identify the parameters as important drivers of the model output variable(s).

3) Models shall have been appropriately reviewed and tested (e.g., ground-truthed using empirical data or results compared against results of similar models) by a recognized, competent organization, or an appropriate peer review group.

4) All plausible sources of model uncertainty, such as structural uncertainty or parameter uncertainty, shall be assessed using recognized statistical approaches such as those described in *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 1, Chapter 3*.

5) Models shall have comprehensive and appropriate requirements for estimating uncertainty in keeping with IPCC or other appropriate guidance, and the model shall be calibrated by parameters such as geographic location and local climate data.

6) Models shall apply conservative factors to discount for model uncertainty (in accordance with the requirements set out in Section 2.1.3), and shall use conservative assumptions and parameters that are likely to underestimate, rather than overestimate, the GHG emission reductions or removals.

Note – The criteria set out in (2)-(6) above are targeted at more complex models. For simple models, certain of these criteria may not be appropriate, or necessary to the integrity of the methodology. Such criteria may be disregarded, though the onus is upon the methodology developer to demonstrate that they are not appropriate or necessary.

2.5.2 Where methodologies use default factors and standards to ascertain GHG emission data and any supporting data for establishing baseline scenarios and demonstrating additionality, the following applies:

1) Where the methodology uses third party default factors and/or standards, such default factors and standards shall meet with the requirements for data set out in Section 3.4.6, *mutatis mutandis*.

2) Where the methodology itself establishes a default factor, the following applies:

   a) The data used to establish the default factor shall comply with the requirements for data set out in Section 3.4.6, *mutatis mutandis*.

   b) The methodology shall describe in detail the study or other method used to establish the default factor.

   c) The methodology developer shall identify default factors which may become out of date (i.e., those default factors that do not represent physical constants or otherwise would not be expected to change significantly over time). Such default factors are subject to periodic re-assessment, as set out in the VCS Program document *Methodology Approval Process*.

3) Where methodologies allow project proponents to establish a project-specific factor, the methodology shall provide a procedure for establishing such factors.

Note – Methodologies may use deemed savings factors which, as set out in the definition of deemed savings factor, are a specific type of default factor.

2.5.3 Where proxies are used, it shall be demonstrated that they are strongly correlated with the value of interest and that they can serve as an equivalent or better method (e.g., in terms of reliability, consistency or practicality) to determine the value of interest than direct measurement of the value itself.

2.6 AFOLU Methodologies

Concept

AFOLU projects may encounter unique circumstances related to project implementation, monitoring and other matters. Methodologies applicable to AFOLU projects shall meet additional requirements in order to address these circumstances. This section sets out high-level methodological requirements related to such AFOLU-specific matters. Note that additional AFOLU-specific requirements are also set out throughout this document.

Requirements

2.6.1 There are currently six AFOLU project categories under the VCS Program, as further described in Appendix 1 Eligible AFOLU Project Categories. Proposed AFOLU methodologies shall fall within one or more of these AFOLU project categories.

2.6.2 Where a methodology combines AFOLU project categories, the methodology shall adhere to all sets of requirements pertaining to each and every project category covered, either separating activities, or where activities cannot be separated, taking a conservative approach to each requirement.

2.6.3 Biofuel crop production activities are eligible as a project activity only to the extent that they generate measurable long-term increases in aboveground, belowground, and/or soil carbon stocks or substantially reduce soil carbon losses. Biofuel crop production on undrained or rewetted wetlands shall follow the wetlands restoration and conservation (WRC) requirements. Although a number of biofuel crops require drainage, some forms of biomass production on wetlands (e.g., paludicultures on peatland) are compatible with rewetting and may even lead to organic matter accumulation. This activity is feasible, for example, with crops that grow on wet peatlands and that do not consume the peat body, such as alder, papyrus and willow. Biofuel crop production activities on drained wetlands or on wetlands cleared of, or converted from, native ecosystems are not eligible.

2.7 ODS Methodologies

Concept

ODS projects may encounter unique circumstances related to project implementation, avoidance of perverse incentives and other matters. Methodologies applicable to ODS projects shall meet additional requirements in order to address these circumstances. This section sets out high-level methodological requirements related to such ODS-specific matters. Note that additional ODS-specific requirements are also set out throughout this document.

Requirements

2.7.1 Methodology elements for ODS destruction projects are categorized under sectoral scope 11, fugitive emissions from production and consumption of halocarbons and sulphur hexafluoride.

2.7.2 ODS projects are eligible for immediate crediting of future avoided emissions and methodology elements may use such a crediting model.

Note – Crediting shall still be in relation to the baseline scenario. In many cases, methodology elements will credit projects for all of the ODS destroyed by the project (minus any project emissions and leakage). However, it is possible that projects could destroy ODS from existing stockpiles and only a portion of the ODS would have been emitted under the baseline scenario. For example, if the baseline scenario includes use of the ODS to service existing equipment and a certain proportion of such ODS would be recovered and destroyed at the end of that equipment's life (whether voluntarily or due to regulation), then the volume of credits granted to the project shall reflect this.

2.8 Methodology Revisions

Concept

VCS methodologies and approved GHG program methodologies may be revised under the VCS Program. Additionally, standardized methods must be re-evaluated periodically to ensure that they are still valid, and necessary updates to a standardized method may require revision to the underlying methodology.

Requirements

General

2.8.1 Methodology revisions are appropriate where a project activity is broadly similar to the project activities eligible under an existing methodology and such project activity can be included through reasonable changes to that methodology. Methodology revisions are also appropriate where an existing methodology can be materially improved. Materially improving a methodology involves comparing the existing and proposed methodologies so as to show that the changes will deliver material improvements that will result in greater accuracy of measurement of GHG emissions reductions or removals, improved conservatism and/or reduced transaction costs.

2.8.2 Methodology revisions shall be prepared using the *VCS Methodology Template* and shall be managed via the methodology approval process. They may be prepared and submitted to the methodology approval process by the developer of the original methodology or any other entity.

2.8.3 The VCS Program distinguishes between revisions to VCS methodologies and revisions to approved GHG program methodologies. The requirements for the development and assessment of each are set out in the VCS Program document *Methodology Approval Process*.

Standardized Methods

2.8.4 Standardized methods approved under the VCS Program shall be periodically reviewed and may require revision, as set out in the VCS Program document *Methodology Approval Process*.

2.8.5 Where an activity method uses the activity penetration option and the level of activity penetration has risen (since initial approval) to exceed the five-percent threshold level, the activity method may not be revised to use the financial feasibility or revenue streams options.

3 METHODOLOGY COMPONENTS

This section sets out the rules and requirements for each component of VCS methodologies.

In order to be approved under the VCS Program, methodologies shall be assessed per the process set out in the VCS Program document *Methodology Approval Process*.

3.1 Definitions

Concept

Methodologies may set out defined terms in addition to those already included in the VCS *Program Definitions* to help users understand the context of the methodology and improve its readability.

Requirements

3.1.1 Definitions shall be written in a clear and concise manner.

3.1.2 Defined terms shall be used within the methodology and methodologies shall not define terms that are already included in the VCS *Program Definitions*.

3.2 Applicability Conditions

Concept

Applicability conditions define the project activities which are eligible to apply a given methodology. These may include conditions such as geographic applicability, technology type, historical land use and any other conditions under which the methodology is or is not applicable.

Requirements

General

3.2.1 Methodologies shall use applicability conditions to specify the project activities to which it applies and shall establish criteria that describe the conditions under which the methodology can (and cannot, if appropriate) be applied. Any applicability conditions set out in tools or modules used by the methodology shall also apply.

Standardized Methods

3.2.2 Precise specification of the project activity is required to provide a carefully targeted standardized method with an appropriate level of aggregation with respect to the project activity. The applicability conditions shall be specified accordingly and shall cause to be excluded from the methodology, to the extent practicable, those classes of project activities that it can be reasonably assumed will be implemented without the intervention created by the carbon market. For example, a methodology may exclude facilities larger than a specific size or capacity, constructed before a given date or that have regular access to lower cost fuels than most facilities. Methodologies shall demonstrate how the applicability conditions achieve such objective with respect to free-riders.

Performance Methods

3.2.3 The applicability conditions shall limit the applicability of the methodology to project activities whose performance can be described in terms of the performance benchmark metric set out in the methodology.

3.2.4 Where a methodology uses a performance method for determining additionality, the applicability conditions shall ensure that the project implements technologies and/or measures that cause substantial performance improvement relative to the crediting baseline and what is achievable within the sector, and the methodology shall explicitly specify such technologies and/or measures (or examples thereof). Note that the implementation date of such technologies and/or measures is the project start date and the VCS Program rules with respect to project start date apply (i.e., implementation will need to have occurred within timeframes permitted under the VCS Program rules on project start date). Activities that have not implemented any such technologies and/or measures, or that have implemented them on a date that is earlier than that permitted under the VCS rules on project start date, shall be excluded from the methodology.

3.2.5 The applicability conditions shall establish the scope of validity of the methodology, and where multiple benchmarks are established, each performance benchmark, including the geographic scope. In establishing the scope of validity of the methodology or each performance benchmark, the methodology shall clearly demonstrate that there is similarity across the sub-areas of the geographic scope in factors such as socio-economic conditions, climatic conditions, energy prices, raw material availability and electricity grid emission factors, as such factors relate to the baseline scenario and additionality, noting that variation is permitted where correction factors address such variation as set out in Section 2.3.8.

It may be necessary to stratify and establish multiple performance benchmarks, or to limit the applicability of the methodology, to comply with this requirement.

3.2.6 The applicability of a methodology or a performance benchmark shall be limited to the geographic area for which data are available, or it shall be demonstrated that data from one geographic area are representative of another or that it is conservative to apply data from one geographic area to another. Representativeness shall be determined in terms of the similarity of the geographic areas considering such factors as those set out in Section 3.2.5 above. Likewise, it shall be determined that it is conservative to apply data from one geographic area by considering the same factors. In determining whether two areas are sufficiently similar, or that it is conservative, to allow data to apply from one area to another, only factors related to the baseline scenario and additionality need to be considered.

Activity Methods

3.2.7 The applicability conditions specify the project activity and they shall therefore serve as the specification of the positive list (i.e., all project activities that satisfy the applicability conditions are deemed as additional).

3.2.8 Methodologies shall clearly specify the project activity in terms of a technology or measure and its context of application. A technology or measure encompasses the plant, equipment, process, management and conservation measure or other practice that directly or indirectly generates GHG emission reductions and/or removals. The context of application refers to the conditions or circumstances under which such technology or measure may be implemented.

3.2.9 The applicability conditions shall establish the scope of validity of the methodology, including the geographic scope. In establishing the scope of validity of the methodology, the methodology shall clearly demonstrate that there is similarity across the sub-areas of the geographic scope in factors such as socio-economic conditions, climatic conditions, energy prices, raw material availability and electricity grid emission factors; as such factors relate to the baseline scenario and additionality, it may be necessary to limit the applicability of the methodology to comply with this requirement.

3.2.10 Where the activity method is set out as a separate module (i.e., is not an integrated part of a methodology), the activity method may be applied to any methodology eligible under the VCS Program that permits the project activity specified in the module (see the VCS Program document *VCS Standard* for further details).

3.3 Project Boundary

Concept

The project boundary includes the GHG sources, sinks and reservoirs that are controlled by the project proponent, are related to the project or are affected by project activities. Methodologies shall describe the project boundary and the GHG sources, sinks and reservoirs included in or excluded from the project boundary.

Requirements

General

3.3.1 Methodologies shall establish criteria and procedures for describing the project boundary and identifying and assessing GHG sources, sinks and reservoirs relevant to the project and baseline scenarios. Justification for GHG sources, sinks and reservoirs included or excluded shall be provided.

3.3.2 In identifying GHG sources, sinks and reservoirs relevant to the project, methodologies shall set out criteria and procedures for identifying and assessing GHG sources, sinks and reservoirs that are controlled by the project proponent, related to the project or affected by the project (i.e., leakage).

3.3.3 In identifying GHG sources, sinks and reservoirs relevant to the baseline scenario, methodologies shall:

1) Set out criteria and procedures used for identifying the GHG sources, sinks and reservoirs relevant for the project.
2) Where necessary, explain and apply additional criteria for identifying relevant baseline GHG sources, sinks and reservoirs.
3) Compare the GHG sources, sinks and reservoirs identified for the project with those identified in the baseline scenario, to ensure equivalency and consistency.

AFOLU Methodologies

3.3.4 The relevant carbon pools for AFOLU project categories are aboveground tree biomass (or aboveground woody biomass, including shrubs, in ARR, ALM and ACoGS projects), aboveground non-tree biomass (aboveground non-woody biomass in ARR and ALM projects), belowground biomass, litter, dead wood, soil (including peat) and wood products. Methodologies shall include the relevant carbon pools set out in Table 1 below.

Table 1: Carbon Pools to be considered in Methodologies

		Above-ground tree* biomass	Above-ground non-tree* biomass	Below-ground biomass	Litter	Dead wood	Soil	Wood products
ARR		Y	S	S	S	S	S	O
ALM		S	N	O	N	N	Y	O
IFM	Reduced Impact Logging (RIL) with no or minimal (<25%) effect on total timber extracted	Y	N	O	N	Y	N	N
	Reduced Impact Logging (RIL) with at least 25% reduction in timber extracted	Y	N	O	N	Y	N	Y
	Logged to Protected Forest (LtPF)	Y	N	O	N	Y	N	Y
	Extended Rotation Age (ERA)	Y	N	O	N	O	N	O
	Low-productive to High-productive Forests (LtHP)	Y	N	O	N	O	O	O
REDD	Planned or unplanned deforestation/degradation (APD or AUDD) with annual crop as the land cover in the baseline scenario	Y	O	O	N	O	O	S
	Planned or unplanned deforestation/degradation (APD or AUDD) with pasture grass as the land cover in the baseline scenario	Y	O	O	N	O	N	S
	Planned or unplanned deforestation/degradation (APD or AUDD) with perennial tree crop[1] as the land cover in the baseline scenario	Y	Y	O	N	O	N	S

[1] Common perennial crops include oil palm, bananas, other fruit trees, spice trees, tea shrubs, and the like, which may or may not meet the definition of a tree used within a host country.

ACoGS	Planned or unplanned conversion	O	O	O	O	O	O	N
WRC		Y	O	O	N	O	Y	O

Y: Carbon pool shall be included in the project boundary.

S: Carbon pool shall be included where project activities may significantly reduce the pool, and may be included where baseline activities may significantly reduce the pool, as set out in Sections 3.3.10 to 3.3.28. The methodology shall justify the exclusion or inclusion of the pool in the project boundary.

N: Carbon pool does not have to be included, because it is not subject to significant changes or potential changes are transient in nature. The pool may be included in the project boundary because of positive impacts to reducing or removing emissions. Where the carbon pool is included in the project boundary, methodologies shall establish criteria and procedures to set out when a project proponent may include the pool.

O: Carbon pool is optional and may be excluded from the project boundary. Where the pool is included in the methodology, the methodology shall establish criteria and procedures to set out when a project proponent shall or may include the pool.

* For ARR, ALM and ACoGS projects, in place of "Aboveground tree" and "Aboveground non-tree", these two carbon pool categories should be read as "Aboveground woody" and "Aboveground non-woody" respectively.

3.3.5 Additional guidance and further requirements with respect to specific carbon pools and GHG sources are set out below in Sections 3.3.10 to 3.3.28.

3.3.6 Specific carbon pools and GHG sources, including carbon pools and GHG sources that cause project and leakage emissions, may be deemed *de minimis* and do not have to be accounted for if together the omitted decrease in carbon stocks (in carbon pools) or increase in GHG emissions (from GHG sources) amounts to less than five percent of the total GHG benefit generated by the project. The methodology shall establish the criteria and procedures by which a pool or GHG source may be determined to be *de minimis*.

For example, peer reviewed literature or the CDM A/R methodological tool *Tool for testing significance of GHG emissions in A/R CDM project activities* may be used to determine whether decreases in carbon pools and increases in GHG emissions are *de minimis*.

Further, the following GHG sources may be deemed *de minimis* and need not be accounted for:

1) ARR, IFM and REDD: N_2O emissions from project activities that apply nitrogen containing soil amendments and N_2O emissions caused by microbial decomposition of plant materials that fix nitrogen. ALM projects that apply nitrogen fertilizer and/or manure or plant nitrogen fixing species shall account for N_2O emissions.

2) ARR, IFM, REDD, ACoGS and WRC: GHG emissions from the removal or burning of herbaceous vegetation and collection of non-renewable wood sources for fencing of the project area.

3) ARR, IFM, REDD, ACoGS and WRC: Fossil fuel combustion from transport and machinery use in project activities. Where machinery use for selective harvesting activities may be significant in IFM project activities as compared to the baseline or where machinery use for earth moving activities may be significant in WRC project activities as compared to the baseline, emissions shall be accounted for if above *de minimis*, in accordance with this Section 3.3.6. Fossil fuel combustion from transport and machinery use in rewetting of drained peatland and conservation of peatland project activities need not be accounted for.

3.3.7 Specific carbon pools and GHG sources do not have to be accounted for if their exclusion leads to conservative estimates of the total GHG emission reductions or removals generated. The methodology shall establish criteria and procedures by which a project proponent may determine a carbon pool or GHG source to be conservatively excluded. Such conservative exclusion may be determined by using tools from an approved GHG program, such as the CDM A/R methodological tool *Procedure to determine when accounting of the soil organic carbon pool may be conservatively neglected in CDM A/R project activities*, or by using peer-reviewed literature.

3.3.8 Reductions of N_2O and/or CH_4 emissions are eligible for crediting if in the baseline scenario the project area would have been subject to livestock grazing, rice cultivation, burning and/or nitrogen fertilization.

3.3.9 Reductions of CH_4 emissions are eligible for crediting if fire would have been used to clear the land in the baseline scenario.

Afforestation, Reforestation and Revegetation (ARR)

3.3.10 Where a methodology is applicable to projects that may reduce the aboveground non-woody biomass, belowground biomass, litter, dead wood or soil pools above *de minimis* (as set out in Section 3.3.6), the relevant carbon pool shall be included in the project boundary.

Agricultural Land Management (ALM)

3.3.11 Where a methodology is applicable to projects with livestock grazing in the project or baseline scenario, CH_4 emissions from enteric fermentation and CH_4 and N_2O emissions from manure shall be included in the project boundary.

3.3.12 Where land-use conversion requires intensive energy inputs or infrastructure development, such as the establishment of irrigation or drainage systems, the methodology shall include the GHG emissions associated with the conversion process in the project boundary.

3.3.13 Where energy-conserving practices reduce emissions of CO_2, such as adopting no-till practices to reduce fuel use, the methodology may include these GHG emissions reductions in the project boundary.

3.3.14 Where activities convert drained, farmed organic soils to perennial non-woody vegetation and reduce or eliminate drainage to reduce CO_2 and N_2O emissions from organic soils, such activities may increase CH_4 emissions. Methodologies applicable to such activities shall include CH_4 emissions in the project boundary.

Improved Forest Management (IFM)

3.3.15 IFM methodologies applicable to activities that reduce harvested timber shall account for the GHG emissions associated with changes in the wood products pool to avoid overestimating project net GHG benefits. The quantity of live biomass going into wood products shall be quantified where above *de minimis* (as set out in Section 3.3.6).

3.3.16 For IFM activities, changes in soil carbon are likely to be *de minimis* for forests on mineral upland soils, though they could be considerably above *de minimis* for forests growing in wetland areas such as peatland forests or mangroves. Although it may be conservative to omit the soil carbon pool for such projects, additional GHG credits may be available if the soil carbon pool is included. Therefore, the pool may be included in the project boundary.

3.3.17 RIL and LtPF methodologies shall include the dead wood carbon pool in the project and baseline scenario. Both of these activities reduce the amount of timber extracted per unit area, which, in turn, may reduce the dead wood pool in the project scenario.

3.3.18 Accounting for the dead wood carbon pool in ERA methodologies is complex because GHG emissions will depend on how post-harvest slash is treated. Slash may either be piled and burned on site, as typically happens in fire prone areas, or left on site to decompose. Extending a harvest rotation or cutting cycle would result in larger trees at harvest, which would increase the amount of dead wood produced at each harvest, but not necessarily the total amount of dead wood produced over time. Because the dead wood pool may increase above the *de minimis* in the baseline or project scenario, this carbon pool is deemed optional.

Reduced Emissions from Deforestation and Degradation (REDD)

3.3.19 Where timber removal is associated with deforestation and/or degradation in the baseline scenario, the wood product pool shall be included in the project boundary because significant quantities of carbon can be stored in wood products instead of entering the atmosphere during deforestation. The quantity of live biomass going into wood products shall be quantified if above *de minimis* (as set out in Section 3.3.6) or may be conservatively excluded (as set out in Section 3.3.7).

3.3.20 Where the baseline scenario is the conversion of forest to annual crops, additional GHG credits may be available if the soil carbon pool is included because decreases in soil carbon stocks in the baseline scenario can be significant.

Avoided Conversion of Grasslands and Shrublands (ACoGS)

3.3.21 Grasslands and shrublands are highly variable in their above- and belowground biomass, so the relevant carbon pools will vary. Non-forest land commonly generates negligible amounts of wood products, hence the pool is not required for ACoGS. All other pools are optional for ACoGS activities, because none of the carbon pools are expected to decrease with the project activity. Soil carbon is likely to be the carbon pool that generates the most GHG emission reductions in ACoGS projects. In addition, in non-forested ecosystems, the belowground biomass pool is often several times larger than the aboveground biomass pools[2]. Methodologies shall set out the carbon pools that shall or may be included in the project boundary.

3.3.22 Grazing is a common practice in many grassland and some shrubland ecosystems. As such, livestock grazing does not preclude ACoGS project eligibility, and grazing may continue on project areas. Projects that incorporate improved grazing practices shall follow the Improved Grassland Management requirements for such activities in the ALM category. Such activities may provide GHG benefits in addition to those achieved by avoiding conversion under this ACoGS category. Where livestock grazing may be present in the project scenario, methodologies shall set out criteria and procedures to account for CH_4 emissions from enteric fermentation and CH_4 and N_2O emissions from manure. Where grazing occurs in both the baseline and project scenarios, net changes in CH_4 and N_2O associated with grazing may be deemed *de minimis* and excluded in accordance with Sections 3.3.6 and 3.3.7.

3.3.23 Where the baseline scenario may include conversion to cropland, methodologies may include CH_4 and N_2O emissions from fertilizer application (manure or synthetic) in the baseline and project scenarios.

3.3.24 Where the baseline scenario may include the conversion of vegetation to perennial crops, such as where oil palm or short-rotation woody crops would be planted, the aboveground woody and non-woody biomass pools shall be included.

Wetlands Restoration and Conservation (WRC)

3.3.25 Methodologies that allow for combined category projects shall apply the relevant WRC requirements for the soil carbon pool and the respective non-WRC AFOLU project category requirements for the other pools, unless the former may be deemed *de minimis* (as set out in Section 3.3.6) or conservatively excluded (as set out in Section 3.3.7)

3.3.26 Methodologies shall include CH_4 emissions in the project boundary (for example, transient peaks of CH_4 that may arise after rewetting peatland). The methodology shall establish the criteria and procedures by which the CH_4 source may be deemed *de minimis* (as set out in Section 3.3.6) or conservatively excluded (as set out in Section 3.3.7)

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[2] Mokany, K., R. J. Raison, and A. S. Prokushkin. 2006. Critical analysis of root: shoot ratios in terrestrial biomes. Global Change Biology 12:84-96.

3.3.27 N_2O emissions shall be included in the project boundary for RWE activities. The methodology shall establish the criteria and procedures by which the N_2O source may be deemed *de minimis* (as set out in Section 3.3.6) or conservatively excluded (as set out in Section 3.3.7).

3.3.28 For project activities implemented on coastal wetlands, methodologies shall establish criteria and procedures for establishing the geographic boundary that considers projections of expected relative sea level rise. The procedures shall account for the potential effect of sea level rise on the lateral movement of wetlands during the project crediting period and the potential that the wetlands will migrate beyond the project boundary.

3.4 Baseline Scenario

Concept

The baseline scenario represents the activities and GHG emissions that would occur in the absence of the project activity. The baseline scenario must be accurately determined so that an accurate comparison can be made between the GHG emissions that would have occurred under the baseline scenario and the GHG emission reductions and/or removals that were achieved by project activities.

Requirements

General

3.4.1 Methodologies using a project method shall establish criteria and procedures for identifying alternative baseline scenarios and determining the most plausible scenario, taking into account the following:

1) The identified GHG sources, sinks and reservoirs.
2) Existing and alternative project types, activities and technologies providing equivalent type and level of activity of products or services to the project.
3) Data availability, reliability and limitations.
4) Other relevant information concerning present or future conditions, such as legislative, technical, economic, socio-cultural, environmental, geographic, site-specific and temporal assumptions or projections.

3.4.2 Methodologies using a standardized method for determining the crediting baseline shall describe (taking into account the factors set out Section 3.4.1 above), as far as is possible, the technologies or measures that represent the most plausible baseline scenario or the aggregated baseline scenario (see Section 3.4.4 for further information on aggregate baseline scenarios), though it is recognized that it may not be possible to specify precisely all technologies or measures given that the baseline may represent a variety of different technologies and measures.

Standardized Methods

3.4.3 Standardized methods shall be developed with the objective of predicting, as accurately as is practicable, the most plausible baseline scenario or aggregated baseline scenario. Notwithstanding this principle, it is recognized that standardized methods cannot perfectly capture the precise baseline behavior for all proposed projects eligible under a standardized method.

Performance Methods

3.4.4 Methodologies shall identify alternative baseline scenarios and determine either the most plausible baseline scenario or an aggregate baseline scenario for the project activity. Aggregate baseline scenarios shall be determined by combining likely scenarios on a probabilistic (i.e., likelihood) basis.

3.4.5 Performance benchmarks shall be established based upon available technologies and/or current practices, and trends, within the sector. Where the analysis of trends shows a clear trend of improvement in the baseline scenario over time, the performance benchmark shall take account of the trend. This means that where the performance benchmark does not use a dataset that is updated at least annually, an autonomous improvement factor shall be used that provides a performance benchmark that tightens annually. Notwithstanding this requirement, methodologies may allow projects to use the level of the performance benchmark metric available at project validation for the duration of their project crediting periods (see also Section 3.4.7 below). Where the analysis of trends shows a trend of increasing GHG emissions or decreasing GHG removals in the baseline scenario over time, the performance benchmark shall not consider such trend.

3.4.6 Appropriate data sources for developing performance methods include economic and engineering analyses and models, peer-reviewed scientific literature, case studies, empirical data, and common practice data. The data and dataset derived from such data sources shall meet the requirements below. The CDM *Guidelines for quality assurance and quality control of data used in the establishment of standardized baselines* also provides useful related guidance.

1) Data collected directly from primary sources shall comply with relevant and appropriate standards, where available, for data collection and analysis, and be audited at an appropriate frequency by an appropriately qualified, independent organization.

2) Data collected from secondary sources shall be available from a recognized, credible source and must be reviewed for publication by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency.

3) Data shall be from a time period that accurately reflects available technologies and/or current practice, and trends, within the sector. Selection of the appropriate temporal range shall be determined based on the guidance provided in the *GHG Protocol for Project Accounting*, Chapter 7 (WRI-WBCSD).

4) Where sampling is applied in data collection, the requirements set out in Section 2.1.3 shall be adhered to. The methodology developer shall demonstrate that sampling results provide an unbiased and reliable estimate of the true mean value (i.e., the sampling does not systematically underestimate or overestimate the true mean value).

5) Data shall be publicly available or made publicly available. Proprietary data (e.g., data pertaining to individual facilities) may be aggregated, and therefore not made publicly available, where there are demonstrable confidentiality considerations. However, sufficient data shall be publicly available to provide transparency and credibility to the dataset.

6) All data shall be made available, under appropriate confidentiality agreements as necessary, to Verra and each of the validation/verification bodies assessing the proposed performance benchmark methodology, to allow them to reproduce the determination of the performance benchmark. Data shall be presented in a manner that enables them to independently assess the presented data.

7) Data shall be appropriate to the methodology's geographic scope and the project activities applicable under it.

8) All reasonable efforts shall be undertaken to collect sufficient data and the use of expert judgment as a substitute for data shall only be permitted where it can be demonstrated that there is a paucity of data. Expert judgment may be applied in interpreting data. Where expert judgment is used, good practice methods for eliciting expert judgment shall be used (e.g., *IPCC 2006 Guidelines for National GHG Inventories*).

9) Where data must be maintained in a central repository on an on-going basis (e.g., in a database that holds sector data for use by project proponents in establishing specific performance benchmarks for their projects), there shall be clear and robust custody arrangements for the data and defined roles and responsibilities with respect to the central repository.

Where such data requirements set out above cannot be met, a performance method shall not be applied except as set out in Section 3.2.5.

3.4.7 The dataset may be documented and contained within the methodology, or may be maintained in a separate repository that is referenced by the methodology. Datasets documented and contained within methodologies are static datasets, where all projects use the level of the performance benchmark metric specified in the methodology (noting that autonomous improvement factors may be used, as set out in Section 3.4.5 above). The following applies with respect to datasets maintained in a separate repository:

1) The dataset may be static or dynamic (i.e., may or may not be periodically updated).

2) The methodology shall establish criteria and procedures for use of the dataset and for establishing specific performance benchmarks for individual projects.

3) The methodology may specify that projects use the level of the performance benchmark metric available at project validation for the duration of their project crediting periods, or

may specify that projects use an updated level of the performance benchmark metric at each verification event. The frequency that data is updated within the dataset shall be determined by the methodology developer.

4) It shall be demonstrated that procedures are in place to maintain the dataset in accordance with the applicable requirements set out for data and datasets in Section 3.4.6 above.

Activity Methods

3.4.8 There are no specific requirements for activity methods, noting that methodologies using an activity method may use a project or performance method for determining the crediting baseline, as set out in Section 2.2.2.

AFOLU Methodologies

3.4.9 The determination and establishment of a baseline scenario shall follow an internationally accepted GHG inventory protocol, such as the *IPCC 2006 Guidelines for National GHG Inventories*.

Agricultural Land Management (ALM)

3.4.10 The criteria and procedures for establishing the baseline scenario shall require the project proponent to take into account current and previous management activities. The quantification of the baseline scenario may be determined from measured inventory estimates and/or activity-based estimation methods, such as those found in the *IPCC 2006 Guidelines for National GHG Inventories*.

Improved Forest Management (IFM)

3.4.11 Methodologies that establish criteria and procedures for establishing the baseline scenario using a project method, rather than a performance method shall require the following:

1) Documented evidence of the project proponent’s operating history, such as five or more years of management records, to provide evidence of normal historical practices. Management records may include, *inter alia*, data on timber cruise volumes, length of roads and skid trails, inventory levels, and harvest levels within the project area. Where the project proponent or implementing partner is a new owner or management entity and does not have a history of management practices within the project area, procedures shall be established to identify the most plausible baseline scenario based upon the most likely owner or operator, noting the following:

   a) For RIL and LtPF projects, where the project proponent takes over ownership or management of a property specifically to implement the project, the baseline scenario shall represent the most likely management plan of the most likely owner or operator (i.e., be based on the projected management plans of the previous property owners and/or operators or the management plans of the most likely operator).

b) In all other cases, the baseline scenario shall reflect the local common practices and legal requirements. However, if the common practice is unsustainable and unsustainable practices are inconsistent with the mission or the historical management practices of the new owner or management entity, then a sustainable baseline is the minimum that can be adopted.

2) Adherence to the legal requirements for forest management and land use in the area unless verifiable evidence is provided demonstrating that common practice in the area does not adhere to such requirements.

3) Baseline environmental management practices shall not be set below (i.e., be less environmentally robust than) those commonly considered a minimum standard among similar landowners in the area. For example, where common practice exceeds minimum legal practice, the baseline cannot be the minimum legal requirement and the baseline scenario shall, at a minimum, be based on common practice.

Reduced Emissions from Deforestation and Degradation (REDD)

3.4.12 The baseline for REDD projects is comprised of a land-use and land-cover (LU/LC) change component and a carbon stock change component. These components may be addressed separately in a methodology as their scale of analysis may differ.

3.4.13 For inclusion of the non-CO_2 gases, methodologies shall require projects to provide evidence to demonstrate that the practice for which the project plans to claim credit is not common practice in the area. The guidance in the *IPCC 2003 Good Practice Guidelines for LULUCF* and the *IPCC 2006 Guidelines for National GHG Inventories* may be used to estimate such GHG emissions.

3.4.14 Determination and establishment of the LU/LC change component of the baseline is handled differently for the two eligible REDD activity types, as follows:

1) APD: The criteria and procedures for establishing the baseline scenario shall require the project proponent to provide verifiable evidence to demonstrate, based on government plans (for publicly owned and managed land), community plans (for publicly owned and community-managed land), concessionary plans (for publicly owned and concession-holder managed) or landowner plans (for privately owned land), that the project area was intended to be cleared. The baseline scenario shall take into account the following:

a) Where it is common practice in the area for timber to be removed before clearing, wood products shall be included in the baseline scenario.

b) Where the agent of deforestation is not the landowner (e.g., in situations where the project proponent successfully outcompeted other agents to acquire a government concession or privately-owned lands) and the project can identify the most-likely agent of deforestation, the baseline scenario shall be determined based on the activities of the most-likely agent who would have acquired control of and cleared the project area.

c) Where the agent of deforestation is not the landowner and cannot be specifically identified, the criteria and procedures for establishing the baseline scenario may be determined based on the most-likely-class of deforestation agents and the intent to deforest. This may be demonstrated through a historical analysis of similar deforestation within the region by the identified most-likely class of deforestation agents. The most-likely-class of deforestation agents are the entities (e.g., individuals, companies or associations) classified based on common characteristics and rates of deforestation that would have been likely to undertake deforestation activities and post-deforestation land-use practices in the project area. The annual rate of forest conversion shall be based on the recent historical practice of the most-likely class (i.e., how much forest is typically cleared each year by similar baseline activities) and projection of the rate of their deforestation activities in the area.

2) AUDD: The criteria and procedures for establishing the baseline scenario shall require the project proponent to take into account deforestation/degradation that would have occurred in the project area during the project crediting period. The baseline scenario shall take into account the following:

a) Methodologies shall set out criteria and procedures to identify where deforestation would likely occur using spatial analysis and projections (except for certain mosaic configurations as set out in Section 3.4.14(2)(c)). Such analysis shall be based on historical factors over at least the previous 10 years that explain past patterns and can be used to make future projections of deforestation.

b) In the frontier configuration, most of the forest area to be protected will have low rates of historical deforestation and/or degradation because most of the project area was not accessible in the past to the agents of deforestation/degradation expected to encroach during the project crediting period. Where the expansion of the deforestation frontier into the project area is linked to the development of infrastructure (e.g., roads) that does not yet exist, clear evidence shall be provided to demonstrate that such infrastructure would have been developed in the baseline scenario. Evidence may include permits, maps showing construction plans, construction contracts or open tenders, an approved budget and/or evidence that construction has started.

c) The criteria and procedures for establishing the baseline scenario in the frontier and mosaic configurations shall take into account such factors as historical deforestation and/or degradation rates and require the project proponent to develop a baseline by determining and analyzing a reference area (which need not be contiguous to the project area), that shall be similar to the project area in terms of drivers and agents of deforestation and/or degradation, landscape configuration, and socio-economic and cultural conditions, noting the following.

i) Where, in the mosaic configuration, no patch of forest in project areas exceeds 1,000 ha and the forest patches are surrounded by anthropogenically cleared land, or where it can be demonstrated that 25 percent or more of the perimeter of the project area is within 120 meters of land that has been anthropogenically deforested within the 10 years prior to the project start date, spatial projections to determine where in the project area deforestation is likely to occur are not required. Though not required, such spatial projections may be applied, in accordance with the methodology. Analysis of historical deforestation rates that explain past deforestation in the reference area is required and shall be applied conservatively to the project area.

Avoided Conversion of Grasslands and Shrublands (ACoGS)

3.4.15 The baseline for ACoGS projects is comprised of a land-use and land-cover (LU/LC) change component, a carbon stock change component and a non-CO_2 GHG component where applicable. These components may be addressed with separate analyses in a methodology because the appropriate scale of analysis may differ for each component.

3.4.16 Determination and establishment of the LU/LC change component of the baseline is handled differently for the two eligible ACoGS activity types, as follows:

1) APC: The criteria and procedures for establishing the baseline scenario shall require the project proponent to provide verifiable evidence to demonstrate, based on government plans (for publicly owned and managed land), community plans (for publicly owned and community-managed land), concessionaire plans (for publicly owned and concession holder managed) or landowner plans (for privately owned land), that the project area was intended to be converted. Documentation of the ability to increase net present value of land through conversion is required, including government subsidies or funding that promotes conversion. Further documentation of landowner plans for conversion may include government approval of conversion or a purchase offer from an entity dedicated to conversion. The baseline scenario shall account for spatial heterogeneity in the project area. Where certain areas are unlikely to be converted, these areas shall be excluded from the baseline scenario. The baseline scenario shall take into account the following:

   a) Where the agent of conversion is not the landowner (e.g., in situations where the project proponent successfully outcompeted other agents to acquire a government concession or privately-owned lands) and the project can identify the most-likely agent of conversion, the baseline scenario shall be determined based on historical and current conversion activities of the most-likely agent who would have acquired control of and converted the project area.

   b) Where the agent of conversion is not the landowner and cannot be specifically identified, the criteria and procedures for establishing the baseline scenario shall be determined based on the most-likely-class of conversion agents and their intent to convert, which shall be demonstrated through a history of similar conversion within the region by the identified most-likely class. The most-likely-class of conversion agents are the entities (e.g., individuals, companies or associations) classified based on common characteristics and rates of conversion that would have been likely to undertake conversion activities and post-conversion land-use practices in the project area. The annual rate of land conversion shall be based on the recent historical practice of the most-likely class (i.e., how much land is typically converted each year by similar baseline activities) and projection of the rate of their conversion activities in the area. The timeframe used to quantify recent historical practice shall be justified by the project proponent as being of long enough duration to average over typical market fluctuations, commonly between 5-15 years. This rate of conversion shall only be extrapolated to lands that were identified as susceptible to conversion in the baseline scenario.

2) AUC: The criteria and procedures for establishing the baseline scenario shall require the project proponent to take into account conversion that would have occurred in the project area during the project crediting period. The baseline scenario shall account for spatial heterogeneity within the project area. Where certain areas are unlikely to be converted, these areas shall be excluded from the baseline scenario. This analysis shall take into account the patch size at which land conversion typically occurs (e.g., areas unsuitable for crops may still be plowed if they are a small part of a larger suitable parcel. Alternatively, even suitable areas may be unlikely to be plowed if they are a small part of a larger unsuitable area). The baseline scenario shall take into account the following:

   a) Methodologies shall set out criteria and procedures to identify where land conversion would likely occur using spatial analysis and projections. Such analysis shall be based on historical factors over at least the previous 10 years that explain past patterns and can be used to make future projections of land conversion.

   b) In cases where future land conversion rates are predicted to exceed historical rates in the project area, evidence documenting the factors contributing to increased conversion must be presented. Where the expansion of the conversion frontier into the project area is linked to the development of infrastructure (e.g., roads) that does not yet exist, clear evidence shall be provided to demonstrate that such infrastructure would have been developed in the baseline scenario. Evidence may include permits, an approved budget or executed construction contracts.

   c) The criteria and procedures for establishing the baseline scenario shall take into account such factors as historical conversion rates and require the project proponent to develop a baseline by determining and analyzing a reference area (which need not be contiguous to the project area), that shall be similar to the project area in terms of drivers and agents of land conversion, landscape configuration, and socio-economic and cultural conditions.

Wetland Restoration and Conservation (WRC)

3.4.17 The criteria and procedures for establishing the RWE baseline scenario shall take into account the following:

1) The current and historic hydrological characteristics of the watershed or coastal plain, and the drainage system in which the project occurs.
2) The long-term average climate variables influencing water table depths and the timing and quantity of water flow. The long-term average climate variables shall be determined using data from climate stations that are representative of the project area and shall include at least 20 years of data.
3) Planned water management activities (such as dam construction).

3.4.18 The criteria and procedures for establishing the RWE baseline scenario shall also consider the relevant non-human induced rewetting brought about by any of the following:

1) Collapsing dikes or ditches that would have naturally failed over time without their continued maintenance.
2) Progressive subsidence of deltas or peatlands leading to a rise in relative water table depths, thus reducing CO_2 emissions but possibly increasing CH_4 emissions in freshwater systems.
3) Non-human induced elevation of non-vegetated wetlands to build vegetated wetlands. Deltaic systems with high sediment load from rivers often do this naturally, and this should be counted as part of the baseline.

3.4.19 The criteria and procedures for establishing the CIW baseline scenario are handled differently for each of the eligible CIW activities, as follows:

1) AUWD: The criteria and procedures for establishing the baseline scenario shall require the project proponent to reference a period of at least 10 years for modeling a spatial trend in conversion, taking into account the long-term average climate variables, and the observed conversion practices (e.g., drainage including canal width, depth, length and maintenance). The long-term average climate variable shall be determined using data from climate stations that are representative of the project area and shall include at least 20 years of data.
2) APWD: The criteria and procedures for establishing the baseline scenario shall require the project proponent to provide verifiable evidence to demonstrate that, based on government plans (for publicly owned and managed wetland), community plans (for publicly owned and community-managed wetland), concessionary plans (for publicly owned and concession holder managed) or landowner plans (for privately owned wetland), the project area was intended to be drained or otherwise converted. The annual rate and depth of drainage or rate of other conversion shall be based on the common practice in the area—that is, how much wetland is typically drained or converted each year by similar baseline activities.

3.4.20 The criteria and procedures for identifying fire in the baseline scenario shall demonstrate with fire maps and historical databases on fires that the project area is now and in the future would be under risk of anthropogenic fires. The procedure for identifying fire in the baseline scenario shall also consider any relevant current and planned land use conditions that may affect the occurrence of fire in order to establish the most plausible scenario for fire in the baseline.

3.4.21 Many land use activities on wetlands (e.g., aquaculture and agriculture) involve the exposure of wetland soils to aerobic decomposition through piling, dredging (expansion of existing channels) or channelization (cutting through wetland plains). Where relevant, the criteria and procedures for identifying WRC baseline scenarios shall account for such processes as they expose disturbed carbon stocks to aerobic decomposition thus increasing the rate of organic matter decomposition and GHG emissions that may continue for years from the stockpiles. Methodologies shall include credible methods for quantifying and forecasting GHG emissions from such degradation.

3.4.22 Where relevant, the criteria and procedures for identifying WRC baseline scenarios shall take account of hydrological processes that lead to increased carbon burial and GHG reductions within the project area. Such processes include changes in the landscape form (i.e., construction of levees to constrain flow and flooding patterns or dams to hold water) and changes in land surface (i.e., forest clearing, and ditching or paving leading to intensified run-off).

3.4.23 Where relevant, the criteria and procedures for identifying WRC baseline scenarios shall take account of processes within the project area that reduce sediment supply associated with changes in the landscape (e.g., construction of upstream dams or stabilization of eroding feeder cliffs along the coast). The supply of sediment varies over time and the time-averaged delivery of sediment shall be considered.

3.4.24 Where relevant, methodologies shall establish criteria and procedures for identifying wetland erosion and/or migration resulting from sea level rise in the baseline scenario on the basis of wetland maps, historical trend data, future projection of sea level rise and how changes in management would impact carbon stocks.

3.4.25 Where relevant, the criteria and procedures for establishing the baseline scenario shall require the project proponent to take into account current and historic management activities outside the project area that have significantly impacted or may significantly impact the project area, including the following:

1) Disruption to or improvement of natural sediment delivery, as this will alter the rate and magnitude of coastal wetlands response to sea level rise.

2) Upstream dam construction, as this will alter water and sediment delivery, as well as salinity in coastal lowlands.

3) Construction of infrastructure inland of coastal wetlands, as this will impair wetland capacity to migrate landwards with sea level rise.

4) Construction of coastal infrastructure, as this can impair sediment movement along shorelines causing wetland loss and increasing risk of carbon emissions with sea level rise.

3.4.26 Methodologies that allow for combined category projects shall require the use of the relevant WRC requirements and the respective non-WRC AFOLU project category requirements for the determination and establishment of the baseline scenario.

ODS Methodologies

3.4.27 Where the destruction of the ODS by the project is mandated by law, statute or other regulatory framework applied in the host country, the baseline shall be the gradually increasing compliance with such law, statute or other regulatory framework, and the baseline emissions shall be calculated as follows:

$$BE_{y,a} = BE_y * (1 - CR_y)$$

Where:

$BE_{y,a}$ = The baseline emissions to be used for the calculation of GHG emission reductions in year y.

BE_y = The baseline emissions in year y.

CR_y = The host country level compliance rate of the law, statute or other regulatory framework in the year y. Calculation of the compliance rate shall exclude other projects implemented under GHG programs. If the compliance rate exceeds 50%, the project shall receive no further credit.

3.5 Additionality

Concept

A project activity is additional if it can be demonstrated that the activity results in emission reductions or removals that are in excess of what would be achieved under a "business-as-usual" scenario and the activity would not have occurred in the absence of the incentive provided by the carbon markets. Additionality is an important characteristic of GHG credits, including VCUs, because it indicates that they represent a net environmental benefit and a real reduction of GHG emissions, and can thus be used to offset emissions. Methodologies shall set out a procedure for demonstrating additionality using a project method or a standardized method (i.e., performance method or activity method).

Requirements

General

3.5.1 Methodologies shall establish a procedure for the demonstration and assessment of additionality based upon the requirements set out below.

The steps which shall be included in methodologies for each method of demonstrating additionality (i.e., project methods, performance methods and activity methods) are set out below.

3.5.2 Methodologies shall use a project method, performance method and/or activity method to determine additionality. The high level specifications and procedural steps for each approach are set out in Sections 3.5.3 to 3.5.9 below. New methodologies developed under the VCS Program shall meet this requirement by doing one of the following:

1) Referencing and requiring the use of an appropriate additionality tool that has been approved under the VCS Program or an approved GHG program;

2) Developing a full and detailed procedure for demonstrating and assessing additionality directly within the methodology; or

3) Developing a full and detailed procedure for demonstrating and assessing additionality in a separate tool, which shall be approved via the methodology approval process, and referencing and requiring the use of such new tool in the methodology.

Note – Reference in a methodology to the VCS Program requirements on additionality is insufficient. The VCS Program requirements are high level requirements and do not represent a full and detailed procedure for the demonstration of additionality. The only exception to this is with respect to regulatory surplus (i.e., methodologies may directly reference the VCS Program requirements on regulatory surplus and do not need to further develop a procedure for demonstrating and assessing regulatory surplus).

Project Method

3.5.3 <u>Step 1: Regulatory Surplus</u>

The project shall not be mandated by any law, statute or other regulatory framework, or for UNFCCC non-Annex I countries, any systematically enforced law, statute or other regulatory framework. For UNFCCC non-Annex I countries, laws, statutes, regulatory frameworks or policies implemented[3] since 11 November 2001 that give comparative advantage to less emissions-intensive technologies or activities relative to more emissions-intensive technologies or activities need not be taken into account. For all countries, laws, statutes, regulatory frameworks or policies implemented since 11 December 1997 that give comparative

[3] Implemented in the context of this paragraph means enacted or introduced, consistent with use of the term under the CDM rules on so-called Type E+ and Type E- policies.

advantage to more emissions-intensive technologies or activities relative to less emissions-intensive technologies or activities shall not be taken into account.

3.5.4 Step 2: Implementation Barriers

The project shall face one or more distinct barrier(s) compared with barriers faced by alternatives to the project:

1) Investment barrier: Project faces capital or investment return constraints that can be overcome by the additional revenues associated with the sale of GHG credits.
2) Technological barriers: Project faces technology-related barriers to its implementation.
3) Institutional barriers: Project faces financial (other than identified in investment barrier above), organizational, cultural or social barriers that the VCU revenue stream can help overcome.

3.5.5 Step 3: Common Practice

The project shall not be common practice, determined as follows:

1) Project type shall not be common practice in sector/region, compared with projects that have received no carbon finance.
2) Where it is common practice, the project proponent shall identify barriers faced compared with existing projects.
3) Demonstration that the project is not common practice shall be based on guidance provided in *The GHG Protocol for Project Accounting*, Chapter 7 (WRI-WBCSD).

Standardized Methods

Performance Methods

3.5.6 Step 1: Regulatory Surplus

The project activity shall meet with the requirements on regulatory surplus set out under the project method in Section 3.5.3.

3.5.7 Step 2: Performance Benchmark

The GHG emissions generated (or carbon sequestered) per unit of output, unit of input or sequestration metric by the project shall be below (or above, for sequestration) the prescribed performance benchmark metric or proxy for such metric (see Section 2.3.6 for specification of the metric). Proxy metrics or conditions may be specified where it can be demonstrated that they are strongly correlated with the performance benchmark metric and that they can serve as an equivalent or better method (e.g., in terms of reliability, consistency or practicality) to determine whether performance is achieved to a level at least equivalent to that of the performance benchmark metric.

GHG emissions generated (or carbon sequestered) may be above (or below, for sequestration) the prescribed performance benchmark metric or proxy for such metric for a given verification period, though the project shall not be granted credit for such verification periods.

Activity Methods

3.5.8 Step 1: Regulatory Surplus

The project activity shall meet with the requirements on regulatory surplus set out under the project method in Section 3.5.3.

3.5.9 Step 2: Positive List

The methodology shall apply one or more of the following three options:

1) Option A: Activity Penetration

The methodology shall demonstrate that the project activity has achieved a low level of penetration relative to its maximum adoption potential, as follows:

a) The methodology shall demonstrate that the project activity has achieved a low level of penetration relative to its maximum adoption potential, determined using the following equation:

$$AP_y = OA_y / MAP_y$$

Where:

AP_y = Activity penetration of the project activity in year y (percentage)

OA_y = Observed adoption of the project activity in year y (e.g., total number of instances installed at a given date in year y, or amount of energy supplied in year y)

MAP_y = Maximum adoption potential of the project activity in year y (e.g., total number of instances that potentially could have been installed at a given date in year y, or the amount of energy that potentially could have been supplied in year y)

The maximum adoption potential is the total adoption of a project activity that could currently be achieved given current resource availability, technological capability, level of service, implementation potential, total demand, market access and other relevant factors within the methodology's applicable geographically defined market. Maximum adoption potential does not consider market price, cost of adoption, consumer education, cultural or behavioral barriers, and laws, statutes, regulatory frameworks or policies.

Maximum adoption potential is constrained by numerous factors each imposing their own limitations on the total adoption of a project activity. The following list provides further specification with respect to factors that do, and do not, need to be considered in determining maximum adoption potential:

i) Resource availability is the limitation imposed by the supply of raw materials or energy resources to the activity.

ii) Technological capability is the limitation imposed by the technical efficiency of the project activity.

iii) Level of service is the limitation imposed by the technical reliability or quality of the service provided by the project activity relative to its alternatives.

iv) Implementation potential is the limitation imposed by the availability of appropriate locations for implementing the project activity.

v) Total demand is the limitation imposed by demand for the product or service provided by, or associated with, the project activity and all relevant alternative sources of the product or service.

vi) Market access is the limitation imposed by current infrastructure and the degree to which the outputs of project activity can be practically supplied to the market.

vii) Market price is the limitation imposed by the current price achievable for outputs from the project activity. Cost of adoption is the limitation imposed by the cost of switching to the project activity from an alternative activity. Consumer education is the public knowledge or awareness of the activity and its benefits. Behavioral or cultural barriers are limitations resulting from social or cultural inertia with respect to the adoption of the project activity.

Data used in determining the level of activity penetration shall meet the requirements for data set out for performance benchmarks in Section 3.4.6, *mutatis mutandis*.

b) The level of penetration of the project activity shall be no higher than five percent.

c) Where the project activity has been commercially available in any area of the applicable geographic scope for less than three years (i.e., it uses a new technology or measure), it shall be demonstrated that the project activity faces barriers to its uptake. Such barriers shall be demonstrated in accordance with Step 3 (barrier analysis) of the latest version of the CDM *Tool for the demonstration and assessment of additionality.*

2) Option B: Financial Feasibility

The methodology shall demonstrate that the project activity is less financially or economically attractive than the alternatives to the project activity using the procedures for investment analysis set out in the CDM *Tool for the demonstration and assessment of additionality*. This requires that Steps 1, 2 and 4 of such tool are followed. The analysis shall be conducted for the class of project activities to which the methodology is applicable, and the following also applies:

a) Sub-step 1a. *Other realistic and credible alternative scenarios* shall be taken to mean the full range of alternatives to the class of project activity that are found and are operational in the applicable geographic scope.

b) Sub-step 1b. Where the methodology is applicable to more than one country, the mandatory applicable legal and regulatory requirements of all countries shall be examined.

c) Sub-step 2b and Sub-step 2c. The following applies:

   i) The full range of circumstances which can influence the project activity shall be considered, and either average circumstances or the circumstances that lead to the most cost effective outcome shall be assumed (e.g., if the observed wind resource in the geographic scope of the methodology leads to plant load factors for wind turbines of between 25 and 30 percent, an average of these figures can be used, or 30 percent may be assumed).

   ii) Likewise, the full range of cost and/or revenue estimates for the project activity shall be considered, and either average estimates or the estimates that lead to the most cost effective outcome shall be assumed.

   iii) The full range of circumstances related to the baseline alternatives shall be considered, and either average circumstances or the circumstances that lead to the most cost effective outcome shall be assumed. Only observed or realistic circumstances shall be included (e.g., in a country where cement plants are all located close to harbors or large rivers with a view to easy access to transport, it would not be realistic to assume cement plants would be located in remote areas without easy access to transport).

   iv) Likewise, the full range of cost and/or revenue estimates for the baseline alternatives shall be considered, and either average estimates or estimates pertaining to the most likely baseline alternative shall be assumed. Where estimates pertaining to the most likely baseline alternative are used, it shall be substantiated that such baseline alternative is the most likely among the alternatives.

d) Sub-step 2b, Option III. Company internal benchmarks may not be used.

e) Sub-step 2d. Where average circumstances or estimates have been used in Sub-step 2b and/or Sub-step 2c (i.e., calculations have been based upon a range of circumstances or estimates, see above), a sensitivity analysis shall be undertaken. The objective of the sensitivity analysis is to test whether the conclusion regarding the financial/economic attractiveness of the class of project activity is robust to reasonable variations in the critical assumptions, and where it does not demonstrate conclusively that the (entire class of) project activity is additional, the project activity shall not qualify for the positive list under this Option B. Where the most cost effective, and therefore most conservative, circumstances or estimates have been used, a sensitivity analysis is not required.

f) Step 2 (General). Where there are multiple circumstances and estimates that must be aggregated in order to calculate output figures, the method of aggregation shall account for the correlations between each circumstance and estimate.

g) Step 4 (Common practice analysis). It shall be demonstrated that the project activity is not common practice using the full procedures for common practice analysis set out in the CDM *Tool for the demonstration and assessment of additionality*.

3) Option C: Revenue Streams

The methodology shall demonstrate that the project activity does not have any significant sources of revenue other than revenue from the sale of GHG credits, as follows:

a) The project activity's gross annual revenue (including cost savings) excluding from the sale of GHG credits shall not exceed five percent of capital expenditure (see the VCS Program document *Program Definitions* for definition of capital expenditure). All capital expenditures incurred during the project crediting period shall be accounted for and where the project activity involves capital expenditure subsequent to year zero, an appropriate discount rate shall be applied.

b) It shall be demonstrated that the project activity is not common practice using the full procedures for common practice analysis set out in the CDM *Tool for the demonstration and assessment of additionality*.

3.6 Baseline and Project Emissions/Removals

Concept

Baseline emissions, and project emissions and/or removals, must be accurately quantified in order to determine net emission reductions and removals achieved by projects. Methodologies shall therefore set out procedures to quantify these emissions and/or removals.

Requirements

General

3.6.1 Methodologies shall establish criteria and procedures for quantifying GHG emissions and/or removals, and/or carbon stocks, for all selected GHG sources, sinks and/or reservoirs identified in the project boundary.

AFOLU Methodologies

3.6.2 *The IPCC 2006 Guidelines for National GHG Inventories* or the *IPCC 2003 Good Practice Guidance for Land Use, Land-Use Change and Forestry* shall be used as guidance for quantifying increases or decreases in carbon stocks and GHG emissions. The IPCC Guidelines shall also be followed in terms of quality assurance/quality control (QA/QC) and uncertainty analysis.

3.6.3 The *IPCC 2006 Guidelines for National GHG Inventories* may be referenced to establish procedures for quantifying GHG emissions/removals associated with the following carbon pools including:

1) Litter;
2) Dead wood;
3) Soil (methodologies may follow the IPCC guidelines for the inclusion of soil carbon, including the guidelines that are in sections not related to forest lands); and
4) Belowground biomass (estimated using species-dependent root-to-shoot ratios, the Mokany et al.[4] ratios and equations, or the Cairns equations).

3.6.4 Where carbon would have been lost in the baseline scenario due to land use conversion or disturbance, GHG emissions from soil carbon, belowground biomass, wood products and dead wood carbon pools generally occur over a period of time following the event. It shall not be assumed that all GHG emissions from these carbon pools in the project categories specified below occur instantaneously or within a short period of time.

Methodologies shall set out criteria and procedures to reliably establish the pattern of carbon loss over time using empirical evidence, such as studies that use primary data or locally calibrated models, or methodologies shall apply an appropriate decay model (such as a linear or exponential decay function) that is scientifically sound, based on empirical evidence and not likely to overestimate early carbon losses.

Where appropriate, belowground biomass, soil carbon and dead wood decay models shall be calibrated. Where models are calibrated using measurement plots or data from research plots, sound and reliable measurement methods shall be applied as set out in Section 3.9.5.

Where the following carbon pools are included in the project boundary, methodologies may opt to comply with the requirement to establish a pattern of carbon loss over time by incorporating the respective procedures below:

1) Belowground biomass pool for IFM LtPF and REDD. The pattern of carbon loss shall be modeled based upon a 10-year linear decay function.

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[4] Mokany, K., Raison, R. J., and Prokushkin, A. S. 2006. *Critical analysis of root:shoot ratios in terrestrial biomes*. Global Change Biology 12: 84-96

2) Dead wood pool in IFM and REDD. The pattern of carbon loss shall be modeled using a 10-year linear decay function.

3) Soil carbon pool in all AFOLU project categories. The pattern of carbon loss shall be modeled based upon a 20-year linear decay function, taking into account the depth of affected soil layers and the total portion of the pool that would have been lost.

4) Wood products pool in IFM and REDD. The pattern of carbon loss shall be modeled as follows:

   a) For short-term wood products and wood waste that would decay within 3 years, all carbon shall be assumed to be lost immediately.

   b) For medium-term wood products that are retired between 3 and 100 years, a 20-year linear decay function shall be applied.

   c) For long-term wood products that are considered permanent (i.e., carbon is stored for 100 years or more), it may be assumed no carbon is released.

Note – Where applying the wood products procedure set out above, it is not required to separately account for the portion of wood products in landfills and the decay rate for such products, due to the current lack of established, reliable data and methods. Such products shall apply the rates for short-, medium-, or long-term wood products, as appropriate.

3.6.5 Where activity-based methods are used for determining baseline soil carbon stocks, estimates shall be conservatively determined relative to the computed maximum carbon stocks that occurred in the designated project area within the previous 10 years. For example, if carbon stocks in the project area were 100 tonnes C/ha in 2002 and declined to 90 tonnes C/ha by 2007 after intensive tillage, the minimum baseline carbon stock for a project established in 2008 would be 100 tonnes C/ha.

Afforestation, Reforestation and Revegetation (ARR)

3.6.6 Where ARR or IFM projects include harvesting, the loss of carbon due to harvesting shall be included in the quantification of project emissions. The maximum number of GHG credits available to projects shall not exceed the long-term average GHG benefit. The GHG benefit of a project is the difference between the project scenario and the baseline scenario of carbon stocks stored in the selected carbon pools and adjusted for any project emissions of N_2O, CH_4 and fossil-derived CO_2, and leakage emissions. The long-term average GHG benefit shall be calculated using the following procedure:

1) Establish the period over which the long-term average GHG benefit shall be calculated, noting the following:

   a) For ARR or IFM projects undertaking even-aged management, the time period over which the long-term GHG benefit is calculated shall include at minimum one full harvest/cutting cycle, including the last harvest/cut in the cycle. For example, where a project crediting period is 40 years and has a harvest cycle of 12 years, the long-term average GHG benefit will be determined for a period of 48 years.

b) For ARR projects under conservation easements with no intention to harvest after the project crediting period, or for selectively-cut IFM projects, the time period over which the long-term average is calculated shall be the length of the project crediting period.

2) Determine the expected total GHG benefit of the project for each year of the established time period. For each year, the total GHG benefit is the to-date GHG emission reductions or removals from the project scenario minus baseline scenario.

3) Sum the total GHG benefit of each year over the established time period.

4) Calculate the average GHG benefit of the project over the established time period.

5) Use the following equation to calculate the long-term average GHG benefit:

$$LA = \frac{\sum_{t=0}^{n} PE_t - BE_t}{n}$$

Where:

LA	=	The long-term average GHG benefit
PE_t	=	The total to-date GHG emission reductions and removals generated in the project scenario (tCO_2e). Project scenario emission reductions and removals shall also consider project emissions of CO_2, N_2O, CH_4 and leakage.
BE_t	=	The total to-date GHG emission reductions and removals projected for the baseline scenario (tCO_2e)
t	=	Year
n	=	Total number of years in the established time period

6) A project may claim GHG credits during each verification event until the long-term average GHG benefit is reached. Once the total number of GHG credits issued has reached this average, the project can no longer issue further GHG credits. The long-term average GHG benefit shall be calculated at each verification event, meaning the long-term average GHG benefit may change over time based on monitored data. For an example of determining the long-term average GHG benefit, see the Verra website.

Buffer credits are withheld only when GHG credits are issued. As set out in Section 3.8.5, the number of buffer credits to withhold is based on the change in carbon stocks only (not the net GHG benefit), as such the buffer credits will be based on the long-term average change in carbon stock. Use the following equation to calculate the long-term average change in carbon stock.

$$LC = \frac{\sum_{t=0}^{n} PC_t - BC_t}{n}$$

Where:

LC = The long-term average change in carbon stock

PC_t = The total to-date carbon stock in the project scenario (tCO_2e)

BC_t = The total to-date carbon stock projected for the baseline scenario (tCO_2e)

t = Year

n = Total number of years in the established time period

Note – VCS guidance document AFOLU Guidance: Example for Calculating the Long-Term Average Carbon Stock for ARR Projects with Harvesting*, available on the Verra website, provides examples for calculating the long-term average carbon stock for a variety of ARR project scenarios with harvesting. The same examples can be applied to IFM projects with harvesting.*

Agricultural Land Management (ALM)

3.6.7 Methodologies that target soil carbon stock increases shall quantify, where significant, concomitant increases in N_2O, CH_4 and fossil-derived CO_2. Similarly, methodologies targeting N_2O emission reductions shall establish the criteria and procedures by which the changes in soil carbon stocks may be deemed *de minimis* (as set out in Section 3.3.6) or conservatively excluded (as set out in Section 3.3.7).

3.6.8 Procedures to quantify GHG emissions/removals from cropland and grassland soil management projects may include activity-based model estimates, direct measurement approaches, or a combination of both.

3.6.9 Procedures to measure soil carbon stocks shall be based on established and reliable sampling methods, with sufficient sampling density to determine statistically significant changes at a 95 percent confidence level. Uncertainty related to sampling shall be addressed as set out in Section 2.4, above.

3.6.10 Procedures to estimate soil carbon stock shall use soil carbon stock change factors that are based on measurements of soil carbon stocks to the full depth of affected soil layers (usually 30 cm), accounting for differences in bulk density as well as organic carbon concentrations.

3.6.11 Procedures to quantify N_2O and CH_4 emissions factors shall be based on scientifically defensible measurements of sufficient frequency and duration to determine emissions for a full annual cycle. Minimum baseline estimates for N_2O and CH_4 emissions shall be based on documented management records averaged over the five-year period prior to the project start date. Documented management records may include fertilizer purchase records, manure production estimates and/or livestock data. For new management entities or where such records are unavailable, minimum baseline estimates may be based on a conservative estimate of common practice in the region.

Improved Forest Management (IFM)

3.6.12 Procedures for quantifying GHG emissions/removals in selected carbon pools may reference the *IPCC 2006 Guidelines for National GHG Inventories* section on forests remaining as forests.

3.6.13 Procedures for quantifying GHG emissions/removals in wood products may reference Skog et al. 2004[5] or other sources published in scientific peer-reviewed literature.

3.6.14 Where biomass is burned as part of the slash removal after harvesting, or nitrogen fertilizer is used, methodologies may reference *IPCC 2006 Guidelines for National GHG Inventories* for the quantification of such GHG emissions.

3.6.15 Where IFM projects include harvesting, the loss of carbon due to harvesting shall be included in the quantification of project emissions. The maximum number of GHG credits available to projects shall not exceed the long-term average GHG benefit, as set out in Section 3.6.6.

Reduced Emissions from Deforestation and Degradation (REDD)

3.6.16 Procedures for quantifying GHG emissions/removals in all selected carbon pools may reference *IPCC 2006 Guidelines for National GHG Inventories* sections on conversion of forest to non-forest (for deforestation) and forests remaining as forest (for degradation).

3.6.17 Procedures for quantifying GHG emissions/removals in long-lived wood products (e.g., wood products lasting longer than five years) may reference published scientific peer-reviewed literature (such as Skog et al. 2004).

3.6.18 Where harvesting is allowed in the project scenario (e.g., the project activity reduces deforestation but selective harvesting is allowed), the methodology shall include criteria and procedures to quantify GHG emissions/removals from such harvesting. The methodology shall also include criteria and procedures by which the change in carbon stocks from such harvesting may be deemed *de minimis* (as set out in Section 3.3.6) or conservatively excluded (as set out in Section 3.3.7).

Avoided Conversion of Grasslands and Shrublands (ACoGS)

3.6.19 Procedures for quantifying N_2O emissions from the use of synthetic fertilizers may reference the CDM A/R methodological tool for the *Estimation of direct and indirect (e.g., leaching and runoff) nitrous oxide emission from nitrogen fertilization*.

3.6.20 Procedures for quantifying GHG emissions/removals in all selected carbon pools may reference *IPCC 2006 Guidelines for National GHG Inventories*. Baseline scenarios may include annual estimates of changes in each carbon pool over the entire project period. Differences in shorter and longer term effects may be accounted for by distinguishing phases of effects. For example, effects of conversion on biomass may occur entirely in year one, whereas effects on soil carbon shall take into account the timing of such effects that may occur over many years, as set out in

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[5] Skog, K.E., K. Pingoud, J. E. Smith. 2004. A method countries can use to estimate changes in carbon stored in harvested wood products and the uncertainty of such estimates. Environmental Management 33 (suppl 1): S65-S73

Section 3.6.4.

3.6.21 Under the default assumption that management does not change in the project scenario and carbon pools are at steady state, the project scenario shall ensure the maintenance (or increase) of existing carbon pools. Where methodologies include criteria and procedures to account for increases in carbon pools on lands where conversion is avoided, evidence shall be provided that such increases may occur. Where changes in management are the basis for increases in carbon pools, ALM accounting rules shall be followed. Where revegetation or restoration is the basis for increases in carbon pools under the project scenario, projects shall follow ARR or ALM requirements for quantifying GHG emissions/removals, depending on whether the project activities involve woody biomass.

3.6.22 GHG emissions associated with conversion and post-conversion land management practices that are avoided shall be estimated based on expected land management practices. Baseline estimates for N_2O and CH_4 emissions shall be based on documented management practices used on lands similar to the project area, or that represent average local or regional land management practices. Preference shall be given to data that are more specific to the project area (e.g., site specific data, where available, are preferable to state or province level data). Documentation of land management practices may include, for example, fertilizer purchase or application records, manure production estimates and/or livestock data.

3.6.23 Quantifying GHG emissions and/or removals from avoided conversion requires estimates of changes in carbon pools that would have occurred if the land protected by the project had been converted. Although the direct measurement of carbon pools on protected lands can provide an estimate of initial carbon stocks for the baseline scenario, subsequent years under the baseline scenario require estimates of the effects of conversion that are extrapolated from lands similar to the project area but which have already undergone conversion. Estimates of expected changes in carbon stocks following conversion may be based on activity-based model estimates, direct measurement (including direct measurements reported in the scientific literature), or a combination of both.

3.6.24 Direct measurements needed for estimating the baseline shall be taken on lands similar to the project area that have already undergone conversion to the same land use as the one(s) being avoided in the project area, rather than direct measurements on the project area itself. Similar lands refers to lands with similar vegetation, climate, topography and soils, and therefore with similar expected responses to conversion. Such extrapolation from similar lands necessarily introduces uncertainty, which shall be accounted for by using methods that allow for calculating a confidence interval as set out in Section 2.4.1 above. Uncertainty from baseline modeling shall be combined with other sources of uncertainty using valid statistical approaches (e.g., as set out in Chapter 5.2 of the *IPCC Good Practice Guidance for LULUCF*).

3.6.25 Estimation of carbon stock change and/or soil emission factors shall be based on data from replicated field experiments whose management treatments have a duration of at least five years (preferably longer), for climate and soil conditions and management activities representative of the project conditions, using established, reliable measurement methods. Stock change factors for soil carbon or woody biomass carbon that are based on experiments shall not be projected over a longer period than the length of the study. Complex, dynamic models that have been validated for conditions representative of the project area are also acceptable. Models shall be parameterized to reflect the range of soil, climate, land use and management conditions in the project area.

Wetland Restoration and Conservation (WRC)

3.6.26 The following applies with respect to the criteria and procedures for quantifying GHG emissions/removals in the baseline scenario:

1) For WRC activities on peatland the peat depletion time (PDT) shall be included in the quantification of GHG emissions and removals in the baseline scenario, and for non-peat wetlands, the soil organic carbon depletion time (SDT) shall be included in the quantification of GHG emissions and removals in the baseline scenario, noting the following:

    a) PDT is the time it would have taken for the peat to be completely lost due to oxidation or other losses, or for the peat depth to reach a level where no further oxidation or other losses occur. No GHG emission reductions may be claimed for a given area of peatland for longer than the PDT. The procedure for determining the PDT shall conservatively consider peat depth and oxidation rate within the project boundary and may be estimated based on the relationship between water table depth, subsidence (e.g., using peat loss and water table depth relationships established in scientific literature), and peat depth in the project area. The PDT is considered part of the baseline and thus shall be reassessed with the baseline in accordance with the requirements set out in the VCS Program document *VCS Standard.*

    b) SDT is the time it would have taken for the soil organic carbon to be lost due to oxidation or to reach a steady stock where no further losses occur. No GHG emissions reductions may be claimed for a given area of wetland for longer than the SDT. The procedure for determining the SDT shall conservatively consider soil organic carbon content and oxidation rate within the project boundary and may be estimated based on the relationship between water table depth and soil organic carbon content in the project area. Where wetland soils are subject to sedimentation or erosion, the procedure for determining the SDT shall conservatively account for the associated gain or loss of soil organic carbon. This assessment is not mandatory in cases where soil organic carbon content on average may be deemed *de minimis* as set out in Section 3.3.6.

2) Any applicable and justifiable proxies, as established in scientific literature, for GHG emissions projected throughout the project crediting period shall be estimated.

3) Net baseline GHG emissions during the project crediting period, including emissions associated with the estimated water table depths, salinity or another justifiable proxy for GHG emissions, plus emissions from other activities such as biomass loss or fires, as well as carbon sequestration, where applicable, shall be estimated.

3.6.27 Baseline emissions shall be estimated conservatively and consider that the water table depth in the project area may rise during the project crediting period due to any or all of the causes identified in alternative baseline scenarios as set out in Section 3.4.18.

3.6.28 The procedure for quantifying CO_2 emissions for the baseline and project emissions may be estimated through hydrological modeling or the modeling of proxies for GHG emissions in place of direct on-site gas flux measurements. The procedure may include estimation through well-documented relationships between CO_2 emissions and other variables such as vegetation types, water table depth, salinity or subsidence, or remote sensing techniques that adequately assess and monitor soil moisture. Because of the dominant relationship between water table depth and CO_2 emissions, drainage depth can be used as a proxy for CO_2 emissions in the absence of emissions data.[6] Where relevant, the micro-topography of the project area (e.g., the proportion of hummocks and hollows and vegetation patterns in peatlands) shall be considered. Net GHG emissions reductions shall be calculated using the same methods that are used for the baseline estimates, but using monitored data.

3.6.29 Where relevant, the fate of transported organic matter as a result of sedimentation, erosion and oxidation shall be assessed conservatively based on peer-reviewed literature and considering the following:

1) It is conservative to not account for the loss of sediment from the project area in the baseline scenario.

2) It is conservative to not account for further sedimentation in the project area in the project scenario. Where soil carbon is included in the project boundary, sedimentation shall be accounted for so that carbon sequestration resulting from the growth of vegetation can be estimated separately from carbon accumulated in sedimentation. In the absence of the project activity, such high carbon silt would be washed out to sea and would not have been oxidized and emitted in the baseline, and in such cases carbon accumulated in sedimentation is not eligible for crediting.

3.6.30 With respect to the soil carbon pool, the maximum quantity of GHG emission reductions that may be claimed by the project shall not exceed the net GHG benefit generated by the project 100 years after its start date. This limit is established because in wetlands remaining partially

[6] Couwenberg, J, Dommain, R, Joosten, H. 2010. Greenhouse gas fluxes from tropical peatlands in south-east Asia. Global Change Biology 16: 1715-1732.

drained or not fully rewetted, or where drainage continues, the soil carbon will continue to erode and/or oxidize leading to GHG emissions and eventually depletion of the soil carbon. To determine this long-term net GHG benefit, methodologies shall establish criteria and procedures to estimate the remaining soil carbon stock adjusted for any project emissions and leakage emissions in both the baseline and project scenarios for 100 years, taking into account uncertainties in modeling and using verifiable assumptions. Projects unable to establish and demonstrate a significant difference in the net GHG benefit between the baseline and project for at least 100 years are not eligible.

3.6.31 Emissions of CH_4 from drained or saline wetlands may be excluded in the baseline scenario where it may be deemed *de minimis* (as set out in Section 3.3.6) or conservatively excluded (as set out in Section 3.3.7).

3.6.32 As WRC activities are likely to influence CH_4 emissions, methodologies shall establish procedures to estimate such emissions, and shall establish the criteria and procedures by which the source may be deemed *de minimis* (as set out in Section 3.3.6) or conservatively excluded (as set out in Section 3.3.7). Where relevant, the micro-topography of the project area (i.e., the proportion of hummocks and hollows and vegetation patterns) shall be considered.

3.6.33 Methodologies that combine project categories shall use the relevant WRC requirements and the respective AFOLU project category requirements for quantifying GHG emissions/removals, unless the former may be deemed *de minimis* (as set out in Section 3.3.6) or conservatively excluded (as set out in Section 3.3.7).

3.6.34 RWE projects on peatland that include an activity designed specifically to reduce incidence and severity of fires shall deduct the amount of peat assumed to burn when estimating peat depletion times. Where peat depletion times are estimated based only on oxidation rates due to drainage, the outcome would be a longer period than when first subtracting the amount of peat that is considered to burn in the baseline.

3.6.35 Methodologies for RWE projects on peatland explicitly addressing anthropogenic peatland fires occurring in drained peatlands shall establish procedures for determining or conservatively estimating the baseline emissions from peatland fire occurring in the project area using defensible data (such as fire maps, historical databases on fires, and where appropriate, combined with temperature and precipitation data). Methods for estimating GHG emissions from fire may be based on the *IPCC 2006 Guidelines for National GHG Inventories*, or other methods based on scientific, peer-reviewed literature.

3.6.36 Where relevant, methodologies shall establish procedures to account for any changes in carbon sequestration or GHG emission reductions resulting from lateral movement of wetlands due to sea level rise, or coastal squeeze associated with any structures that prevent wetland landward migration and cause soil erosion.

3.7 Leakage

Concept

Leakage is the net change of anthropogenic GHG emissions that occurs outside the project boundary and is attributable to project activities. Methodologies shall establish procedures to quantify leakage, where the potential for leakage is identified, as projects may otherwise overestimate their net emission reductions and/or removals.

Requirements

General

3.7.1 The methodology shall establish criteria and procedures for quantifying leakage.

AFOLU Methodologies

3.7.2 The methodology shall establish procedures to quantify all significant sources of leakage. Leakage is defined as any increase in GHG emissions that occurs outside the project boundary (but within the same country), and is measurable and attributable to the project activities. All leakage shall be accounted for, in accordance with this Section 3.7. The three types of leakage are:

1) Market leakage occurs when projects significantly reduce the production of a commodity causing a change in the supply and market demand equilibrium that results in a shift of production elsewhere to make up for the lost supply.

2) Activity-shifting leakage occurs when the actual agent of deforestation and/or forest or wetland degradation moves to an area outside of the project boundary and continues its deforestation or degradation activities elsewhere.

3) Ecological leakage occurs in WRC projects where a project activity causes changes in GHG emissions or fluxes of GHG emissions from ecosystems that are hydrologically connected to the project area.

3.7.3 Leakage that is determined, in accordance with Section 3.3.6, to be below *de minimis* (i.e., insignificant) does not need to be included in the GHG emissions accounting. The significance of leakage may also be determined using the CDM A/R methodological tool *Tool for testing significance of GHG Emissions in A/R CDM Project Activities*.

3.7.4 GHG emissions from leakage may be determined either directly from monitoring, or indirectly when leakage is difficult to monitor directly but where scientific knowledge provides credible estimates of likely impacts. The GHG credit calculation table provided below in Section 3.8 includes an example of indirect leakage accounting.

3.7.5 The methodology shall require projects to account for market leakage where the production of a commodity (e.g., timber, aquacultural products or agricultural products) is significantly affected by the project. The significance of timber production is determined as set out in

Section 3.3.6 above or as set out in Section 3.7.15 below.

3.7.6 Leakage occurring outside the host country (international leakage) does not need to be quantified.

3.7.7 Where leakage mitigation measures include tree planting, aquacultural intensification, agricultural intensification, fertilization, fodder production, other measures to enhance cropland and/or grazing land areas, leakage management zones or a combination of these, then any significant increase in GHG emissions associated with these activities shall be accounted for, unless deemed *de minimis* (as set out in Section 3.3.6) or can be conservatively excluded (as set out in Section 3.3.7).

3.7.8 Methodologies shall not allow for projects to account for positive leakage (i.e., where GHG emissions decrease or removals increase outside the project area due to project activities).

Afforestation/Reforestation/Revegetation (ARR)

3.7.9 Activity-shifting leakage in ARR projects can result from, inter alia, the shifting of grazing animals, shifting of households or communities, shifting of aquacultural or agricultural activities or shifting of fuelwood collection (from non-tree sources). Leakage emissions may also result from transportation and machinery use. The requirements for assessing and managing leakage in ARR projects are similar to those for CDM afforestation/reforestation project activities, and methodologies may require or allow projects to apply CDM tools for estimating leakage, such as the *Tool for calculation of GHG emissions due to leakage from increased use of non-renewable woody biomass attributable to an A/R CDM project activity*.

3.7.10 Where deforestation increases outside the project area due to leakage from project activities, methodologies shall set out criteria and procedures for projects to assess and quantify the effects of this deforestation on all carbon pools, unless determined to be *de minimis* (as set out in Section 3.3.6) or conservatively excluded (as set out in Section 3.3.7).

Agricultural Land Management (ALM)

3.7.11 ALM projects setting aside land for conservation shall quantify activity-shifting leakage emissions associated with the displacement of pre-project activities, unless deemed *de minimis* (as set out in Section 3.3.6) or conservatively excluded (as set out in Section 3.3.7). Guidance on accounting for leakage associated with shifting of pre-project activities due to land conversions from agriculture to grassland is functionally similar to conversion of land to forest vegetation under ARR (see Section 3.3.6 and 3.3.7).

3.7.12 Market leakage in ALM projects involving cropland or grassland management activities is likely to be negligible because the land in the project scenario remains maintained for commodity production, and therefore does not need to be included in the GHG emissions accounting, unless determined to be above *de minimis* in accordance with Section 3.3.6.

3.7.13 Where livestock are displaced to outside the project area, methodologies shall set out criteria and procedures for projects to quantify such activity-shifting leakage to capture potential reductions in carbon stocks and potential increases in livestock-derived CH_4 and N_2O emissions from outside the project area.

Improved Forest Management (IFM)

3.7.14 Leakage in IFM projects can result from activities shifting within the project proponent's operations. Methodologies shall set out criteria and procedures for projects to demonstrate that there is no leakage to areas that are outside the project area but within the project proponent's operations, such as areas where the project proponent has ownership of, management of, or legally sanctioned rights to use forest land within the country. Methodologies shall set out criteria and procedures for projects to demonstrate that the management plans and/or land-use designations of all other lands operated by the project proponent (which shall be identified by location) have not materially changed as a result of the project activity (e.g., harvest rates have not been increased or land has not been cleared that would otherwise have been set aside). Where the project proponent is an entity with a conservation mission, it may be demonstrated that there have been no material changes to other lands managed or owned by the project proponent by providing documented evidence that it is against the policy of the organization to change the land use of other owned and/or managed lands including evidence that such policy has historically been followed.

3.7.15 Leakage in IFM projects is predominantly attributable to market leakage (market effects). Methodologies shall set out criteria and procedures to quantify market leakage by either of the following:

1) Applying the appropriate market leakage discount factor identified in Table 2 to the net change in carbon stock associated with the activity that reduces timber harvest.

2) Directly accounting for market leakage associated with the project activity. Where directly accounting for leakage, market leakage shall be accounted for at the country-scale applied to the same general forest type as the project (i.e., forests containing the same or substitutable commercial species as the forest in the project area) and shall be based on methods for quantifying leakage from scientific peer-reviewed journal sources.[7]

[7] The following three papers may be helpful in assessing market leakage:

- Murray, B.C., B.A. McCarl, and H. Lee. 2004. Estimating Leakage from Forest Carbon Sequestration Programs. Land Economics 80(1):109-124. (http://ideas.repec.org/p/uwo/uwowop/20043.html)
- Murray, B.C., B.L. Sohngen, et al. 2005. EPA-R-05-006. Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture. Washington, D.C: U.S. Environmental Protection Agency, Office of Atmospheric Programs. (www.epa.gov/sequestration/pdf/greenhousegas2005.pdf)
- Sohngen, B. and S. Brown. 2004. Measuring Leakage from Carbon Projects in Open Economies: A Stop Timber Harvesting Project as a Case Study, Canadian Journal of Forest Research. 34: 829-839 (http://www.winrock.org/ecosystems/files/Sohngen_Brown_2004.pdf)

Table 2: Market Leakage Discount Factors

Project Action	Leakage Risk	Market Leakage Discount Factor
IFM activity with no effect or minimal effect on total timber harvest volumes (e.g., RIL with less than 25% reduction)	None	0%
IFM activity that leads to a shift in harvests across time periods but minimal change in total timber harvest over time (e.g., ERA with rotation extension of 5-10 years)	Low	10%
IFM activity that substantially reduces harvest levels permanently (e.g., RIL activity that reduces timber harvest across the project area, or project that halts logging by at least 25%)	Moderate to High	Conditional upon where timber harvest is likely to be shifted, as follows: • Where the ratio of merchantable biomass to total biomass is higher within the area to which harvesting is displaced compared to the project area, 20% • Where the ratio of merchantable biomass to total biomass is similar within the area to which harvesting is displaced compared to the project area, 40% • Where the ratio of merchantable biomass to total biomass is lower within the area to which harvesting is displaced compared to the project area, 70% • Where the leakage is out of country, 0%

Reduced Emissions from Deforestation and Degradation (REDD)

3.7.16 Methodologies shall set out criteria and procedures to assess and manage leakage for the two eligible REDD project types as follows:

1) APD: Leakage shall be quantified by directly monitoring the activities of the deforestation agent identified in the baseline scenario. The deforestation agent can be an entity that has ownership of, management of, or legally sanctioned rights to use, multiple parcels of forest land within the country or can be the most-likely-class of deforestation agent. Such forest land could be used to make up for the generation of goods and/or services lost through implementation of the REDD project, therefore leading to reductions in carbon stocks or increases in GHG emissions outside the project boundary. Leakage shall be accounted for

as follows:

a) Where the specific deforestation agent can be identified, leakage need not be considered where it can be demonstrated that the management plans and/or land-use designations of the deforestation agent's other lands (which shall be identified by location) have not materially changed as a result of the project (e.g., the deforestation agent has not designated new lands as timber concessions, increased harvest rates in lands already managed for timber, cleared intact forests for agricultural production or increased fertilizer use to enhance agricultural yields). Where management plans and/or land-use designations of the deforestation agent's other lands have materially changed, leakage shall be quantified by directly monitoring the activities of the deforestation agent.

b) Where the specific deforestation agent cannot be identified, leakage shall be quantified based upon the difference between historic and with-project rates of deforestation by the identified most-likely-class of deforestation agent within the region. Alternatively, where such agents are driven by the demand for market commodities, the project may directly account for market leakage associated with the specific project activity. Where directly accounting for leakage, market leakage shall be accounted for at the country-scale, taking into account the supply and demand elasticities for the commodity affected, and shall be based on methods for quantifying leakage from scientific peer-reviewed journal sources, as described above in Section 3.7.15.

2) AUDD: The potential for leakage shall be identified and the project shall address (and describe in the project description) the socio-economic factors that drive deforestation and/or degradation. Leakage shall be calculated by monitoring forested areas surrounding the project and other forested areas within the country susceptible to leakage from project activities.

3.7.17 Where the project baseline includes illegal logging activities that supply regional, national and/or global timber markets, domestic market leakage shall be quantified using the market leakage discount factors for IFM projects set out in Sections 3.7.14 and 3.7.15. The market leakage effects associated with stopping illegal logging need not be considered where GHG emissions are not included in the baseline and GHG credits from stopping such activities are not claimed.

Avoided Conversion of Grasslands and Shrublands (ACoGS)

3.7.18 Leakage in ACoGS projects can result from activities shifting within the project proponent's operations. It shall be demonstrated that there is no leakage to areas that are outside the project area but within the project proponent's operations, such as areas where the project proponent has ownership of, management of, or legally sanctioned rights to use land within the country. It shall be demonstrated that the management plans and/or land-use designations of all other lands operated by the project proponent (which shall be identified by location) have not materially changed as a result of the project activity (e.g., land has not been cleared that would otherwise have been set aside).

Where the project proponent is an entity with a conservation mission, it may be demonstrated that there have been no material changes to other lands managed or owned by the project proponent by providing documented evidence that it is against the policy of the organization to change the land use of other owned and/or managed lands including evidence that such policy has historically been followed.

3.7.19 Methodologies shall set out criteria and procedures to assess and manage leakage for the two eligible ACoGS project types as follows:

1) APC: Leakage shall be quantified by directly monitoring the activities of the conversion agent identified in the baseline scenario. The conversion agent can be an entity that has ownership of, management of, or legally sanctioned rights to use, multiple parcels of land within the country or can be the most-likely-class of conversion agent. Such land could be used to make up for the generation of goods and/or services lost through implementation of the ACoGS project, therefore leading to reductions in carbon stocks or increases in GHG emissions outside the project boundary. Leakage shall be accounted for as follows:

    a) Where the specific conversion agent can be identified, leakage need not be considered where it can be demonstrated that the management plans and/or land-use designations of the conversion agent's other lands (which shall be identified by location) have not materially changed as a result of the project (e.g., land has not been cleared that would otherwise have been set aside). Where management plans and/or land-use designations of the conversion agent's other lands have materially changed, leakage shall be quantified by directly monitoring the activities of the conversion agent.

    b) Where the specific conversion agent cannot be identified, leakage shall be quantified based upon the difference between historic and with-project rates of conversion by the identified most-likely-class of conversion agent within the region. Alternatively, where such agents are driven by the demand for market commodities, the project may directly account for market leakage associated with the specific project activity. Where directly accounting for leakage, market leakage shall be accounted for at the country-scale, taking into account the supply and demand elasticities for the commodity affected, and shall be based on methods for quantifying leakage from scientific peer-reviewed journal sources, as described above in Section 3.7.15.

2) AUC: The potential for leakage shall be identified and the project shall address (and describe in the project description) the socio-economic factors that drive conversion. Leakage shall be calculated by monitoring areas surrounding the project and areas within the country susceptible to leakage from project activities.

Wetland Restoration and Conservation (WRC)

3.7.20 RWE projects involving rewetting of forested wetlands are likely to reduce the productivity of the forest or make harvesting more difficult, which could lead to fewer forest products and thus result in leakage (i.e., GHG emissions from logging and drainage elsewhere). Where the project results in activity shifting of forest products, the applicable requirements for leakage in IFM or REDD project activities shall be followed, accounting for both activity-shifting and/or market leakage. Where the project results in the shifting of drainage activities or other activities that would lower the water table, the expected GHG emissions from a lower water table shall also be accounted for. RWE projects on peatland shall assume that the PDT of leakage activities occurs over the length of the project crediting period if the PDT is longer than the project crediting period.

3.7.21 Rewetting in the project area may lead to higher water table depths in some areas beyond the project boundary, and consequently leading to lower water table depths in downstream areas further beyond the project boundary (e.g., in the case of project activities that reverse subsidence), or cause transportation of organic matter to areas beyond the project boundary. In such cases, the project proponent shall be required to demonstrate that such changes in water table depths or export caused by the project do not lead to increases in GHG emissions outside the project area, or the affected areas shall be identified and the resulting leakage shall be quantified and accounted for.

3.7.22 Methodologies shall set out criteria and procedures to assess and manage leakage for CIW, REDD+CIW and IFM+CIW projects as follows, noting that for combined category projects, the IFM or REDD leakage requirements also apply:

1) APWD: Activity-shifting leakage shall be quantified by directly monitoring the activities of the land conversion agent (e.g., deforestation agent or agent causing other forms of wetland degradation) identified in the baseline scenario. The land conversion agent can be an entity that has ownership of, management of, or legally sanctioned rights to use multiple parcels of wetland within the country, or can be the most-likely-class of land conversion agent. These other wetlands could be used to make up for the generation of goods and/or services lost through implementation of the WRC project, therefore leading to reductions in carbon stocks or increases in GHG emissions outside the project boundary. Leakage shall be accounted for as follows:

   a) Where the specific land conversion agent can be identified, leakage need not be considered where it can be demonstrated that the management plans and/or land-use designations of the land conversion agent's other lands (which shall be identified by location) have not materially changed as a result of the project (e.g., a deforestation agent has not designated new lands as timber concessions, increased harvest rates in lands already managed for timber, cleared intact forests for agricultural production or increased fertilizer use to enhance agricultural yields). Where management plans and/or land-use designations of the land conversion agent's other lands have materially changed, leakage shall be quantified by directly monitoring the activities of the land conversion agent.

b) Where the specific land conversion agent cannot be identified, leakage shall be quantified based upon the difference between historic and with-project rates of wetland degradation by the identified most-likely-class of land conversion agent within the region.

2) AUWD: The potential for leakage shall be identified and the project shall address the socio-economic factors that drive wetland degradation. Leakage shall be calculated by monitoring wetland areas surrounding the project and other wetland areas within the country susceptible to leakage from project activities.

3.7.23 Wetland restoration methodologies including fire reduction activities shall follow the requirements for accounting for fire under REDD, where land use changes are identified as the cause (or one of the causes) of anthropogenic fires in the project region.

ODS Methodologies

3.7.24 Methodologies shall establish criteria and procedures to quantify and account for GHG emissions associated with any substitute substances that can be assumed to be used to provide the service previously provided by the ODS destroyed by the project.

For example, where a project destroys ODS that under the baseline would have been recovered and reused, the project shall account for the GHG emissions associated with substitute substances, since the market demand that was being serviced by the ODS can be assumed to be supplied from alternative sources. Conversely, where a project destroys ODS that under the baseline would have leaked or been released to the atmosphere, the ODS was not meeting any market demand and accounting for GHG emissions associated with substitute substances is not applicable. Such quantification and accounting shall be done using one of the following options:

1) Identify the actual type and quantity of substitute substances used to provide the service previously provided by the ODS destroyed by the project, calculate or monitor the GHG emissions associated with such substances that arise during the project crediting period, and deduct such GHG emissions from the GHG emission reductions;

2) Identify the actual type and quantity of substitute substances used to provide the service previously provided by the ODS destroyed by the project, assume 100 percent of such substances leak or are released to the atmosphere during the project crediting period, and deduct such GHG emissions from the GHG emission reductions;

3) Identify, based on conservative assumptions using appropriate data, the type and quantity of substitute substances used to provide the service previously provided by the ODS destroyed by the project, assume 100 percent of such substances leak or are released to the atmosphere during the project crediting period, and deduct such GHG emissions from the GHG emission reductions claimed by the project; or

4) The project shall not claim GHG emission reductions for the ODS destroyed by the project that under the baseline would have been recovered and reused.

3.8 Quantification of GHG Emission Reductions and Removals

Concept

Net GHG emission reductions and removals achieved by projects are the basis for the volume of VCUs that can be issued. Methodologies shall establish criteria and procedures for quantifying net GHG emission reductions and removals.

Requirements

General

3.8.1 Methodologies shall establish criteria and procedures for quantifying GHG emissions and/or removals, and/or carbon stocks, for the selected GHG sources, sinks and/or reservoirs, separately for the project (including leakage) and baseline scenarios.

3.8.2 Methodologies shall establish criteria and procedures for quantifying net GHG emission reductions and removals generated by the project, which shall be quantified as the difference between the GHG emissions and/or removals, and/or as the difference between carbon stocks, from GHG sources, sinks and reservoirs relevant for the project and those relevant for the baseline scenario. The GHG emissions and/or removals in the project scenario shall be adjusted for emissions resulting from project activities and leakage. Where appropriate, net GHG emission reductions and removals, and net change in carbon stocks, shall be quantified separately for the project and the baseline scenarios for each relevant GHG and its corresponding GHG sources, sinks and/or reservoirs.

Standardized Methods

Performance Methods

3.8.3 In any given verification period, a methodology may result in the project's GHG emission reductions or removals being quantified as negative. This is permitted and the project shall be granted no credit in such periods.

AFOLU Methodologies

3.8.4 AFOLU methodologies shall establish procedures for quantifying the net change in carbon stocks, so that the number of buffer credits withheld in the AFOLU pooled buffer account and market leakage emissions may be quantified for the project.

3.8.5 AFOLU methodologies shall include procedures to determine the number of GHG credits issued to projects, which is determined by subtracting out the buffer credits from the net GHG emission reductions or removals (including leakage) associated with the project. The buffer credits are calculated by multiplying the non-permanence risk rating (as determined by the

AFOLU Non-Permanence Risk Tool) times the change in carbon stocks only. The full rules and procedures with respect to assignment of buffer credits are set out in the VCS Program document *Registration and Issuance Process*. This calculation process is illustrated in the example below.

3.8.6 To illustrate the calculation of buffer credits, the following example is provided:

At the first verification event, the example project in Table 3 below has generated a change in carbon stocks in the project scenario compared to the baseline scenario of 1000 tonnes. It also reduced GHG emissions by 60 tonnes by avoiding machinery use as compared to the baseline, resulting in a total change in GHG emissions from baseline to project scenario of 1060 tonnes. The project displaced some pre-project activities and resulted in leakage totalling 280 tonnes, including a reduction in carbon stocks outside the project boundary and associated emissions (note that carbon stock losses caused by leakage are considered permanent). Such leakage is subtracted from the change in GHG emissions of the project, resulting in 780 GHG emission reductions or removals (net GHG benefit). The project is assessed to have a 20 percent non-permanence risk rating, which is multiplied by the change in carbon stocks only (not the net GHG benefit). This results in a buffer withholding of 200 credits, with 580 GHG credits issued as VCUs.

Table 3: Example GHG credit calculation

Project Compared to Baseline	tCO_2e	Comment
Change in carbon stocks	1000	Reversal risk
Change in non-stock related GHG emissions (e.g., from decrease in machinery use)	60	No reversal risk
Total change in GHG emissions for project vs. baseline	1060	= 1000 + 60
Leakage		
Change in carbon stocks outside the project area (e.g., 20% market leakage, as determined in Table 2)	-200	= 1000 × 0.2 (considered permanent)
Change in GHG emissions	-80	No reversal risk
Total leakage	-280	= -200 - 80
Total GHG Credits Generated		
GHG emission reductions and removals generated (net GHG benefit)	780	= 1060 − 280

Buffer credits (determined as a percentage of net change carbon stocks*)	200	= 1000 × 20%
GHG credits issued (VCUs)	580	= 780 - 200

* Where the net change in carbon stocks is not a whole number, round the calculated VCU and buffer credit volumes down to the nearest whole number. Where the net change in carbon stocks is a whole number, round the calculated buffer volume up, and the VCU volume down, to the nearest whole number.

3.9 Monitoring

Concept

Methodologies shall describe the data and parameters available at validation (i.e., those that are fixed for the duration of the project crediting period) and data and parameters monitored (i.e., those that must be monitored during the project crediting period for each verification). Additionally, methodologies shall describe the criteria and procedures for obtaining, recording, compiling and analyzing monitored data and parameters.

Requirements

General

3.9.1 The methodology shall describe the data and parameters to be reported, including sources of data and units of measurement.

3.9.2 When highly uncertain data and information are relied upon, conservative values shall be selected that ensure that the quantification does not lead to an overestimation of net GHG emission reductions or removals.

3.9.3 Metric tonnes shall be used as the unit of measure and the quantity of each type of GHG shall be converted to tonnes of CO_2e consistent with the requirements set out in the VCS Program document *VCS Standard*.

3.9.4 The methodology shall establish criteria and procedures for monitoring, which shall cover the following:

1) Purpose of monitoring.
2) Monitoring procedures, including estimation, modeling, measurement or calculation approaches.
3) Procedures for managing data quality.
4) Monitoring frequency and measurement procedures.

AFOLU Methodologies

3.9.5 Where measurement plots or data from research plots are used to calibrate belowground biomass, soil carbon and dead wood decay models (as described above in Section 3.6.4), sound and reliable methods for monitoring changes in carbon stocks, including representative location of samplings sites and sufficient frequency and duration of sampling shall be applied. In addition, plots used to calibrate soil carbon models shall be measured considering appropriate sampling depths, bulk density and the estimated impact of any significant erosion (or plots with significant erosion shall be avoided). Data used to calibrate belowground biomass and dead wood models shall consider an estimation of oven-dry wood density and the state of decomposition.

ODS Methodologies

3.9.6 The methodology shall establish procedures for monitoring the chemical composition and quantity of the ODS destroyed by the project.

3.9.7 Where projects destroying ODS contained in products or mixed with other substances are eligible under the methodology, the methodology shall establish procedures for monitoring the mass of ODS contained in such products or other substances. This shall be achieved using a mass balance analysis and/or other approach (based on conservative assumptions), as appropriate to the nature and scale of the project.

APPENDIX 1 ELIGIBLE AFOLU PROJECT CATEGORIES

As set out in Section 2.6 above, there are currently six AFOLU project categories under the VCS Program, as further described below. Proposed AFOLU methodologies shall fall within one or more of these AFOLU project categories and shall meet with the criteria and requirements set out below.

Afforestation, Reforestation and Revegetation (ARR)

A1.1 Eligible ARR activities are those that increase carbon sequestration and/or reduce GHG emissions by establishing, increasing or restoring vegetative cover (forest or non-forest) through the planting, sowing or human-assisted natural regeneration of woody vegetation. Eligible ARR projects may include timber harvesting in their management plan. The project area shall not be cleared of native ecosystems within the 10-year period prior to the project start date, as set out in the VCS Program document *VCS Standard*.

Note – Activities that improve forest management practices, such as enrichment planting and liberation thinning, are categorized as IFM project activities.

Agricultural Land Management (ALM)

A1.2 Eligible ALM activities are those that reduce net GHG emissions on croplands and grasslands by increasing carbon stocks in soils and woody biomass and/or decreasing CO_2, N_2O and/or CH_4 emissions from soils. The project area shall not be cleared of native ecosystems within the 10-year period prior to the project start date. Eligible ALM activities include:

1) Improved Cropland Management (ICM): This category includes practices that demonstrably reduce net GHG emissions of cropland systems by increasing soil carbon stocks, reducing soil N_2O emissions, and/or reducing CH_4 emissions, noting the following:

    a) Soil carbon stocks can be increased by practices that increase residue inputs to soils and/or reduce soil carbon mineralization rates. Such practices include, but are not limited to, the adoption of no-till, elimination of bare fallows, use of cover crops, creation of field buffers (e.g., windbreaks or riparian buffers), use of improved vegetated fallows, conversion from annual to perennial crops and introduction of agroforestry practices on cropland. Where perennial woody species are introduced as part of cropland management (e.g., field buffers and agroforestry), carbon sequestration in perennial woody biomass may be included as part of the ALM project.

    b) Soil N_2O emissions can be reduced by improving nitrogen fertilizer management practices to reduce the amount of nitrogen added as fertilizer or manure to targeted crops. Examples of practices that improve efficiency while reducing total nitrogen additions include improved application timing (e.g., split application), improved formulations (e.g., slow release fertilizers or nitrification inhibitors) and improved placement of nitrogen.

c) Soil CH_4 emissions can be reduced through practices such as improved water management in flooded croplands (in particular flooded rice cultivation), through improved management of crop residues and organic amendments and through the use of rice cultivars with lower potential for CH_4 production and transport.

2) Improved Grassland Management (IGM): This category includes practices that demonstrably reduce net GHG emissions of grassland ecosystems by increasing soil carbon stocks, reducing N_2O emissions and/or reducing CH_4 emissions, noting the following:

a) Soil carbon stocks can be increased by practices that increase belowground inputs or decrease the rate of decomposition. Such practices include increasing forage productivity (e.g., through improved fertility and water management), introducing species with deeper roots and/or more root growth and reducing degradation from overgrazing.

b) Soil N_2O emissions can be reduced by improving nitrogen fertilizer management practices on grasslands as set out in Section A1.2(1)(b), above.

c) N_2O and CH_4 emissions associated with burning can be reduced by reducing the frequency and/or intensity of fire.

d) N_2O and CH_4 emissions associated with grazing animals can be reduced through practices such as improving livestock genetics, improving the feed quality (e.g., by introducing new forage species or by feed supplementation) and/or by reducing stocking rates.

3) Cropland and Grassland Land-use Conversions (CGLC): This category includes practices that convert cropland to grassland or grassland to cropland and reduce net GHG emissions by increasing carbon stocks, reducing N_2O emissions, and/or reducing CH_4 emissions, noting the following:

a) The conversion of cropland to perennial grasses can increase soil carbon by increasing belowground carbon inputs and eliminating and/or reducing soil disturbance. Decreases in nitrogen fertilizer and manure applications resulting from a conversion to grassland may also reduce N_2O emissions.

b) Conversion of drained, farmed organic or wetland soils to perennial non-woody vegetation, where there is substantial reduction or elimination of drainage, is an eligible practice but shall follow both the WRC and ALM requirements.

c) Grassland conversions to cropland production (e.g., introducing orchard crops or agroforestry practices on degraded pastures) may increase soil and biomass carbon stocks. Only conversions where the crop in the project activity does not qualify as forest are included under ALM. Land conversions of cropland or grassland to forest vegetation are considered ARR activities. Projects that convert grasslands shall demonstrate that they do not have a negative impact on local ecosystems as set out in the VCS Program document *VCS Standard*.

Note – Project activities relating to manure management are eligible under sectoral scope 15 (livestock, enteric fermentation, and manure management), not sectoral scope 14 (AFOLU).

Improved Forest Management (IFM)

A1.3 Eligible IFM activities are those that increase carbon sequestration and/or reduce GHG emissions on forest lands managed for wood products such as sawtimber, pulpwood and fuelwood by increasing biomass carbon stocks through improving forest management practices. The baseline and project scenarios for the project area shall qualify as *forests remaining as forests*, such as set out in the *IPCC 2006 Guidelines on National GHG Inventories*, and the project area shall be designated, sanctioned or approved for wood product management by a national or local regulatory body (e.g., as logging concessions or plantations).

A1.4 Various sanctioned forest management activities may be changed to increase carbon stocks and/or reduce emissions, but only a subset of these activities make a measurable difference to the long-term increase in net GHG emissions compared to the baseline scenario. Eligible IFM activities include:

1) Reduced Impact Logging (RIL): This category includes practices that reduce net GHG emissions by switching from conventional logging to RIL during timber harvesting. Carbon stocks can be increased by:

    a) Reducing damage to other trees (e.g., by implementing directional felling or vine cutting);

    b) Improving the selection of trees for harvesting based on inventoried knowledge concerning tree location, size and quality;

    c) Improving planning of log landing decks, skid trails and roads (e.g., in peatland forests this could include avoiding the use of canals, which drain the peat and increase GHG emissions, to extract the logs); and/or

    d) Reducing the size of logging roads, skid trails and log landing decks.

2) Logged to Protected Forest (LtPF): This category includes practices that reduce net GHG emissions by converting logged forests to protected forests. By eliminating harvesting for timber, biomass carbon stocks are protected and can increase as the forest re-grows and/or continues to grow. Harvesting of trees to advance conservation purposes (e.g., the removal of diseased trees) may continue in the project scenario. LtPF activities include:

    a) Protecting currently logged or degraded forests from further logging.

    b) Protecting unlogged forests that would otherwise be logged.

3) Extended Rotation Age/Cutting Cycle (ERA): This category includes practices that reduce net GHG emissions of evenly aged managed forests by extending the rotation age or cutting cycle and increasing carbon stocks. Because trees are typically harvested at an economically optimal rotation age before they are fully mature, extending the age at which the trees are cut increases the average carbon stock on the land. There is no fixed period of years over which the extension should occur, but generally the longer the period, on the order of 5 to 20 years, the more the average carbon stock increases. ERA activities may also include extending the cutting cycle or harvest schedule in uneven-aged forest management that may have similar effects as extending rotation age in even-aged forest management. Though such activities may have a limited carbon benefit, where methodologies are able to establish criteria and procedures for the credible monitoring of such activities, they are eligible. Examples of extending cutting cycles are:
   a) Increasing the minimum diameter limit of cutting thresholds.
   b) Extending the re-entry period for selective harvesting.
4) Low-Productive to High-Productive Forest (LtHP): This category includes practices that increase carbon sequestration by converting low-productivity forests to high-productivity forests. Carbon stocks can be increased by improving the stocking density of low-productivity forests, noting the following:
   a) Low-productivity forests usually satisfy one of the following conditions:
      i) They qualify as forest as defined by the host country for its UNFCCC national inventory accounting, but contain minimal to no timber of commercial value.
      ii) They are in a state of arrested succession, where regeneration is inhibited for extended periods of time, following either a catastrophic natural event to which the forest is maladapted thus causing massive mortality, or ongoing human-induced disturbance, for example uncharacteristically severe fire or widespread flooding, animal grazing, or burning.
      iii) They have a very slow growth rate or low crown cover.
   b) Improving the stocking density of low-productivity forests can be achieved through the following activities:
      i) Introducing other tree species with higher growth rates.
      ii) Adopting enrichment planting to increase the density of trees.
      iii) Adopting other forest management techniques to increase carbon stocks (e.g., fertilization or liming).

Note – Activities that reduce GHG emissions from unsanctioned forest degradation (e.g., illegal logging) are considered REDD activities. Projects focusing solely on the reduction of forest fires are not eligible under IFM. Activities that degrade wetlands to increase forest production are not eligible.

Reduced Emissions from Deforestation and Degradation (REDD)

A1.5 Eligible REDD activities are those that reduce net GHG emissions by reducing deforestation and/or degradation of forests. Deforestation is the direct, human-induced conversion of forest land to non-forest land. Degradation is the persistent reduction of canopy cover and/or carbon stocks in a forest due to human activities such as animal grazing, fuelwood extraction, timber removal or other such activities, but which does not result in the conversion of forest to non-forest land (which would be classified as deforestation), and qualifies as *forests remaining as forests*, such as set out under the *IPCC 2003 Good Practice Guidance*. The project area shall meet an internationally accepted definition of forest, such as those based on UNFCCC host-country thresholds or FAO definitions, and shall qualify as forest for a minimum of 10 years before the project start date. The definition of forest may include mature forests, secondary forests, and degraded forests. Under the VCS Program, secondary forests are considered to be forests that have been cleared and have recovered naturally and that are at least 10-years-old and meet the lower bound of the forest threshold parameters at the start of the project. Forested wetlands, such as floodplain forests, peatland forests and mangrove forests, are also eligible provided they meet the forest definition requirements mentioned above.

A1.6 Avoiding deforestation and/or degradation can affect GHG emissions and removals in a number of ways. The main effect is on carbon emissions that are reduced by preventing the conversion of forest lands with high carbon stocks to non-forest lands with lower carbon stocks. Where the forest is young or degraded, stopping its further degradation and deforestation also allows for additional sequestration of carbon on the land as the forest re-grows (with or without assisted regeneration). Avoiding conversion of forests to cropland or pasture can reduce emissions of N_2O and CH_4 that are associated with biomass burning used to clear the land, fertilizer use and other agricultural practices that would have occurred if the forests had been converted.

A1.7 Activities covered under the REDD project category are those that are designed to stop planned (designated and sanctioned) deforestation or unplanned (unsanctioned) deforestation and/or degradation. Avoided planned degradation is classified as IFM.

A1.8 Activities that stop unsanctioned deforestation and/or illegal degradation (such as removal of fuelwood or timber extracted by non-concessionaires) on lands that are legally sanctioned for timber production are eligible as REDD activities. However, activities that reduce or stop logging only, followed by protection, on forest lands legally designated or sanctioned for forestry activities are included within IFM. Projects that include both avoided unplanned deforestation and/or degradation as well as stopping sanctioned logging activities, shall follow the REDD guidelines for the unplanned deforestation and/or degradation and the IFM guidelines for the sanctioned logging activities, and shall follow the requirements set out in the VCS Program document *VCS Standard*.

A1.9 Eligible REDD activities include:

1) Avoiding Planned Deforestation and/or Degradation (APDD): This category includes activities that reduce net GHG emissions by stopping or reducing deforestation or degradation on forest lands that are legally authorized and documented for conversion, noting the following:

    a) This practice can occur in degraded to mature forests.

    b) Planned deforestation can encompass a wide variety of activities where forest land is converted to non-forest land, including inter alia:

        i) National resettlement programs from non-forested to forested regions.

        ii) National land plans to reduce the forest estate and convert it to industrial-scale production of commodities such as soybeans, pulpwood and oil palm, where the converted land would not qualify as forest land.

        iii) Plans to convert community-owned forests to other non-forest uses.

        iv) Planned forest conversion for urban, rural and infrastructure development.

    c) Planned degradation includes activities where a forest system would have been cleared and replaced by a different forest system with a lower carbon stock and where the recovery of timber was not the primary objective of the initial forest clearance. For example, national land plans to reduce the forest estate and convert it to industrial-scale production of commodities such as pulpwood and oil palm, where the converted land would still meet the country definition of forest land, are considered planned degradation.

    d) Avoided planned deforestation and degradation can include decisions by individual land owners, governments, or community groups, whose land is legally zoned for agriculture, not to convert their forest(s) to crop production or biofuel plantations. For example, a community may determine that GHG credits from forest protection are more valuable than the potential revenue from crop or commodity production. Similarly, an owner of land zoned for conversion to agriculture or urban development may choose to protect forested lands by partnering with a conservation organization, either in a joint management agreement or an outright sale.

    e) Avoiding planned degradation in a managed forest (e.g., legally sanctioned timber extraction) is an eligible activity under IFM.

Note – Activities that only reduce or avoid logging, followed by protection, on forest lands legally designated or sanctioned for forest products are eligible as IFM activities.

2) Avoiding Unplanned Deforestation and/or Degradation (AUDD): This category includes activities that reduce net GHG emissions by stopping deforestation and/or degradation of degraded to mature forests that would have occurred in any forest configuration, noting the following:

a) Unplanned deforestation and/or degradation can occur as a result of socio-economic forces that promote alternative uses of forest land and the inability of institutions to control these activities. Poor law enforcement and lack of property rights can result in piecemeal conversion of forest land. Unplanned deforestation and/or degradation activities can include, inter alia, subsistence farming or illegal logging occurring on both public lands legally designated for timber production and on public or communal lands that are poorly managed or otherwise degraded.

b) Methodologies may be designed for frontier and/or mosaic configurations, which are described as follows:

   i) The frontier deforestation and/or degradation pattern can result from the expansion of roads and other infrastructure into forest lands. Roads and other infrastructure can improve forest access and lead to increased encroachment by human populations, such as subsistence farming and fuelwood gathering on previously inaccessible forest lands.

   ii) The mosaic deforestation and/or degradation pattern can result when human populations and associated agricultural activities and infrastructure are spread out across the forest landscape. In a mosaic configuration most areas of the forest landscape are accessible to human populations.

   Mosaic deforestation and/or degradation typically occur: where population pressure and local land use practices produce a patchwork of cleared lands, degraded forests, secondary forests of various ages, and mature forests; where the forests are accessible; and where the agents of deforestation and/or degradation are present within the region containing the area to be protected.

Avoided Conversion of Grasslands and Shrublands (ACoGS)

A1.10 Eligible ACoGS activities are those that reduce net GHG emissions by reducing the conversion of grassland and shrubland ecosystems to other land uses with lower carbon densities. Eligible avoided conversion activities include avoiding, at a minimum, the removal/replacement of vegetation and may also include avoiding soil disturbance. There is no specific requirement with respect to the post-conversion land use that would have occurred in the baseline scenario.

A1.11 The project area shall be native grasslands (including savanna) and/or shrublands (including chaparral). Non-forested wetlands, including peatlands, are not eligible under ACoGS and are covered under other AFOLU project categories.

A1.12 Avoiding conversion of ecosystems can affect GHG emissions in a number of ways. Avoiding the conversion of grasslands and shrublands to cropland can reduce emissions from both soil and biomass carbon pools, with the bulk of avoided emissions likely coming from the soil carbon pool. Avoiding conversion to cropland can also reduce emissions of N_2O that are associated with fertilizer use and other agricultural practices that would have occurred following conversion. Avoiding conversion of shrublands or savanna to agriculture or development uses can reduce GHG emissions associated with the activities of clearing aboveground woody biomass.

A1.13 Activities covered under the ACoGS project category are those that are designed to stop planned (designated and sanctioned) conversion or unplanned (unsanctioned) conversion on public or private lands. This category type only includes avoided conversion of non-forested lands, noting that other management activities on non-forested land may qualify under ALM or ARR project categories.

A1.14 For both avoided planned conversion and avoided unplanned conversion, spatially explicit analysis is required to demonstrate that lands included in the project area are economically and physically suitable for the type of conversion being avoided. For example, where protecting lands from conversion to cropland, areas that are too steep, rocky, infertile for crops, or otherwise not viable for agricultural use, shall be considered unsuitable for conversion. The spatial analysis shall take into account local land use practices that may include the conversion of marginally suitable lands due to subsidies or population pressures. Unsuitable lands shall be excluded from baseline conversion scenarios.

A1.15 Eligible ACoGS activities include:

1) Avoiding Planned Conversion (APC): This category includes activities that reduce net GHG emissions by stopping conversion of grasslands or shrublands that are legally authorized and documented for conversion.

   Planned conversion may include decisions by individual land owners or community groups, whose land is legally zoned for agriculture or other development, not to convert their land(s). Similarly, an owner of land zoned for conversion to agriculture or development may choose to protect lands by partnering with an NGO or conservation organization either in a joint management agreement, conservation easement, or outright sale or lease.

2) Avoiding Unplanned Conversion (AUC): This category includes activities that reduce net GHG emissions by stopping unplanned conversion of grasslands or shrublands.

   Unplanned conversion can occur as a result of socio-economic forces that promote alternative uses of native grasslands or shrublands and the inability of institutions to control these activities. Poor law enforcement and weak or lacking property rights can result in piecemeal land conversion. Unplanned conversion activities may include, inter alia, subsistence agriculture, unsanctioned commercial agriculture and collection of biomass fuel where such collection would result in land conversion.

Wetlands Restoration and Conservation (WRC)

A1.16 Eligible WRC activities are those that increase net GHG removals by restoring wetland ecosystems or that reduce GHG emissions by rewetting or avoiding the degradation of wetlands. The project area shall meet an internationally accepted definition of wetland, such as from the IPCC, Ramsar Convention on Wetlands, those established by law or national policy, or those with broad agreement in the peer-reviewed scientific literature for specific countries or types of wetlands. Common wetland types include peatland, salt marsh, tidal freshwater marsh, mangroves, wet floodplain forests, prairie potholes and seagrass meadows. WRC activities may be combined with other AFOLU project categories, as further explained in Section A1.20.

A1.17 Avoiding the degradation or conversion of a wetland can reduce GHG emissions by preventing the release of carbon stored in wetland soils and vegetation. Many wetlands rely on a natural supply of sediments to support soil formation. Sediment supply may be interrupted by a physical alteration to the landscape, such as a river diversion, canal construction or isolation of wetlands behind man-made structures (e.g., road or rail embankments, levees or dams).

Restoring wetland ecosystems_reduces and/or removes GHG emissions by creating the necessary physical, biological or chemical conditions that enhance carbon sequestration. Activities that affect the hydrology of the project area are only eligible where changes in hydrology result in the accumulation or maintenance of soil carbon stock.

A1.18 A peatland is an area with a layer of naturally accumulated organic material (peat) at the surface (excluding the plant layer). Peat originates due to water saturation, and peat soils are either saturated with water for long periods or have been artificially drained. Common peatland types include peat swamp forest, mire, bog, fen, moor, muskeg and pocosin. Rewetting of drained peatland and the conservation of undrained or partially drained peatland are sub-categories of restoring wetland ecosystems and conservation of intact wetlands, respectively. These activities reduce GHG emissions by rewetting or avoiding the drainage of peatland. There are specific requirements regarding reductions of GHG emissions from fire (as set out in Sections 3.4.21, 3.6.25, 3.6.33, 3.6.34 and A1.19).

A1.19 Activities that generate net reductions of GHG emissions from wetlands are eligible as WRC projects or combined category projects (such as REDD on peatland). Activities that actively lower the water table depth in wetlands are not eligible. Eligible WRC activities include:

1) <u>Restoring Wetland Ecosystems (RWE)</u>: This category includes activities that reduce GHG emissions or increase carbon sequestration in a degraded wetland through restoration activities. Such activities include enhancing, creating and/or managing hydrological conditions, sediment supply, salinity characteristics, water quality and/or native plant communities. For the purpose of these requirements, restoration activities are those that result in the reestablishment of ecological processes, functions, and biotic and/or abiotic linkages that lead to persistent, resilient systems integrated within the landscape, noting the following:

a) Restoration or management of water table depth (e.g., the rewetting of peatlands, the reintroduction of river flows to floodplains, or the reintroduction of tidal flows to coastal wetlands) implies long-term and measurable changes in water table depth that sequester carbon and/or reduce emissions. Methodologies shall establish the appropriate change in water table depth (such as raising, lowering or restoring hydrological function) that is expected for eligible project activities, considering the following baseline scenario conditions:

   i) Drained wetlands have a water table depth that is lower than the natural average annual water table depth due to accelerated water loss or decreased water supply resulting from human activities and/or construction, either on- and/or off-site. Baseline activities include purposeful draining through pumping, ditching, stream channelization, levee construction, and purposeful decreases in water supply through dams and water diversions. Examples of this include selectively logged peatland swamp forests in Southeast Asia impacted by logging canals or wetlands with water tables lowered for agriculture.

      Activities shall raise the average annual water table depth in a drained wetland by partially or entirely reversing the existing drained state. Rewetting does not require the restoration of the average annual water table depth to the level of the soil or peat surface. However, RWE projects shall raise the water table depth close to the surface in order to be eligible to generate GHG credits. A clear relationship between GHG emissions and water table depth in wetlands, including peatlands[8] has been established in scientific literature with most changes in emissions occurring with water table depths close to the surface. This relationship is most dramatic on highly-organic soils (e.g., peatland). On such sites, activities that establish a higher water table depth compared to the baseline scenario can be eligible where they measurably decrease the rate of soil subsidence due to oxidation to decrease or cease within the project crediting period, and where the permanence requirements set out in Section 3.6.28 can be satisfied.

   ii) Impounded wetlands have a water table that has been artificially raised, intentionally or unintentionally, as a result of impaired natural drainage behind a constructed feature and can result in CH_4 emissions. Examples of impounded wetlands include flooded areas behind artificial barriers to natural drainage (such as road or rail embankments or levees), flooded areas for the purpose of subsidence reversal, man-made reservoirs and fish and shrimp ponds.

      Activities that restore hydrological function to an impounded wetland or lower the water table depth shall restore hydrological flow, considering the dynamics of the

[8] For a literature review see Couwenberg, J, Dommain, R, Joosten, H. 2010. *Greenhouse gas fluxes from tropical peatlands in south-east Asia*. Global Change Biology 16: 1715-1732.

system and the hydrological connectivity necessary to maintain carbon stock and GHG fluxes.

iii) Open water is an area continuously flooded or subject to natural periods of flooding, without in-situ vegetation contributing to soil carbon accumulation. Wetlands convert to open water in response to impaired sediment supply, sea level rise and/or impaired water quality.

Activities that restore hydrological function to an open water wetland shall restore the hydrological flow, considering the dynamics of the system and the hydrological connectivity necessary to maintain carbon stock and GHG fluxes.

b) RWE projects may generate GHG credits from the reduction of GHG emissions associated with avoiding peat fires on drained or partially drained peatlands. Fire-related activities on peatlands that exclude rewetting as part of the project are not eligible, because fire reduction activities on drained peatland are unlikely to be effective over the long term without rewetting.

Note – Activities that increase net GHG removals through carbon sequestration by restoring soil carbon sequestration conditions (e.g., peat-forming conditions) are eligible under RWE. The restoration of conditions that favor soil carbon sequestration requires high water table depths over the long term and the presence of vegetation that produces soil carbon. Carbon sequestration rates resulting from rewetting and restoring drained non-tidal wetlands tend to be low on a unit-per-land area basis compared to GHG emissions reduced by avoiding soil carbon oxidation. Soil carbon sequestration restoration is therefore considered to have a relatively small contribution to GHG mitigation from non-tidal RWE projects. Soil carbon sequestration in tidal wetlands can be relatively rapid compared to non-tidal wetlands and will typically be expected to contribute significantly to the GHG mitigation effectiveness of RWE projects. Methodologies for forecasting soil carbon sequestration in tidal wetlands may be proposed, noting that they shall separate the sequestration of carbon as a result of project activities from the deposit of carbon rich soil into the project area as a result of sedimentation, (as set out in Section 3.6.29).

2) <u>Conservation of Intact Wetlands (CIW)</u>: This category includes activities that reduce GHG emissions by avoiding degradation and/or the conversion of wetlands that are intact or partially altered while still maintaining their natural functions, including hydrological conditions, sediment supply, salinity characteristics, water quality and/or native plant communities.

Wetland degradation or conversion can be planned (designated and sanctioned) or unplanned (unsanctioned). Planned and unplanned degradation or conversion of wetlands can therefore encompass a wide variety of activities such as those listed under REDD while adding a wetland component. Activities covered under the CIW project category are those that are designed to stop or reduce planned or unplanned degradation or conversion in the project area to other land uses. The following CIW activities are eligible:

a) <u>Avoiding Planned Wetland Degradation (APWD)</u>: This activity reduces GHG emissions by avoiding degradation of wetlands, or further degradation in partially drained wetlands that are legally authorized and documented for conversion.

b) Avoiding Unplanned Wetland Degradation (AUWD): This activity reduces GHG emissions by avoiding unplanned degradation of wetlands, or by avoiding further degradation in partially degraded wetlands. Unplanned wetland degradation can occur as a result of socio-economic forces that promote alternative uses of wetlands and the inability of institutions to control these activities. Poor law enforcement and weak or lack of property rights can result in piecemeal wetland conversion. Unplanned conversion activities may include, inter alia, subsistence farming, illegal logging, unsanctioned commercial agriculture and collection of biomass fuel where such collection would result in land conversion subsistence agriculture.

Note – Activities where drainage is continued or maintained are not eligible. This includes, for example, projects that require the maintenance of drainage channels to maintain the pre-project drainage level on a partially drained peatland (e.g., where periodic deepening may be needed to counteract peat subsidence). Projects that allow selective harvesting that results in a lowering of the water table depth (e.g., by extracting timber using drainage canals) or affects the ability of vegetation to act as a major hydrological regulation device (e.g., extracting trees which support the peat body) are also not eligible. Project activities may include selective harvesting where harvesting does not lower the water table, for example by extracting timber using wooden rails instead of drainage canals.

Note – WRC activities that are unable to establish and demonstrate a significant difference in the net GHG benefit between the baseline and project scenarios for at least 100 years are not eligible, as set out in Section 3.6.30.

A1.20 Activities that generate net GHG emission reductions by combining other AFOLU project activities with wetlands restoration or conservation activities are eligible as WRC combined projects. RWE may be implemented without further conversion of land use or it may be combined with ARR, ALM, IFM, REDD or ACoGS activities, referred to as ARR+RWE, ALM+RWE, IFM+RWE, REDD+RWE or ACoGS+RWE, respectively. CIW may be implemented on non-forest land or combined with IFM, REDD or ACoGS activities, referred to as IFM+CIW, REDD+CIW or ACoGS+CIW, respectively.

Table 4 illustrates the types of WRC activities that may be combined with other AFOLU project categories. The table identifies the applicable AFOLU requirements that shall be followed for combined category projects, based on the condition of the wetland in the baseline scenario, the land use in the baseline scenario and the project activity.

Table 4: Eligible WRC Combined Category Projects

Baseline Scenario		Project Activity	Applicable Guidance
Condition	Land Use		
Degraded wetland (including, drained, impounded, and with interrupted sediment supply)	Non-forest (including aquacultures, grasslands and shrublands)	Restoration of wetlands*	RWE
		Restoration of wetlands* and revegetation or conversion to forest	ARR+RWE
		Restoration of wetlands* and conversion to wetland agriculture (including paludiculture)	ALM+RWE
		Restoration of wetlands* and avoided conversion of grasslands or shrublands	ACoGS+RWE
	Forest	Restoration of wetlands*	RWE
	Forest with deforestation/ degradation	Restoration of wetlands* and avoided deforestation/degradation	REDD+RWE
	Forest managed for wood products	Restoration of wetlands* and improved forest management	IFM+RWE
Non-wetland or open water	Non-forest	Creation of wetland conditions and afforestation, reforestation or revegetation	ARR+RWE
	Open water or impounded wetland	Creation or restoration of conditions for vegetation development and afforestation, reforestation or revegetation	ARR+RWE
Intact wetland	Non-forest (including grasslands and shrublands)	Avoided drainage and/or interrupted sediment supply	CIW
		Avoided conversion to open water or impounded wetland (including excavation to create fish ponds)	CIW
		Avoided drainage and/or interrupted sediment supply and avoided conversion of grasslands and shrublands	ACoGS+CIW
	Forest	Avoided drainage and/or interrupted sediment supply	CIW
		Avoided conversion to open water or impounded wetland	CIW
	Forest with deforestation/ degradation	Avoided drainage and/or interrupted sediment supply and avoided deforestation/degradation	REDD+CIW
		Avoided conversion to open water or impounded wetland and avoided	REDD+CIW

		deforestation/degradation	
	Forest managed for wood products	Avoided drainage and/or interrupted sediment supply and improved forest management	IFM+CIW

* *Restoration of wetlands* includes all the activities set out in Section A1.19(1).

The eligible WRC combined categories are further elaborated below:

1) ARR on Wetland (ARR+RWE): RWE may be implemented in combination with ARR, for example by planting a native or adapted tree or shrub species on peatland or in mangroves. While existing oxidation in drained conditions is accounted for in the baseline, ARR activities on peatland shall not enhance peat oxidation, therefore this activity requires at least some degree of rewetting. ARR+RWE on already drained peatland without full rewetting is permitted in cases where the biomass carbon stock increases more than the peat carbon stock decreases by oxidation over a period of centuries.[9]

   Note – ARR activities that involve nitrogen fertilization, active peatland drainage or lowering of the water table depth, such as draining in order to harvest, are not eligible project activities, as they are likely to enhance net GHG emissions. Activities involving selective logging, combined with artificial drainage and/or construction of channels to extract the timber are not eligible as these may result in decomposition and subsidence of the peat which could be accompanied by an increase in CO2 emissions or additional GHG fluxes.

2) ALM on Wetland (ALM+RWE): This is an eligible activity if the water table depth of an agricultural wetland is raised to a level that can still support agriculture. The following ALM+RWE practices qualify as eligible activities:

   a) Rewetting a wetland combined with adapted wet agriculture that includes the cultivation of biomass on undrained or rewetted wetland. The wetland shall be sufficiently wet so as to avoid long-term net soil organic carbon losses as set out in Section 3.6.28.

   b) Improved grassland management activities that reduce overgrazing, high-intensity use and gully erosion for reducing peat erosion on sloping peatlands. In many steppe and mountain regions with dry climates, and also in cold or humid regions ("blanket bogs"), peatlands are the most productive and attractive, or the only available, lands for grazing. Overgrazing on sloping peatlands, frequently leads to vegetation damage and peat soil degradation.

[9] For more information on the relationship between biomass carbon stock increases and peat carbon stock decreases, see Laine, J. & Minkkinen, K. 1996. *Forest drainage and the greenhouse effect*. In: Vasander, H. (Ed.) Peatlands in Finland. Finnish Peatland Society, Helsinki, pp 159-164.

c) Improved cropland and grassland management activities that reduce wind erosion on peatlands that are devegetated or sparsely vegetated due to overgrazing, soil degradation or crop production.

Note – ALM activities that involve regular tillage and/or nitrogen fertilization on wetland soil or that actively lower the water table depth in wetlands are not eligible project activities.

3) IFM, REDD and ACoGS on Wetland (IFM+RWE, IFM+CIW, REDD+RWE, REDD+CIW, ACoGS+RWE and ACoGS+CIW): RWE and CIW may be implemented in combination with IFM, REDD and ACoGS project activities. Such activities reduce GHG emissions by increasing, or avoiding the loss of, forest, shrubland or grassland carbon stocks, and avoiding the drainage required to undertake such baseline activities, noting the following:

a) IFM, REDD and ACoGS project activities on wetlands shall not increase drainage. With respect to the forest biomass component, the requirements provided for IFM, REDD or ACoGS apply.

b) For IFM+CIW projects on peatland that include harvesting activities in the project scenario, selective harvesting shall not significantly affect the hydrology of the peat layer and cause peat decomposition. Where the peat layer in the baseline scenario is partially drained, the effect of harvesting on top soil hydrology is likely to be much less significant. CIW projects that have clear-cut or patch-cut harvesting activities are not eligible.

c) For IFM+RWE projects, activities that avoid fire of a peat layer are eligible for crediting. IFM activities focusing solely on the reduction of forest fires are not eligible under AFOLU, as set out in Section A1.4.

A1.21 Many seagrass meadows sit upon significant stocks of soil carbon. Degradation of seagrass meadows likely increases the vulnerability of carbon stocks to disturbance and recirculation. Increases in CO_2 in the water column from decomposition of seagrass bed carbon stocks will lead to an increased CO_2 flux to the atmosphere, although the flux to the atmosphere could be reduced by dissolution of the carbonate soils underlying some seagrass meadows or by the export of CO_2-enriched waters to deeper waters below the mixing depth. Methodologies shall include credible methods for quantifying and forecasting GHG emissions to the atmosphere associated with seagrass degradation.

A1.22 Peat may be used as fuel, soil improver or horticultural substrate. Due to the existence of extensive local, regional and global markets, projects that avoid peat mining are likely to suffer significant (and potentially 100 percent) leakage emissions and therefore are not eligible. Project activities that serve the demand side and avoid peat mining by providing alternatives for peat as fuel or substrate, are outside the scope of AFOLU but may qualify under another sectoral scope.

APPENDIX 2 DOCUMENT HISTORY

Version	Date	Comment
v4.0	19 Sep 2019	Initial version released under VCS Version 4.

VERRA

Standards for a Sustainable Future

Verified Carbon Standard

Climate, Community & Biodiversity Standards

Sustainable Development Verified Impact Standard

Program Definitions

19 September 2019

v4.0

ABOUT VERRA

Verra supports climate action and sustainable development through the development and management of standards, tools and programs that credibly, transparently and robustly assess environmental and social impacts, and drive funding for sustaining and scaling up these benefits. As a mission-driven, non-profit (NGO) organization, Verra works in any arena where we see a need for clear standards, a role for market-driven mechanisms and an opportunity to achieve environmental and social good.

Verra manages a number of global standards frameworks designed to drive finance towards activities that mitigate climate change and promote sustainable development, including the Verified Carbon Standard (VCS) Program and its Jurisdictional and Nested REDD+ framework (JNR), the Verra California Offset Project Registry (OPR), the Climate, Community & Biodiversity (CCB) Standards and the Sustainable Development Verified Impact Standard (SD VISta). Verra is also developing new standards frameworks, including LandScale, which will promote and measure sustainability outcomes across landscapes. Finally, Verra is one of the implementing partners of the Initiative for Climate Action Transparency (ICAT), which helps countries assess the impacts of their climate actions and supports greater transparency, effectiveness, trust and ambition in climate policies worldwide.

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1 INTRODUCTION

This document provides the definitions for terms used in the VCS Program documents. In addition, the definitions set out in *ISO 14064-2:2006*, *ISO 14064-3:2006* and *ISO 14065:2016* shall apply to the VCS Program. Note that defined terms in the VCS Program documents, in common with ISO convention, are used without capital first letters. Section 3 lists acronyms used in the VCS Program documents. This document will be updated from time-to-time and readers shall ensure that they are using the most current version of the document.

2 DEFINITIONS

Aboveground Biomass

Living biomass above the soil, including the stem, stump, branches, bark, seeds and foliage

Agroforestry

An ecologically-based natural resource management system in which trees are integrated in farmland and rangeland

Agro-ecological zones

Geographic areas based on similar characteristics such as combinations of soil, landform and climatic conditions

Accession Representation

- The deed issued by the project proponent, and an acceding entity, made in respect of an acceding entity joining a project as project proponent, and which is prepared using the *VCS Deed of Accession in Respect of Registration Deed of Representation Template*; or
- The deed issued by the jurisdictional proponent, and an acceding entity, made in respect of an acceding entity joining a jurisdictional baseline or program as jurisdictional proponent, and which is prepared using the *VCS Deed of Accession in Respect of JNR Baseline Registration Deed of Representation Template* or the *VCS Deed of Accession in Respect of JNR Program Registration Deed of Representation Template*, respectively

Activity Method

A methodological approach that determines additionality for a given class of project activity in accordance with the VCS Program rules

Afforestation

The direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources

Afforestation, Reforestation and Revegetation (ARR)

Activities that increase carbon stocks in woody biomass (and in some cases soils) by establishing, increasing and/or restoring vegetative cover through planting, sowing and/or the human-assisted natural regeneration of woody vegetation

Agriculture, Forestry and Other Land Use (AFOLU)

The sectoral scope that covers GHG emissions and emission reductions and/or removals from project or program activities in the agriculture, forestry, and other land use/land use change sectors and for which the VCS Program has established rules and requirements with respect to specific project categories

Agricultural Land Management (ALM)

Activities that increase carbon stocks in soils and woody biomass and/or decrease CO_2, N_2O and/or CH_4 emissions from soils on croplands and/or grasslands

AFOLU Expert

A person with expertise and experience in AFOLU methodologies, tools, modules and/or projects, and who is approved by Verra for methodology element assessments within a given AFOLU project category

AFOLU Pooled Buffer Account

The account in the Verra registry containing non-tradable AFOLU buffer credits for covering the risk of unforeseen losses in carbon stocks across the AFOLU project portfolio

Approved GHG Program

A GHG program that has been approved by the Verra Board, through a gap analysis, as a VCS Program approved GHG program

Authorized Representative

An entity authorized by the project or jurisdictional proponent to communicate with and provide instructions to the Verra registry on its behalf, with such authorization granted through a communications agreement signed by both/all parties and submitted to the Verra registry

Belowground Biomass

Living biomass of live roots, sometimes excluding fine roots of less than 2 mm diameter because these often cannot be distinguished empirically from soil organic matter or litter

Cancellation

The permanent removal of a VCU from circulation in the Verra registry system for purposes other than retirement (e.g., converting VCUs into another form of GHG credit, compensating for excess VCU issuance)

Capacity Limit

A limitation on any quantity in relation to the project imposed by a methodology applied to the project, the GHG program under which the methodology applied to the project was developed or the GHG program under which the project was developed

Capital Expenditure

The costs to the project activity of acquiring new assets or improving existing assets that are utilized for the duration of the project crediting period

Carbon Pools

A reservoir of carbon that has the potential to accumulate (or lose) carbon over time, which for AFOLU projects or programs encompasses aboveground biomass, belowground biomass, litter, dead wood, soil and wood products

Carbon Stock

The quantity of carbon held within a pool, measured in tonnes of CO_2

Catastrophic Reversal

A type of reversal caused by disasters such as hurricanes, earthquakes, flooding, drought, fires, tornados or winter storms, or man-made events over which the project proponent has no control such as acts of terrorism or war

Commercially Sensitive Information

See “Sensitive Information”

Communications Agreement

The agreement by which the project or jurisdictional proponent authorizes a third party to communicate with and provide instructions to the Verra registry on its behalf, the form and scope of which shall be determined solely by the Verra registry and the signatories to the agreement

Crediting Period

The time period for which GHG emission reductions or removals generated by the project are eligible for issuance as VCUs, the rules with respect to the length of such time period and the renewal of the project crediting period being set out in the *VCS Standard*. Also referred to as “Project Crediting Period”; or

The time period for which GHG emission reductions or removals generated by the jurisdictional REDD+ program are eligible for issuance as VCUs, the rules with respect to the length of such time period and the renewal of the program crediting period being set out in the VCS Program document *JNR Requirements.* Also referred to as “Program Crediting Period”.

Cropland

Arable and tillage land and agro-forestry systems where vegetation falls below the threshold used for the forest land category

Dead Wood

Non-living woody biomass not contained in the litter, either standing, lying on the ground or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter or any other diameter used by the host country for its UNFCCC national inventory accounting

Deemed Savings Factor

A type of default factor used to estimate the GHG emission reductions or removals associated with a unit of activity implemented by the project, such as a project activity instance

Default Factor

A parameter value that is specified in a methodology with the intention of standardizing the calculation of net GHG emission reductions and/or removals and providing greater consistency of calculations across projects

Deforestation

The direct human-induced conversion of forest land to non-forest land

Degradation

The persistent reduction of canopy cover and/or carbon stocks in a forest due to human activities such as animal grazing, fuelwood extraction, timber removal or other such activities, but that does not result in the conversion of forest to non-forest land, and falls under the *IPCC 2003 Good Practice Guidance* land category of *forest remaining forest*

Drained Peatland

A peatland having a lower than natural average annual water level due to accelerated water loss or decreased water supply resulting from human activities and constructions, both on- and off-site

Double Counting

The scenario under which a singular GHG emission reduction or removal is monetized separately by two different entities or where a GHG emission reduction or removal is sold to multiple buyers

Free-rider

An activity that is undertaken without requiring any intervention from the carbon market but that nonetheless receives credit for the GHG emission reductions or removals that it generates

Forest

Land with woody vegetation that meets an internationally accepted definition (e.g., UNFCCC, FAO or IPCC) of what constitutes a forest, which includes threshold parameters, such as minimum forest area, tree height and level of crown cover, and may include mature, secondary, degraded and wetland forests

Emission Trading Program

A voluntary or regulatory program that allows for trading in GHG credits or allowances

GHG Program

A formal or organized program, system or arrangement for the recognition of activities leading to GHG emission reductions or removals, and/or the crediting or issuance of instruments representing, or acknowledging, GHG emission reductions or removals

Grassland

Areas dominated by grasses with a density of trees too low to meet an internationally accepted definition of forest, including savannas (i.e., grasslands with scattered trees). Grasslands also include managed rangeland and pastureland that is not considered cropland where the primary land use is grazing, and which may also include grass-dominated systems managed for conservation or recreational purposes

Grouped Project

A project to which additional instances of the project activity, which meet pre-established eligibility criteria, may be added subsequent to project validation

Implementing Partner

The individual or organization operating the project or program activity (or activities) in partnership with the project or jurisdictional proponent, respectively

Improved Forest Management (IFM)

Activities that change forest management practices and increase carbon stock on forest lands managed for wood products such as saw timber, pulpwood and fuelwood

Internal Allocation Mechanism

The mechanism for the distribution of GHG credits and/or other benefits, established by the jurisdictional proponent as part of the jurisdictional REDD+ program

Issuance Representation

- The unilateral representation issued by the project proponent at each VCU issuance request, made in respect of the GHG emission reductions and/or removals generated by the project, and which is prepared using the *VCS Issuance Deed of Representation Template*; or
- The unilateral representation issued by the jurisdictional proponent at each VCU issuance request, made in respect of the GHG emission reductions and/or removals generated by the jurisdictional

program, and which is prepared using the *VCS JNR Program Issuance Deed of Representation Template*

Jurisdiction

The administrative unit such as a nation, state, province, region, department or district, or an eco-region or other defined area, specified in the jurisdictional program description

Jurisdictional and Nested REDD+ (JNR)

The approach under the VCS Program by which reduced emissions from deforestation, reduced emissions from degradation and removals from carbon stock enhancements can be credited at the jurisdictional and/or nested project levels

Jurisdictional Approval Authority

The government agency, department or organization that has control of and responsibility for reviewing and giving approval, or the no-objection letter, to lower-level jurisdictional REDD+ programs and/or projects, and that may or may not be the same entity as the jurisdictional proponent

Jurisdictional Baseline Period

The time period for which the baseline for a jurisdictional REDD+ program is valid

JNR Program Description (Program Description)

The document that describes the jurisdictional baseline and/or program GHG emission reductions or removals and that uses the *VCS JNR Baseline Description Template* (for jurisdictions registering only a jurisdictional baseline) or the *VCS JNR Program Description Template* (for jurisdictional REDD+ programs), respectively

Jurisdictional Proponent

The government agency, department or organization that has overall control and responsibility for the jurisdictional REDD+ program, or a government agency, department or organization that together with others, each of which is also a jurisdictional proponent, has overall control of or responsibility for the jurisdictional REDD+ program. The entity(s) that can demonstrate program ownership in respect of the jurisdictional REDD+ program.

JNR Expert

A person with expertise and experience in jurisdictional baselines and/or REDD+ programs who is approved by Verra for participation on expert panels for the validation/verification of jurisdictional REDD+ programs

Jurisdictional REDD+ Program and Jurisdictional Program

See “Program”

Jurisdictional Pooled Buffer Account

The account in the Verra registry containing non-tradable jurisdictional and nested REDD+ buffer credits for covering the risk of unforeseen losses in carbon stocks across the jurisdictional REDD+ program and REDD+ project portfolio

Land-Based Accounting

A method of GHG accounting in which all land in an entire geographic area or jurisdiction is included in the accounting through categorization of land-use types and a sampling or modeling approach sufficient to capture carbon stocks and changes in carbon stocks, irrespective of activity

Large Project

A project that generates 300,000 tonnes CO_2e or more of GHG emissions reductions or removals per year

Large-Scale Commercial Deforestation

An area of deforestation that exceeds 1,000 ha, cleared in a single monitoring period (or, between two points of remotely sensed historical data), that has a single post-deforestation land use (e.g., commercial agriculture or timber plantation), not including areas covered by the footprint of large infrastructure (such as a dam) or those affected by natural disturbances (i.e., due to geologic or weather-related events)

Leakage

Net changes of anthropogenic emissions by GHG sources that occur outside the project or program boundary, but are attributable to the project or program

Listing Representation

- The unilateral representation issued by the project proponent at the time of the project pipeline listing request, made in respect of the project, and which is prepared using the *VCS Listing Representation Template*; or

- The unilateral representation issued by the jurisdictional proponent at the time of the jurisdictional baseline or program listing request, made in respect of the jurisdictional baseline or program, and which is prepared using the *VCS JNR Baseline Listing Deed of Representation Template* or the *VCS JNR Program Listing Deed of Representation Template*, respectively

Litter

Non-living biomass, with a size less than a minimum threshold diameter (e.g., 10 cm) chosen by the host country for its UNFCCC national inventory accounting, lying dead, in various states of decomposition above the mineral or organic soil, including litter, fumic and humic layers. Live fine roots (of less than the threshold diameter for belowground biomass) are included in litter where they cannot be distinguished from it empirically.

Loss Event

- In an AFOLU project, any event that results in a loss of more than five percent of previously verified emission reductions and removals due to losses in carbon stocks in pools included in the project boundary that is not planned for in the project description (e.g., harvesting as set out in management plans and described in the project description is not a loss event). Examples include catastrophic events (see definition of catastrophic reversal) as well as human-induced losses such as those caused by poor management, tillage, over-harvesting or encroachment by outside actors (e.g., illegal logging or fuelwood collection); or

- In a jurisdictional program, any event that results in a loss of more than five percent of previously verified emission reductions and removals due to losses in carbon stocks in pools included in the program boundary that is not planned for in the program description (e.g., harvesting as set out in management plans and described in the program description is not a loss event). Examples include harvesting beyond levels predicted in the baseline, construction of roads or other infrastructure not included in the baseline, or significant natural disturbances .

Loss Event Report

The document that describes and records a loss event using the *Loss Event Report Template*

Loss Event Representation

- The unilateral representation issued by the project proponent, prepared using the *VCS Loss Event Deed of Representation Template* and made in respect of the carbon stock loss estimate in a loss event report; or

- The unilateral representation issued by the jurisdictional proponent, prepared using the *VCS JNR Program Loss Event Deed of Representation Template* and made in respect of the carbon stock loss estimate in a loss event report

Market Leakage Evaluation

The evaluation by the project or jurisdictional proponent of the project's or program's market leakage impacts and discount factor, documented in the project description, program description or monitoring report, as applicable

Materiality

The concept applied to determine if errors, omissions and misstatements in information could affect the GHG assertion and influence decisions resulting from it

Methodology

A specific set of criteria and procedures, which apply to specific project activities, for identifying the project boundary, determining the baseline scenario, demonstrating additionality, quantifying net GHG emission reductions and/or removals, and specifying the monitoring procedures

Methodology Approval Process

The process by which new methodology elements are approved under the VCS Program

Methodology Deviation

A deviation from the criteria and procedures for monitoring or measurement set out in a methodology applied to the project

Methodology Element

A methodology, methodology revision, module or tool (including additionality tools, performance benchmarks and technology benchmarks)

Methodology Element Developer

An entity that develops a methodology element

Methodology Revision

A revision to the criteria and procedures of an existing methodology

Model

A formula or set of formulae that uses parameters and input values to establish the value of one or more output variables

Module

A component of a methodology that can be applied to perform a specific methodological task

Monitoring Report

- The document that records data to allow the assessment of the GHG emission reductions or removals generated by the project during a given time period in accordance with the monitoring plan set out in the project description, and which is prepared using the *VCS Monitoring Report Template* or an approved combined monitoring report template available on the Verra website; *or*
- The document that records data to allow the assessment of the GHG emission reductions or removals generated by the program during a given time period in accordance with the monitoring plan set out in the jurisdictional program description, and which is prepared using the *VCS JNR Monitoring Report Template* available on the Verra website

Natural Disturbance

Non-anthropogenic events or non-anthropogenic circumstances that cause significant emissions from forests and are beyond the control of, and not materially influenced by, a project or jurisdictional proponent, such as wildfires, insect and disease infestations, extreme weather events and/or geological disturbances. Harvesting and prescribed burning are not considered natural disturbance.

Native Ecosystem

A landscape composed of indigenous vegetation not established by planting and/or seeding

Nested Project

A registered REDD+ project, that is not currently subject to a grandparenting period, and that is located within a jurisdiction covered by a registered jurisdictional REDD+ program

Nested Subnational Jurisdiction

A subnational jurisdiction that is located within a national jurisdiction covered by a jurisdictional REDD+ program that is also registered under the VCS Program

No-Objection Letter

A written letter or other written communication from the jurisdictional approval authority of the higher-level jurisdiction stating that it does not object to a specific (lower-level) jurisdictional REDD+ program element or project being submitted for registration under the VCS Program

Non-Project Areas

Forest areas (or areas converted to forest or otherwise revegetated) within a jurisdiction, but outside project boundaries or nested subnational jurisdiction boundaries, that are included in the accounting of GHG emissions and emission reductions and/or removals (e.g., areas where GHG emission reductions and/or removals are generated through the implementation of government policies and programs, rather than by projects or activities implemented within nested subnational jurisdictions)

Non-Permanence Risk Analysis

- The assessment of the risk of a potential loss in carbon stock in the project over a period of 100 years, prepared by the project proponent using the *VCS Non-Permanence Risk Report Template*; or

- The assessment of the risk of a potential loss in carbon stock in the jurisdictional program over a period of 100 years, prepared by the jurisdictional proponent using the *VCS JNR Non-Permanence Risk Report Template*

Official Translation

A translation by a member of a member body of the International Federation of Translators

Partial Release Representation

- The deed issued by the project proponents and the Verra registry, made in respect of a project proponent leaving a project, and which is prepared using the *VCS Deed of Partial Release in Respect of Registration Deed of Representation Template*; or

- The deed issued by the jurisdictional proponent and the Verra registry, made in respect of a jurisdictional proponent leaving a jurisdictional baseline or jurisdictional program, and which is prepared using the *VCS Deed of Partial Release in Respect of JNR Baseline Registration Deed of Representation Template* or the *VCS Deed of Partial Release in Respect of JNR Program Registration Deed of Representation Template*, respectively

Peatland

An area with a layer of naturally accumulated organic material (peat) that meets an internationally accepted threshold (e.g., host-country, FAO or IPCC) for the depth of the peat layer and the percentage of organic material composition. Peat originates because of water saturation. Peat soil is either saturated with water for long periods or is artificially drained. Common names for peatland include mire, bog, fen, moor, muskeg, pocosin and peat swamp (forest).

Performance Benchmark

A benchmark against which the performance of individual projects is assessed for the purpose of determining additionality and/or the crediting baseline

Performance Benchmark Metric

The indicator, specified in terms of tonnes of CO_2e per unit of output, tonnes of CO_2e per unit of input or as a sequestration metric, used to define the performance benchmark

Performance Method

A methodological approach that establishes a performance benchmark to determine additionality and/or the crediting baseline in accordance with the VCS Program rules

Program

The program established by a national or subnational jurisdictional proponent that establishes and operationalizes rules and requirements to enable accounting and crediting of REDD+ policies and measures and/or nested projects, implemented as GHG mitigation activities, and described in the jurisdictional program description. Also referred to as "Jurisdictional REDD+ Program" or "Jurisdictional Program".

Program Activity

The specific set of REDD+ policies and measures, specified by the jurisdictional REDD+ program, that alter the conditions identified in the baseline scenario and which result in GHG emission reductions or removals

Program Crediting Period

See "Crediting Period"

Program Ownership

The legal right to control and operate the program activities. Distinct from proof of right.

Program Start Date

See "Start Date"

Program Sensitive Information

See "Sensitive Information Project". The project activity or activities implemented as a GHG project and described in the project description.

Project Activity

The specific set of technologies, measures and/or outcomes, specified in a methodology applied to the project, that alter the conditions identified in the baseline scenario and which result in GHG emission reductions or removals

Project Activity Instance (Instance)

A particular set of implemented technologies and/or measures that constitute the minimum unit of activity necessary to comply with the criteria and procedures applicable to the project activity under the methodology applied to the project

Project Crediting Period

See "Crediting Period"

Project Crediting Period Start Date

The date on which the first monitoring period commences

Project Description

The document that describes the project's GHG emission reduction or removal activities and that uses either the *VCS Project Description Template*, an approved combined project description template available on the Verra website or the project description template specified by the relevant approved GHG program

Project Description Deviation

A deviation from the project design, procedures and other specifications set out in the project description

Project Documents

The documents required to register the project and/or issue VCUs, as set out in the VCS Program document *Registration and Issuance Process*

Project Method

A methodological approach that uses a project-specific approach for the determination of additionality and/or the crediting baseline in accordance with the VCS Program rules

Project Ownership

The legal right to control and operate the project activities. Distinct from proof of right.

Project Pipeline

The list of projects on the Verra registry, which are either *under development* or *under validation*

Project Proponent

The individual or organization that has overall control and responsibility for the project, or an individual or organization that together with others, each of which is also a project proponent, has overall control or responsibility for the project. The entity(s) that can demonstrate project ownership in respect of the project.

Project Proponent Representation

A unilateral deed of representation issued by the project proponent(s) and/or individuals or organizations accorded certain rights in respect of a project

Project Start Date

See "Start Date"

Proof of Right

The document(s) demonstrating the entity's right to all and any GHG emission reductions or removals generated by the project or program during the crediting period or verification period, as the case may be. Distinct from project ownership and program ownership.

Proxy

A parameter that is monitored or measured to determine the value of a strongly correlated parameter that is not monitored or measured

Reduced Emissions from Deforestation and Degradation (REDD)

Activities that reduce GHG emissions by slowing or stopping conversion of forests to non-forest land and/or reduce the degradation of forest land where forest biomass is lost

REDD+

Activities that reduce GHG emissions from deforestation and/or degradation by slowing or stopping conversion of forests to non-forest land and/or reducing the degradation of forest land where forest biomass is lost; and/or activities that enhance carbon stocks through improved forest management and/or afforestation, reforestation or revegetation

Registration Representation

- The unilateral representation issued by the project proponent at the time of the project registration request, made in respect of the project, and which is prepared using the *VCS Registration Deed of Representation Template*; or

- The unilateral representation issued by the jurisdictional proponent at the time of the program registration request, made in respect of the jurisdictional baseline or program, and which is prepared using the *VCS JNR Baseline Registration Deed of Representation Template* or the *JNR Program Registration Deed of Representation Template*, respectively

Reforestation

The direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources on land that was once forested but has been converted to non-forested land

Remote Sensing (RS)

The use of an instrument, such as a radar device or camera, to scan the earth from a distance in order to collect data (e.g., for forest inventory or monitoring)

Retirement

The permanent removal of a VCU from circulation in the Verra registry system which represents an offset of one metric tonne of CO_2 equivalent

Revegetation

A direct human-induced activity to increase carbon stocks of woody biomass on sites through the establishment of vegetation that covers a minimum area of 0.05 hectares and does not meet the definitions of afforestation and reforestation

Reversal

A situation where the net GHG benefit, taking into account project or program emissions, removals and leakage, in any monitoring period is negative. The amount of a reversal is calculated as the difference between the current total to-date net GHG benefit of the project or program, compared to the total to-date net GHG benefit of the project or program at the previous verification event.

Rewetting

The elevation of the average annual water table in drained peatland by partially or entirely reversing the existing drained state

Sensitive Information

- Trade secrets, financial, commercial, scientific, technical or other information whose disclosure could reasonably be expected to result in a material financial loss or gain, prejudice the outcome of contractual or other negotiations or otherwise damage or enrich the person or entity to which the information relates. Also referred to as "Commercially Sensitive Information"; or
- Internal policy decisions, classified, financial, commercial, scientific, technical or other information whose public disclosure could reasonably be expected to undermine or negatively affect the development and/or implementation of a program, or damage national security. Also referred to as "Program Sensitive Information".

Shrubland

Areas dominated by shrubs, with a density of trees too low to meet an internationally accepted definition of forest, including chaparral, scrubland, heathland and thickets

Soil organic carbon

Organic carbon in mineral and organic soils (including peat) to a specified depth chosen by the host country for its UNFCCC national inventory accounting and applied consistently through the crediting period. Live fine roots (of less than the threshold diameter limit for belowground biomass) are included with soil organic matter where they cannot be distinguished from it empirically. In organic soils, soil organic carbon encompasses the entire depth of the organic layer (i.e., up to the depth of the mineral substrate). In the case of peatland, this depth can be several meters.

Standardized Method

A methodological approach that standardizes elements of additionality and/or the crediting baseline, for a given class of project activity, via a performance method or activity method

Standardized Methods Expert

A person with expertise and experience in standardized approaches to baselines and additionality, and who is approved by Verra for assessments of methodology elements that use standardized methods

Start Date

- The date on which the project began generating GHG emission reductions or removals. Also referred to as "Project Start Date"; or
- The date on which the jurisdictional REDD+ program began generating GHG emission reductions or removals. Also referred to as "Program Start Date"

Subnational Jurisdiction

An administrative- or other sub-unit within a country, such as a state, province, region, department, district, or an eco-region or other defined area, specified in the jurisdictional program description

Tool

A type of module that provides a procedure for performing a specific analysis

Uncertainty

Uncertainty is a parameter associated with the result of measurement that characterizes the dispersion of the values that could be reasonably attributed to the measured amount

Validation Report

The written report of validation prepared by the validation/verification body in accordance with the VCS Program rules

Validation Representation

- The deed issued by the validation/verification body, referencing the validation report to which it relates, containing a unilateral representation that it has validated the project's compliance with the applicable VCS Program rules, and which is prepared using the *VCS Validation Deed of Representation Template*; or
- The deed issued by the validation/verification body, referencing the validation report to which it relates, containing a unilateral representation that it has validated the jurisdictional baseline's or program's compliance with the applicable VCS Program rules, and which is prepared using the *VCS JNR Baseline Validation Deed of Representation Template* or the *VCS JNR Program Validation Deed of Representation Template*, respectively

Validation/Verification Body (VVB)

An organization approved by Verra to act as a validation/verification body in respect of providing validation and/or verification services in accordance with the VCS Program rules

VCS Program

The GHG program operated by Verra which establishes rules and requirements that operationalize the *VCS Standard* to enable the validation of GHG projects and programs, and the verification of GHG emission reductions and removals

VCS Program Rules

The rules and requirements set out in the *VCS Program Guide*, the *VCS Standard* and the other VCS Program documents; such rules and requirements may be updated from time–to-time

VCU Conversion Representation

The unilateral representation issued by the project proponent, prepared using the applicable VCS Program template and made in respect of cancellation of GHG credits under another GHG program and/or conversion of GHG credits issued under an approved GHG program into VCUs

VCU Issuance Levy

The fee charged by Verra at the time of VCU issuance to cover the administration costs of the VCS Program

Verification Period

The time period specified in a verification report during which the GHG emission reductions or removals were generated and have been verified by a validation/verification body

Verification Report

The written report of the verification prepared by the validation/verification body in accordance with the VCS Program rules

Verification Representation

- The deed issued by the validation/verification body, referencing the verification report to which it relates, containing a unilateral representation that it has verified the relevant GHG emission reductions or removals in accordance with the applicable VCS Program rules, and which is prepared using the *VCS Verification Deed of Representation Template*; or
- The deed issued by the validation/verification body, referencing the verification report to which it relates, containing a unilateral representation that it has verified the relevant GHG emission reductions or removals in accordance with the applicable VCS Program rules, and which is prepared using the *VCS JNR Program Verification Deed of Representation Template*

Verified Carbon Unit (VCU)

A unit issued by and held in the Verra registry representing the right of an accountholder in whose account the unit is recorded to claim the achievement of a GHG emission reduction or removal in an amount of one (1) metric tonne of CO_2 equivalent that has been verified by a validation/verification body in accordance with the VCS Program rules. Recordation of a VCU in the account of the holder at the Verra registry is prima facie evidence of that holder's entitlement to that VCU.

Verra Registry

The platform that records all projects and programs (listed and registered) and VCUs issued under the VCS Program. Provides public access to all project, program and VCU information, including retirement and tracking of the AFOLU and jurisdictional pooled buffer accounts, and provides project and jurisdictional proponents with the ability to list and register projects and programs, and issue, hold and retire VCUs.

Verra Website

The Verra website: www.verra.org

Vintage

The set of GHG emission reductions or removals generated by a project or program during a single vintage period

Vintage Period

The time period for which a particular set of GHG emission reductions or removals generated by the project or program are verified, which may be any subset of a verification period

Wetland

Land that is inundated or saturated by water for all or part of the year (e.g., peatland), at such frequency and duration that under natural conditions they support organisms adapted to poorly aerated and/or saturated soil. Wetlands (including peatlands) cut across the different AFOLU categories. Project activities may be specific to wetlands or may be combined with other AFOLU activities.

Wood products

Products derived from wood harvested from a forest, including fuelwood and logs and the products derived from them such as sawn timber, plywood, wood pulp and paper

3 ACRONYMS

ACoGS	Avoiding Conversion of Grasslands and Shrublands
AFOLU	Agriculture, Forestry and Other Land Use
ALM	Agricultural Land Management
ANSI	American National Standards Institute
APC	Avoiding Planned Conversion
APDD	Avoiding Planned Deforestation and Degradation
APWD	Avoiding Planned Wetland Degradation
ARR	Afforestation, Reforestation and Revegetation
AUC	Avoiding Unplanned Conversion
AUDD	Avoiding Unplanned Deforestation and Degradation
AUWD	Avoiding Unplanned Wetland Degradation
CDM	Clean Development Mechanism
CGLC	Cropland and Grassland Land-use Conversions
CIW	Conservation of Intact Wetlands
DBH	Diameter at breast height
DSH	Diameter at stump height
ERA	Extended Rotation Age
FAO	Food and Agriculture Organization
GHG	Greenhouse Gas
GWP	Global Warming Potential
ICM	Improved Cropland Management
IFM	Improved Forest Management
IGM	Improved Grassland Management
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
JNR	Jurisdictional and Nested REDD+

LtHP	Low-productive to High-productive Forests
LtPF	Logged to Protected Forests
ODS	Ozone-Depleting Substances
PDT	Peat Depletion Time
REDD	Reduced Emissions from Deforestation and Degradation
RIL	Reduced Impact Logging
RS	Remote Sensing
RWE	Restoring Wetland Ecosystems
SDT	Soil Organic Carbon Depletion Time
UNFCCC	United Nations Framework Convention on Climate Change
VVB	Validation/Verification Body
VCS	Verified Carbon Standard
VCU	Verified Carbon Unit
WRC	Wetlands Restoration and Conservation

APPENDIX 1 DOCUMENT HISTORY

Version	Date	Comment
v4.0	19 Sep 2019	Initial version released under *VCS Version 4*.

VERRA

Standards for a Sustainable Future

Verified Carbon Standard

Climate, Community & Biodiversity Standards

Sustainable Development Verified Impact Standard

VCS Methodology

VM0001

Infra-red Automatic Refrigerant Leak Detection Efficiency Project Methodology

Version 1.1

17 March 2017

Sectoral Scope 11

I. SOURCE, DEFINITIONS AND APPLICABILITY

Sources

This methodology is based on the project activity "HFC Refrigerant Carbon Credit Project", whose baseline and monitoring methodology and project design document were prepared by CN Business Network in consultation with its Environmental Advisory Board.

This methodology also draws upon the latest approved versions of the following tools:

- The CDM "tool for the demonstration and assessment of additionality"
- WRI/WBCSD's "The GHG Protocol for Project Accounting"

Both tools lay out useful guidance regarding the investment and barriers analysis referenced in this VCS methodology; the GHG Protocol is also germane to the common practice assessment. For more information regarding the CDM tools please refer to http://cdm.unfccc.int/goto/MPappmeth.
For more information on the WRI/WBCSD tool, please refer to http://www.ghgprotocol.org/files/ghg_project_protocol.pdf.

Selected approach from paragraph 48 of the CDM modalities and procedures

The project will be assessed based upon the following approach:

1. Using "Existing actual or historical emissions, as applicable"

Definitions: Please provide definitions of key terms that are used in this proposed new methodology

2. For the purpose of this methodology, the following definitions apply:

- **Infrared (IR) real time automatic leak detection system**: Refrigerant leak detection system that monitors refrigerant at regular intervals throughout the day using infrared technology and communicates readings back to a central monitoring center on a real time basis.
- **DX refrigeration equipment**: Direct Expansion (DX) refrigeration equipment that uses a two-phase fluid directly in an evaporator to absorb heat through an expansion and evaporation process.
- **HVAC system**: An air conditioning system that provides comfort heating and cooling to a room, area or entire building.
- **Seasonal top-offs and draw-downs**: The adjustment of the refrigerant charge quantity of a system to compensate for the additional refrigerant needed for condenser flooding in winter to maintain head pressure and the removal of refrigerant in the summer to prevent overfilling of the system receiver.
- **EPA GreenChill program**: An EPA program open to supermarket chains, refrigerant producers and supermarket refrigeration manufacturers whose goal is to reduce supermarket refrigeration leak rates through the collaborative effort of its members.
- **HFC**: Hydrofluorocarbon, a greenhouse gas covered under Kyoto Protocol
- **HCFC**: Hydrochlorofluorocarbon, a greenhouse gas not covered under Kyoto Protocol but under consideration by the VCS as a qualifying credit.

Applicability conditions/Eligibility Criteria

3. This methodology applies to project activities that install infra-red, real-time leak detection systems on US retail DX refrigeration equipment systems in order to reduce leaks of HFC refrigerants. A parallel methodology has been prepared which will include HCFC refrigerants pending VCS board determination regarding the parameters for their eligibility.

4. The methodology is applicable under the following conditions:

   - Applies to the installation of infra-red (IR), real-time automatic leak detection/management systems installed in commercial refrigeration systems in US supermarkets provided the IR equipment is new or has been sourced from within the project boundary as the underlying refrigeration equipment is replaced or decommissioned
   - When installed onto DX refrigeration systems, so that there is no change in underlying refrigeration system technologies
   - Including any associated HVAC systems in these same locations which are managed using the same IR systems
   - Focused exclusively upon HFC leakage rates (since these are the Kyoto gases) (with a contingency to expand to HCFC's pending any VCS policy review as outlined in the second accompanying methodology)
   - Within the United States
   - Focused, in the US, only on refrigeration systems containing less than 2000 lbs[1] refrigerant charge
   - Supported by data systems for leak reporting/management which are used for ozone depleting substance (ODS) compliance purposes

NOTE: If projects seek to qualify located outside of the US, the VCS double approval process will be required to establish whether the conservative baseline cap (in the US provided by EPA's Green Chill program leak rates) can be provided on a credible basis by appropriate entities in those locations.

NOTE: If a country's designated agency is unable to provide the conservative cap baseline cap, then the methodology will still stand without including this potential conservative cap baseline process since the additionality of a project, based upon its historical baseline, can still be adequately assessed, on a retrofit basis, using the CDM and WRI tools reference.

II. BASELINE METHODOLOGY PROCEDURE

Project boundary

5. The physical boundary is the set of retail stores in which the infra-red, real-time leak (IR) detection systems have been installed and HFC refrigerants are used. When HVAC systems in these stores are supported by these same IR detection systems, then the physical boundary includes these HVAC systems also.

6. The greenhouse gases included are HFC's, which are increasingly used as refrigerants in retail refrigeration systems. [A parallel methodology has been developed to potentially also include HCFC's pending VCS board confirmation of their status and eligibility criteria.]

7. The methodology covers following categories of HFC emissions reductions from the equipment within the project boundary:
   - HFC emissions during DX refrigeration equipment operations and/or repairs/maintenance
   - HFC emissions during seasonal "top offs" and "draw downs"

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[1] Quantities are indicated in the imperial units (lb) since the scope of this methodology is currently the US: however, if the methodology is extended to other regions, SI-units should be used and adapted accordingly.

Table 1: Emissions sources included in or excluded from the project boundary

Source		Gas	Included?	Justification / Explanation
Baseline	Emissions from Retail Refrigeration Equipment	HFC	Yes	Project activity is prevention of HFC leaks to atmosphere
		HCFC	Pending	Separate methodology considers project activity which would include prevention of HCFC leaks to atmosphere, pending VCS board decision regarding inclusion of ODS's and relevant eligibility criteria. This methodology does not include HCFCs.
		Other: CO_2 CH_4	No	IR systems do not impact energy efficiency of underlying DX systems; rather, more timely maintenance of refrigerant levels enables refrigeration equipment to run more efficiently and thus positive CO_2 gains are conservatively set to zero.
	Upstream/ Downstream	HFC	No	Project activity produces positive gains upstream, which are conservatively set at zero. Project activity has no impact or influence on separate end of life decisions regarding refrigerant disposal as equipment is decommissioned: separate credit methodologies exist for these actions taken in this realm
		HCFC	No	Ibid
		Others	No	Ibid
Project activity	Emissions from Retail Refrigeration Equipment	HFC	Yes	Project activity is prevention of HFC leaks to atmosphere
		HCFC	Pending	Separate methodology considers project activity which would include prevention of HCFC leaks to atmosphere, pending VCS board decision regarding inclusion of ODS's and relevant eligibility criteria. This methodology does not include HCFCs.
		Other: CO_2 CH_4	No	IR systems do not impact energy efficiency of underlying systems; rather, more timely maintenance of refrigerant levels enables refrigeration equipment to run more efficiently and thus positive CO_2 gains are conservatively set to zero. Electricity required to run IR systems is de minimis (91kwh/year vs 3-4m kwh/year for each store of which 1.5-2m kwh/year for refrigerant equipment/HVAC systems: less than 0.01%)
	Upstream/ Downstream	HFC	Yes	Project activity produces positive gains upstream, which are conservatively set at zero. Project activity has no impact or influence on separate end of life decisions regarding refrigerant disposal as equipment is decommissioned: separate credit methodologies exist for these actions taken in this realm
		HCFC	Pending	Ibid
		Other: CO_2 CH_4	No	Ibid

Procedure for the Selection of the Most Plausible Baseline Scenario

8. Since IR detection systems are retrofitted on top of existing refrigeration management systems, the baseline scenario shall be determined by analyzing the following potential alternatives
   - Implementing the project activity without carbon financing; and
   - Continuation of the present practice without IR detection systems, which shall be described in the PDD.

9. Although retrofit projects do not require any further conservative measure to ensure that credits are not granted for reductions from levels considered to be unacceptably high, this methodology will ideally also include the consideration of a conservative cap baseline. Thus this further conservative cap baseline option will be founded upon the following:
   - Best practice leak rates as demonstrated by a national voluntary leak reduction program supported by a credible agency or organization whose average reported leak rates (at some agreed level of performance) and eligibility as a conservative cap baseline has been separately approved by VCS validators, through a double approval process, as reasonable
     - In the US, this alternative baseline will be provided by EPA Green Chill program's reported leak rates for their supermarket members, as estimated to represent the 50% percentile of industry performance based on their memberships' reported leak rates and share of industry stores (see 20 below)

10. Assessment of National Policy/regulations on HFCs
    - List national or regional policies/regulation to evaluate whether they a) place a fixed limit on cumulative basis for the total HFC emissions within a given year's operations; b) transfer ownership of all resulting HFC reductions to other entities to meet their separate compliance obligations (e.g. such as would arise in upstream cap/trade requirements); c) stipulate the installation of IR leak detection systems as the only option to fulfill retail operations' compliance purposes.
    - If such policies exist, assess the enforcement of the policies.
    - If above-mentioned policies/regulation exist and are enforced, then the project activity without carbon financing is the baseline scenario and thus the project does not qualify for credits.

    This regulatory assessment should be undertaken again when the project comes forward for re-validation at the end of the first and second crediting period (see article 25).

11. This methodology is applicable only if the baseline scenario includes the continuation of the present practice.

12. NOTE: Consistent with the GHG Protocol for Project Accounting, a review of the barriers faced by the two baseline alternatives – continuation of current practice and adoption of the IR project -- is undertaken in the Additionality section below. In a retrofit project, continuation of the present practice typically faces no barriers and thus constitutes the baseline. This methodology is only applicable if, in the barriers analysis below, the continuation of present practice faces no barriers and the IR project without carbon financing can demonstrate, as in the additionality section below, that it faces barriers to implementation.

13. NOTE for US: If EPA Green Chill program is unable in a given year to provide the alternative baseline cap information, then the methodology will still stand without including this potential conservative cap baseline since the additionality of the project, based upon its historical baseline, can still be adequately assessed, on a retrofit basis, using the CDM and WRI tools referenced.

Additionality: Please describe the procedure for demonstrating additionality

14. The additionality of the project activity shall be demonstrated and assessed using the latest version of "Tool for the demonstration and assessment of additionality" agreed by the CDM Executive Board, which is available on the UNFCCC CDM web site. (See Sources).

Proponents will use the required referenced CDM tool, and it is required that the investment analysis be performed: this will require applying the investment benchmark (2b Option III) analysis since this is a retrofit project (which precludes 2b Option II) and there are refrigerant cost savings which arise, alongside the carbon reductions(which precludes 2b Option I).

Using the CDM tool, if a further barriers analysis is required, the investment barriers as outlined in the CDM tool may be augmented with demonstration of other barriers from WRI/WBCSD (e.g. Table 8.1, see sources).

Baseline emissions

15. The baseline emissions will be determined using the yearly average leak rate arising from the total HFC and HCFCs emitted during the baseline period, whether emitted during operations, repair or maintenance of the equipment within the project boundary, and incurred in locations where HFCs are in use. The baseline period will be either:
    a) a period of three years prior to the installation of the IR equipment (year (x))
    b) a three year consecutive period including the IR installation year (x) which can extend at most three years subsequent to such installation if data records for emission rates are not accessible for a)

16. The historical baseline is anchored upon emissions rates for both HFC's and HCFC's since this is more conservative: while HFC's are gradually substituting for HCFC's, HCFC leak rates are lower than those for HFC's as confirmed by both EPA and leading companies. Thus, to adopt a baseline based only on HFC leak rates would potentially inflate credits. Since both refrigerants perform functionally comparable service, taking the blended leak rates for all refrigerants as the historical baseline for HFC credits reflects both historical emission rates for any given location while remaining conservative.

17. The data inputs will be based upon those which the company uses for its ODS/refrigerant compliance purposes. The baseline data shall therefore be based on such corporate records for the relevant project locations including the equipments' refrigerant charges and leaks/use data (based upon the leak records and/or purchase records for replacement refrigerant as reflected in the compliance systems) according to the steps described below.

18. Since this is a retrofit project and the installed base of stores in which IR systems are present may be increasing year on year, this historical baseline will need to be recalculated for each year (y) in which project credits are to be estimated based on the set of stores' equipment which has IR systems installed by year y, the year in which credits are currently to be calculated. This ensures that the historical baseline is taken from the same set of systems against which the new total IR systems have been retrofitted and against which the leak rates for year y will be estimated. Thus the baseline emissions will be given by a baseline leak rate tailored to year y: BLRy

19. The baseline emissions of HFC's are estimated using the following approach and equations:

For the year x, when the first IR systems are installed: the historical baseline would be calculated based on totals for <u>*all*</u> refrigerants in use (HCFC and HFCs), using totals for both leaks and charges across all the refrigeration systems in stores where IR systems have been installed and HFC's are in use by year y, the year in which the carbon credits are to be calculated, as:

$$BLRy = [Lx / Cx + Lx\text{-}1 / Cx\text{-}1 + Lx\text{-}2/ Cx\text{-}2\ ] / 3$$

Where:
BLRy = Baseline leak rate from stores which have IR systems installed by year *y* and which have HFC's in use by year y (%)
Lx = Total leaks from HFC and HCFC refrigerants in year x (lb) from equipment in stores which a) have the IR systems installed by year y and b) provided that HFC's are in use in this store by year y
Cx = Total Charge for HFC and HCFC refrigerants in year x (lb) from equipment in stores which a)

have the IR systems installed by year y and b) provided that HFC's are in use in this store by year y
Note: C_x will be measured consistent with the requirements for EPA ODS reporting.

Note: as confirmed in the data tables below (see 27), the total leaks and total charge volumes are estimated from the database systems used for ODS management purposes which measure the amounts of refrigerants used to refill the refrigeration equipment each time a leak occurs, reflecting the amount of refrigerant leaked. Each entry will describe the number of pounds of refrigerant installed into the equipment at the time of a leak – thus providing the data inputs which summarized over a year give totals for Lx. These same datasystems also document the refrigerant charges for each piece of equipment in the stores. Thus, again, adding these refrigerant charges for each piece of relevant equipment will give the totals for Cx.

Note: L_x includes adjustments for seasonal "top offs" and "draw downs" if practiced. These are seasonal increases and decreases in the refrigerant charge levels to adjust for seasonal temperature changes in the environment. "Top offs" will be considered a "leak" (thus an addition to emissions); "draw downs" will be considered the opposite and thus a credit to the leakage tally.

If historical leak rate information prior to IR installation is not available, a more conservative alternative historical baseline can be created using emission rates from the year x when IRs are first installed through the subsequent two years:
That is:
BLRy = [Lx / Cx + Lx+1 / Cx+1 + Lx+2/ Cx+2] / 3

Alternative Baseline Cap:

This alternative baseline cap is introduced only to provide a further measure of conservatism:

20. In parallel, an alternative baseline cap will be calculated using the leak rate information from the credible agency approved under "Applicable Eligibility Conditions". In the US, this will be the EPA Green Chill program leak rates, which EPA will provide annually to reflect, based on its members' annually reported leak rates, its estimate for the 50th percentile performance leak rate for the industry.

EPA will establish this EPA BLR_y leak rate by:

1. Estimating its members' share of total industry emissions, based on their Green Chill members' total number stores divided by the EPA's estimate of the industry's total number of stores
2. If Green Chill members' share of industry is less than 50%, the EPA BLR_y will be the lowest performing leak rate (that is the highest leak rate) from among their members' averages (provided this is not more than the EPA's estimate for the US industry average leak rate of 25% whereupon the EPA BLR_y will be considered EPA's estimate for the industry average, which is 25% in 2007).
3. If Green Chill members' share of industry is more than 50%, the EPA BLR_y will be the leak rate achieved by the supermarket member which, on a ranked basis from highest performing to lowest performing (that is lowest leak rate to highest leak rate) represents the 50[2] percentile of stores.
4. A supermarket's industry capacity will be calculated as its number of stores divided by the industry's total number of stores (consistent with #1 above)

Supermarket "i"	LR_i	IC_i	Sumi = 0 through i (ICi)
(anonymous)	Avg leak rate For Supermarket i	% Industry capacity	Cumulative Capacity
Supermarket A	7%	3%	3%
Supermarket B	9%	15%	18%

[2] Example: 50th Percentile Leak Rate Estimate at 17%

Supermarket C	11%	4%	22%
Supermarket D	13%	12%	34%
Supermarket E	15%	8%	42%
Supermarket F	17%	10%	52%
Supermarket G	19%	5%	57%
Supermarket H	21%	3%	60%

Thus EPA BLR_y is given by:

<u>If sum over all GC members for ICi <50%, then:</u>

If EPA Green Chill program has members whose total share of industry capacity has not yet reached 50% of the industry, then:

EPA BLR_y = minimum (LR_i=L_i/C_i, 25%)
Where supermarket i has the highest leak rate of the GC members and thus:
Sumi = 0 through i (ICi) is the highest for the group; and
sumi = 0 through i (ICi) < 50%
And
ICi = Si / EPA ST
And 25% is the EPA stated average for leak rates in the supermarket sector

<u>If sum over all GC members for ICi >50%, then:</u>

If EPA Green Chill program has members whose total share of industry capacity has now reached more than 50% of the industry, then:

EPA BLR_y = minimum (LR_i=L_i/C_i, 25%)
Where, for supermarket i, the sumi = 0 through i (ICi-1) <50% and sumi = 0 through i (ICi) > 50% And
ICi = Si / EPA ST
And 25% is the EPA stated average leak rate for the supermarket sector.

Where:
EPA BLRy = Baseline leak rate for HFC's and HCFC's for the Green Chill member company estimated to represent the 50th percentile performance leak rate for the industry in year x (%)
LRi = Average leak rate reported to EPA Green Chill by the supermarket "i" (across its HFC and HCFC refrigerants) in year x (%) whose performance sits at this 50th percentile
Li = Total leaks from HFC and HCFC refrigerants in year x (lb) from supermarket "i" as reported to EPA Green Chill
Ci = Total Charge for HFC and HCFC refrigerants in year x (lb) reported by supermarket "i" to EPA Green Chill
ICi = Share of industry capacity represented by supermarket i in year x Si = Number of stores operated by supermarket i
EPA ST = Total number US supermarket stores as determined by EPA Green Chill Program

NOTE: If the EPA BLR_y data does not exist for year x for a project seeking validation, because year x precedes 2007, then the first year of EPA Green Chill program available data shall be used as the conservative cap baseline. The EPA 50th percentile leak rate is determined to be 25% for 2007. This approach is conservative, given the gradual improvements which will take place over time in the conservative cap baseline at the 50th percentile leak rate level.

NOTE: If EPA's BLR_y data is not available in a given year, then the prior year's estimates will be used. If the EPA Green Chill program ceases to exist or cannot provide further data, then the alternative baseline will not be considered as part of this methodology.

Final Baseline Selection:

21. If the historical project baseline (BLRy) is greater than the alternative baseline cap, (EPA BLRy,) then the alternative baseline cap shall be the baseline. This approach is included in order to ensure that a supermarket chain who's historical emissions rate was particularly large would not be awarded credits for reductions from a baseline that, although historically accurate, could arguably be considered inflated. Using the EPA BLRy also ensures that, unless the historical baselines are already more conservative, a baseline is selected that will reflect any gradual improvements in the leak rate efficiencies for the Green Chill member companies and thus the industry.

Thus, if BLRy > EPA alternative baseline selected (EPA BLRy), then the Final BLRy would the lower of these options

This is given by:
Final BLRy = @ min (BLRy, EPA BLRy)

Where:
Final BLRy = Baseline leak rate to be adopted for the project for use by year y (%)
BLRy = Baseline leak rate for the supermarket submitting the project, arising from stores which have IR systems installed by year *y* and which have HFC's in use by year y (%)
EPA BLRy = Baseline leak rate for HFC's and HCFC's for the Green Chill member company estimated to represent the 50^{th} percentile performance leak rate for the industry in year x (%)

Note: the project's emission reductions will then be calculated by comparing the final baseline leak rate to the later year's leak rate to derive the total pounds of refrigerant avoided in year y (by applying the difference in leak rates to the refrigerant change in situ in year y). The composition of refrigerants used by year y may have changed from year x. So the average global warming potential of the released gases in year y will then be applied to these pounds reduced in year y since the global warming reduction reflects the reduced usage of the gas combinations used during that particular year y This thus ensures that the credits granted in year y reflects the reduction efficiencies in pounds of refrigerant emitted in year y compared to year x (since the refrigerant types are interchangeable) but using GWP intensities that reflect the refrigerant usage from the particular crediting year y.

Project emissions

22. Project emissions will be determined using the average leak rate arising from the total HFC emitted during year y, the year in which credits are sought, whether emitted during operations, repair or maintenance of the equipment within the project boundary.

The project emissions from HFC's are estimated using the following approach and equations:

PLRy = [Ly / Cy]

Where:
PLRy = Project leak rate from equipment which has both HFC's and IR systems installed by year *y* (%) Ly = Total leaks from HFC refrigerants in year y (lb) from this same set of equipment
Cy = Total Charge in year y for HFC refrigerants (lb) within this same set of equipment
Note: Ly includes adjustments for HFC top offs and draw downs if practiced

Again, the project's emission reductions will be calculated by comparing the final baseline leak rate to the project year y's leak rate to derive the total pounds of refrigerant avoided in year y (by applying the difference in leak rates to the refrigerant change in situ in year y). The weighted average global warming potential of the released gases in year y will then be applied to these pounds reduced in year y since the global warming benefits reflects the reduced usage of the gases used during that particular year.

Leakage

23. There is no requirement for the project to consider leakage as it is not likely to occur for the following reasons:

a. Any refrigerant savings achieved in the supermarket location due to lower leak rates will result in smaller refrigerant purchases. Thus any upstream leaks during manufacture or transportation of the refrigerant (which are estimated to be a relatively low percentage of the total supply chain leaks from refrigerant use) will also be saved. This constitutes "positive leakage": efficiencies during supermarket use will achieve further leak reductions upstream. These are conservatively set at zero in this methodology and thus there is no further project requirement to consider leakage.

b. Any "top up" or "draw down" changes in refrigerant use for the relevant periods is already captured under L_y and L_x

c. The IR systems do not control, influence or impact the release of refrigerants as equipment is decommissioned. Separate credit methodologies already exist to address whether beyond business as usual GHG reductions are gained through completely separate and distinct actions which are not related to IR system installations. Without any influence, this methodology must assume that the refrigeration equipment's original charges are handled on a business as usual basis during decommissioning. Incorporating their future decommissioning choices also risks double counting reductions with other project methodologies which VCS is developing and already exist under CCX and CDM.

d. The methodology does not apply to used IR equipment sourced from outside the project boundary (since in this case emissions could rise in the external location while credits were counted within the project). Note: IR equipment already installed within the project boundary DX equipment can be removed (e.g. if DX equipment is being decommissions) and the IR equipment used again (e.g. if new DX equipment is purchased) since these changes all take place within the project boundary.

Emission reductions

24. Emission reductions are calculated as

follows: LRRy =Final BLRy - PLRy

Where:
LRRy = Leak rate reduction for project in year *y* (%)
PLRy = Project leak rate from equipment which has both HFC's and IR systems installed by year *y*
(%) Final BLRy = Final baseline leak rate (as defined above as the lower of the historical leak rate
BLR_y (from equipment which has IR systems installed by year *y* (%)) and the EPA Baseline Cap (%))

ERy = LLRy * Cy * GWPHFC-y

Where:
ERy = Emissions reduction in year y (tCO2e/yr)
LRRy = Leak rate reduction for project in year
y (%)
Cy = Total Charge for HFC refrigerants in year y (lb) within this same set of equipment
GWPHFC-y = Weighted average global warming potential of HFC's installed/used in year y (tCO2e/lbHFC)

And, to be clear, GWPHFC-y is calculated by:

GWPHFC-y = sum over all HFC types T [LHFC-T-y * GWPHFC-T-y] / sum (over T) LHFC-

T-y Where:
LHFC-T-y = Total leaks from HFC refrigerant Type T in year y (lb) from this same set of equipment
GWPHFC-T-y = Weighted average global warming potential of HFC's Type T installed/used in year y (tCO2e/lbHFC)

Elaborating on this calculation, again for clarity, this is estimated as:
GWPHFC-y =
[sum HFC leaks (lbs) from HFC #1 * GWP #1 + sum HFC leaks from HFC #2 * GWP #2 + etc + sum HFC leaks (lbs) from HFC#m * GWP#m]
Divided by:
[Total HFC leaks (lbs) (across # 1 through m) from systems with IR installed by year y]

Changes required for methodology implementation in 2nd and 3rd crediting periods

25. No changes are required for consideration of the methodology in future crediting periods. It should be noted that the project developer will need to check on national and regional policies at the renewal of each crediting period, in case these have changed paying particular attention to those already outlined above. In case the project, or part of the project activity, has become part of the baseline due to changes in policies, the project developer will have to redefine the baseline as appropriate or potentially withdraw the project from consideration for a new VCS project period.

Data and parameters not monitored

26. In addition to the parameters listed in the tables below, the provisions on data and parameters not monitored in the tools referred to in this methodology apply.

Data / parameter:	1 GWPHFC-T-y / GWP of HFC type T
Data unit:	t CO2e/lb HFC
Description:	Global warming potential of HFC used in year y
Source of data:	GWP values must be derived from sources specified by the VCS rules
Measurement procedures (if any):	
Any comment:	

Data / parameter:	2 GWPHCFC-T-y / GWP of HCFC type T
Data unit:	t CO2e/lb HCFC
Description:	Global warming potential of HCFC Type T used in year y
Source of data:	GWP values must be derived from sources specified by the VCS rules
Measurement procedures (if any):	
Any comment:	y

Data / parameter:	3 EPA Alternative Baseline Leak Rate EPA BLRy
Data unit:	%
Description:	Baseline leak rate coverage HFC's and HCFC's for the Green Chill member company estimated to represent the 50th percentile performance leak rate for the industry in year x (%)
Source of data:	EPA Green Chill Program Director
Measurement procedures (if any):	For the US: EPA will report these results to the VCS or other designated agency on a yearly basis
Any comment:	Use EPA BLRy cited for year x unless project initiated prior to 2007 whereupon EPA BLR2007 will be used If the EPA Green Chill program ceases to exist or cannot provide further data, then the alternative baseline will not be considered as part of this methodology.

III. MONITORING METHODOLOGY

27. All data collected as part of monitoring should be archived electronically and be kept at least for 2 years after the end of the last crediting period. 100% of the data should be monitored if not indicated otherwise in the tables below. All measurements should be conducted with calibrated measurement equipment according to relevant industry standards.

28. As an overview, the monitoring and verification/validation (M&V) system will require:

- Leak management data to be drawn from companies' compliance records for ODS refrigerants under Montreal Protocol
    - Thus the data management systems upon which a project's core leak/charge data draws will already be in place and used for complementary regulatory purposes.
    - If the project draws upon HFC reductions, (when the refrigerant is not an ODS), the HFC leaks must be using the same process and compliance systems that apply to ODS refrigerants in order for this data to have the integrity needed.
- Review of the further calculations performed in order to establish cumulative annual leak rates for systems and relevant averages (historical leak rates and current year leak rates) which will typically be conducted separately from compliance records
    - Including the review of seasonal invoices or data logs for "top up" "draw down" changes in refrigerants if these are not automatically included in the compliance real time data systems.
- Comparison of a companies' historical baseline leak rates (BLRy) to the EPA Green Chill conservative cap baseline (EPA BLRy) in order to pick the more conservative baseline and not award credits to those whose historical performance would be outside sensible industry average or better practice norms.
- Review of calculations of the average weighted GWP based on the volume of refrigerants used by the supermarket in the crediting year, allocating GWP savings across HFC404A, HFC507 and other HFC's on an accurate pro-rata annual basis as established by the methodology

NOTE: While the IR systems has a real time, electronic LDMS system in order to provide timely alerts and communications, this methodology does not assume that the monitoring and verification systems are necessarily electronically based. Similarly, although some companies have chosen to use third party agencies (e.g. contractors such as Verisae, Parasense), there is not requirement in this methodology that the data management be performed by such entities. The project's third party

VCS verifier is sufficient to establish the integrity of the data systems applied to the project crediting purposes. However, consistent with conflict of interest concerns, the company's third party service agency which provides real time leak rate monitoring services cannot simultaneously serve as the third party carbon credit verifier for VCS carbon crediting purposes.

29. Thus, for clarity's sake only, the verification actions would focus upon:

1. Ensuring that the charge and leak data are consistent with the logs in the companies' compliance record
    a. Measurement units: weight
2. Assessing whether top up/draw down procedures are used for seasonal variations and, if so, ensuring that these refrigerant changes are part of the cumulative leak rate data base (even if they are not part of the compliance records)
3. Reviewing the calculations for the cumulative annual leak rates for the relevant systems to ensure these are accurately assessed
4. Reviewing the calculations for the historical leak rate baseline and current year leak rates across the relevant systems to ensure they meet the Methodology specifications
5. Comparing the historical leak rate to the EPA alternative baseline cap in order to ensure that the more conservative one is selected
6. Accurate estimates of the average GWP for the refrigerants used in each year (since this is updated annually to reflect any changes in the composition of refrigerants used) consistent with the methodology. The lbs of refrigerants used is again taken from the same data log in #1 and 3

30. All the calculations are outlined in the Methodology. The monitoring frequencies and measurement procedures from which the refrigerant leaks are tracked will have been established by the underlying compliance requirements for ODS and will be considered sufficient. In the US, this will typically mean that refrigerant leaks will be aggregated on a monthly basis while refrigerant charges will be updated annually, drawing again on the underlying ODS compliance databases. Similarly, the measurement and monitoring equipment in the IR systems will be calibrated according to current good practice consistent with such compliance requirements.

Data and parameters monitored

Data / parameter:	Lx
Data unit:	Lbs
Description:	Total leaks from HFC and HCFC refrigerants in year x (lb) from all DX equipment in stores which a) have the IR systems installed by year y and b) in which HFC's are in use by year y
Source of data:	Refrigerant compliance logs for relevant stores/equipment
Measurement procedures (if any):	The total leaks volumes are derived from the database systems used for ODS management purposes. These measure the amounts of refrigerants used to refill the refrigeration equipment each time a leak occurs during year x, reflecting the amount of refrigerant leaked. Thus each entry will describe the number of pounds of refrigerant installed into the equipment at the time of a leak during year x – thus providing the data inputs which summarized over year x give the total leak volumes for Lx.
Monitoring frequency:	Lx is annually updated if the IR systems are installed in new stores each year. Leaks are typically reported in compliance logs as new refrigerant is installed in the equipment. Compliance logs report these as monthly totals from which annual totals can be calculated.

QA/QC procedures:	Check for consistency between project data logs and compliance logs
Any comment:	Ensure that any seasonal "top up" or "draw down" additions/removals are included/netted out in Lx even if these are not incorporated into compliance logs

Data / parameter:	Cx
Data unit:	Lbs
Description:	Total Charge for HFC and HCFC refrigerants in year x (lb) from all DX equipment in stores which a) have the IR systems installed by year y and b) in which HFC's are in use by year y
Source of data:	Refrigerant compliance logs for relevant stores/equipment
Measurement procedures (if any):	These same ODS management datasystems also document the refrigerant charges for each piece of equipment in the stores. Thus, again, adding these refrigerant charges for each piece of relevant equipment as itemized for year x will give the totals for Cx.
Monitoring frequency:	Cx is annually updated if the IR systems are installed in new stores each year to include the total HFC + HCFC capacity charges for the new stores
QA/QC procedures:	Check for consistency between project data logs and compliance logs
Any comment:	Note that charge capacities for HFCs may have changed over baseline period because these refrigerants are gradually replacing HCFC's, whose charge levels could be declining. Since Cx can fractionally change if IR systems are installed in new stores, annual monitoring of data/compliance logs in year y for total HFC and HFCF charge amounts in baseline years is required to take into accounts stores where new IR systems have been installed by year y. Note: Cx will be measured consistent with the requirements for EPA ODS reporting.

Data / parameter:	Ly
Data unit:	Lbs
Description:	Total leaks from HFC refrigerants in year y from equipment which has HFC's installed by year y and which also has IR systems installed by year y
Source of data:	Refrigerant compliance logs for relevant stores/equipment
Measurement procedures (if any):	The total leaks volumes are derived from the database systems used for ODS management purposes. These measure the amounts of refrigerants used to refill the refrigeration equipment each time a leak occurs during year y, reflecting the amounts leaked. Thus each entry will describe the number of pounds of refrigerant installed into the equipment at the time of a leak during year y – thus providing the data inputs which summarized over year y give the total leak volumes for Ly.
Monitoring frequency:	Assessed once for year y. Leaks typically totalled on a monthly basis in compliance logs.
QA/QC procedures:	Check for consistency between project data logs and compliance logs

Any comment:	Ensure that any seasonal "top up" or "draw down" additions/removals are included/netted out in Ly even if these are not incorporated into compliance logs

Data / parameter:	Cy
Data unit:	Lbs
Description:	Total charge in year y for equipment which has HFC installed as refrigerant by year y and which also has IR systems installed by year y
Source of data:	Refrigerant compliance logs for relevant stores/equipment
Measurement procedures (if any):	These same ODS management datasystems also document the refrigerant charges for each piece of equipment in the stores. Thus, again, adding these refrigerant charges for each piece of relevant equipment as itemized for year y will give the totals for Cy.
Monitoring frequency:	Assessed once for year y.
QA/QC procedures:	Check for consistency between project data logs and compliance logs
Any comment:	Note that charge capacities for HFCs will likely be rising over time as these refrigerants are installed across more equipment in a given store, replacing HCFC's. Thus annual monitoring of data/compliance logs in year y for total HFC charge amounts is required since they will likely not equal C_X.

Data / parameter:	LHFC-T-y
Data unit:	Lbs
Description:	Total leaks from HFC refrigerant Type T (only) in year y (lb) from equipment which has HFC's installed by year y and which also has IR systems installed by year y
Source of data:	Refrigerant compliance logs for relevant stores/equipment
Measurement procedures (if any):	As above for Lx and Ly for relevant HFC leaks by individual type.
Monitoring frequency:	Assessed once for year y. Leaks typically totalled on a monthly basis in compliance logs.
QA/QC procedures:	Check for consistency between project data logs and compliance logs
Any comment:	Ensure that any seasonal "top up" or "draw down" additions/removals are included/netted out in LHFC-T-y even if these are not incorporated into compliance logs

IV. REFERENCES AND OTHER INFORMATION

ICF report for GreenChill Partnership,
EPA http://www.epa.gov/Ozone/partnerships/greenchill/downloads/EPASupermarketReport_PUBLIC_30Nov05.pdf

CARB: Appendix A http://www.arb.ca.gov/cc/reftrack/refrigerant_mgmt_program_appendix_a_1_26.pdf

CARB: Appendix B http://www.arb.ca.gov/cc/reftrack/refrigerant_mgmt_program_appendix_b_1_26.pdf

CARB: Draft Regulations http://www.arb.ca.gov/cc/reftrack/refrigerant_mgmt_program_draft_rule_1_26.pdf

EPA Award to Giant Eagle
http://www.achrnews.com/Articles/Breaking_News/BNP_GUID_9-5-2006_A_10000000000000424358

EPA Green Chill Update: "EPA and the Supermarket Industry: Partnership in Environmental Protection"

Appendix 1: Document History

Version	Date of Issue	Comment
1.0	16 Feb 2010	Initial version, developed by CN Business Network
1.1	17 Mar 2017	Clarified that GWP values must be derived from sources specified by the VCS rules (GWP parameter tables listed below paragraph 26)

NEW COGENERATION FACITILITES SUPPLYING LESS CARBON INTENSIVE ELECTRICITY TO GRID AND STEAM AND/OR HOT WATER TO ONE OR MORE GRID CUSTOMERS

SOURCE

This Methodology is based on elements of the following CDM methodologies:

- AM0029 V 02 " Baseline Methodology for Grid Connected Electricity Generation Plants Using Natural Gas";
- AM0048 "New Cogeneration facilities supplying electricity and/or steam to multiple customers and displacing grid/off grid electricity generation with more carbon intensive fuels".

This methodology also refers to the latest approved version of the following tools:

- Methodological "Tool for the demonstration and assessment of additionality";
- Methodological "Tool to calculate the emissions factor of an electricity system";
- Methodological "Combined tool to identify the baseline scenario and demonstrate additionality";
- Methodological "Tool to calculate baseline, project and/or leakage emissions from electricity consumption".

DEFINITIONS

Waste Heat A by-product thermal energy from machines or process equipment for which no useful application is found in the absence of project activity and which is demonstrated to be unused in other activities

Project Customer An industrial and/or commercial and/or residential entity receiving electricity, steam and/or hot water from the project facility. This may include the power grid, in the case of electricity and the steam and/or hot water generating facility or the entity that draws steam and/or hot water off a steam and/or hot water grid. Clusters of smaller residential or commercial customers can be considered as a single project customer.

Project Facility Combined heat and power generation facility developed as a project activity to supply electricity to the power grid and steam and/or hot water to grid/off-grid to any industrial, commercial and/or residential entities.

APPLICABILITY

- The project activity is the construction and operation of a new gas fired cogeneration plant which is connected to the electrical grid and where all the electricity produced other than that required to operate the cogeneration facility is exported to the grid;

- The geographical/physical boundaries of the baseline power grid can be clearly identified and information is publicly available to establish the grid emissions factor;

- Natural gas is sufficiently available in the region or country, for example future natural gas power capacity additions of similar size to that of the project activity are not constrained by the use of natural gas in the project activity;

- This methodology is only applicable to cases in which the steam and/or hot water that is to be displaced by the project activity is either produced for export to a steam/hot water grid or is drawn from a steam/hot water grid. It shall not be applied to situations in which it would lead to the displacement of steam and/or hot water that is generated at a project customer's installations to meet its heating/process requirements;

- Where the project activity results in the substitution of imported steam and/or hot water, the project proponent shall provide evidence to prove that the thermal energy which is displaced is that which the project customer(s) would have otherwise imported from the grid and not that which is self-generated, assuming that such option exists for the project customer(s);

- The methodology is applicable only to project customers that do not cogenerate electricity, steam and/or hot water in the baseline scenario;

- Only applicable to project customers that ensure that the equipment displaced by the project activity will not be sold for other purposes;

IDENTIFICATION OF THE BASELINE SCENARIO AND DEMONSTRATION OF ADDITIONALITY

STEP 1. Identification of realistic and credible alternative baseline scenarios that are consistent with current laws and regulations

Substep 1a. Define realistic and credible alternatives to the project activity.

Project proponents shall identify realistic and credible alternative(s) available to both the project developer and project customer(s) that enable electricity, steam and/or hot water:

- to be produced in similar quantities as by the project activity;
- to deliver similar services;
- to be provided at the same grade, quality or properties as those provided by the proposed VCS project activity .

In other words, they shall identify possible baseline scenario alternatives that enable:

- electricity to be generated and sold to the grid, for base or peak load service;
- steam at a required pressure and temperature to be generated, delivered and sold to one or more project customers;
- hot water to be generated at the required temperature and sold to one or more project customers.

The proposed VCS project activity constitutes an alternative means for both the project developer and the project customers to produce electricity and thermal energy (when the project customer is a District Heating Plant that produces steam and/or hot water) or to source or buy it from (when the project customer is a thermal energy end user connected to a District heating steam/hot water grid). Hence, project developer and project customers, be it through the actions they take or do not take, define what the most plausible baseline scenario would most likely be in the absence of the project activity. In the case of power generation, the baseline scenario is shaped by the actions taken or not by the project developer and other market players that sell power to the grid.

Hence, in establishing what the most likely baseline scenario is, baseline alternative scenarios shall be identified for both the project developer and the project customer(s). Technologies or practices that have been implemented previously or are currently being introduced in the relevant country and that constitute alternatives for an independent utility producer shall be considered as part of this exercise. Those technologies or practices that do not meet this condition, shall not be considered a baseline scenario alternative, because they would be a “first of their kind”.

Baseline alternative scenarios for the project participants are therefore related to the technology and circumstances but also to the investor’s line of business or activity.

It shall be noted that for the purpose of this methodology, actions taken by project customers which are energy end users (i.e. purchase thermal energy to use it for heating/ process needs as opposed to selling it on to project customers who in turn resell it to their own customers) and result in a reduction in the end user demand of energy in the form of steam and/or hot water are not considered to be alternatives to the project activity. This is because such actions do not constitute a similar product/service: the provision of electricity, steam and hot water, which in the case of the project activity is carried out in a less carbon intensive manner than that which would have otherwise occurred. i.e. from the utilization of waste heat to generate steam and/or hot water.

Energy efficiency measures that enable the production, transmission and distribution of thermal energy to the end users with a lesser amount of GHG generation which may be implemented in the future, during the crediting period however are considered for the purpose of calculating the baseline emissions, but not as part of the process for the selection of the most plausible baseline scenario, because they do not constitute alternative means to providing the same services as those provided by the project activity. Similarly, improvements in energy efficiency undertaken by the project customer(s) may lead to an increase or decrease in the efficiency with which each unit of thermal energy is produced, depending on the operating point on the boiler's efficiency – load curve. The baseline emissions calculations given in section (5) of this methodology take this into consideration.

Procedure for the identification of Baseline Scenario Alternatives to the project activity

The project proponent shall clearly indicate the amount of electricity, steam and/or hot water which the proposed project activity would generate, indicating whether the electricity which is planned to be generated is peak/base load power, as well as the conditions of the steam and hot water to be produced.

This establishes a common technical basis upon which to identify the baseline scenario alternatives.

Electricity, steam and or hot water in similar amounts, service type and quality may be delivered in a separate manner (e.g. a gas turbine generator set and steam and hot water boilers) or in an integrated manner (e.g. a Combined Heat and Power Plant).

Therefore, possible baseline scenario alternatives for the project participants (project developer and project customer(s) with regards to the production/provision of electricity, steam and hot water, may include, either a combination of different options to generate each of the utilities independently from one another (non-integrated options) or through combined heat and power systems, which provide all three of such utilities (integrated options):

Step A. Non integrated baseline scenario alternatives for the production of electricity, steam and hot water

A.1 Electricity production

The project activity involves the construction and operation of an energy plant that produces several utilities, one of which is electricity which is exported to the grid.

In assessing what baseline scenario alternatives exist for electricity generation it shall be noted that these need not consist solely of power plants of the same capacity, load factor and operational characteristics (i.e. several smaller plants or the share of a larger plant may be a reasonable alternative to this portion of the project activity). However all the options considered must be capable of delivering a similar service (e.g. peak vs. base load power).

The proponents shall include those power generation options that are available to them. In this sense, project proponents shall ensure that all relevant power plant technologies that have been recently constructed or are under construction or are being planned are considered when building the list of baseline scenario alternatives.

Alternatives for electricity generation include, amongst others, but are not limited to the following:

- grid connect power plants;
- new steam turbine power plants;
- new gas turbines power plants;
- new IC engine power plants.

The project proponents shall establish which of the identified baseline scenario alternatives can be considered credible and realistic alternatives

A.2 Thermal energy (Steam and/or hot water):

Baseline scenario alternatives that enable the production of the same quantity and grade of steam and/or hot water as the proposed project activity for export (if the project customer is a centralized district heating plant) or importing (where a project customer draws steam and/or hot water from a district heating grid) may include but are not limited to the following:

- continued generation of steam and/or hot water for export purposes to a district steam and or hot water grid, by a district heating plant;

- continued use of the existing sources of imported steam and or imported hot water by a project customer connected to the steam and/or hot water grid;

- waste heat derived steam and or hot water from waste heat sources available at the project customer's facility;

- the installation of standalone steam and or hot water generation equipment;

- the installation of steam and or hot water generation equipment for export into a district heating grid or supplying to a specific customer.

The outcome of step A will be the realistic baseline scenario alternatives for the combined production of electricity, steam and/or hot water from separate sources subject to the conditions given in Substep 1(a).

Step B. Integrated generation baseline scenario alternatives for the production electricity, steam and/or hot water (cogeneration of electricity, steam and/or hot water)

Integrated forms of generating the above mentioned utilities shall be considered, as they constitute alternatives to the production of electricity, steam and/or hot water. As indicated above, only those options that meet technical requirements and are available to the project participants established in Substep 1a shall be considered as possible baselines alternatives.

Combined heat and power baseline scenario alternatives may include:

1. Steam turbine CHP plant
    - CHP with back-pressure turbine
    - CHP with extraction / condensing turbine

2. CHP with gas turbine

3. Internal combustion (IC) reciprocating engine generator with waste heat recovery

4. Combined-cycle HP plant

The outcome of Step B will be realistic baseline alternatives for the co production of electricity, steam and/or hot water from an integrated energy facility subject to the conditions indicated in Substep 1 (a)

Outcome of Sub Step 1a: After having applied the above procedure realistic and credible alternatives baseline scenario that remain may include:

From Step A:

- One or more combinations of forms of generating electricity and thermal energy using independent technologies, and/or;

- Electricity from the grid and thermal energy from a district heating plant (continuation of existing practice).

From Step B

- One or more options of combined heat and power generation, including the VCS project activity without VER's.

Substep 1.b: Consistency with mandatory laws and regulations:

Ensure that the baseline scenario alternatives identified above comply with mandatory laws and regulations. This assessment shall be carried as described in the "Tool for Demonstration and Assessment of Additionality"

Outcome of Step 1b: Identified realistic and credible alternative scenario(s) to the project activity that are in compliance with mandatory legislation and regulations taking into account the enforcement in the region or country and VCS decisions on national and/or sectoral policies and regulations.

STEP 2. Determination of additionality and the most plausible baseline scenario

The most plausible baseline scenario shall be the one that includes the most likely means of producing electricity, steam and hot water in the absence of the proposed VCS project activity. It is the result of the combination of the most likely baseline scenarios for both the project developer and the project customer(s).

After having applied the procedure given in Step 1, three (3) realistic baseline scenario alternative categories will have been identified. The definition of the most plausible baseline scenario shall be assessed from both the project developer and project customer(s) perspectives. The project proponent may demonstrate this by applying investment or barrier analysis as deemed appropriate.

Step 2.1: Assessment and demonstration of additionality

The project proponent shall demonstrate that the proposed project activity is not an attractive option for the project developer to undertake unless the project activity can be registered under the VCS.

Project proponent shall demonstrate additionality by applying either one or two of the following options:

Option 1: Investment analysis

Option 2: Barrier analysis

Project proponents may also elect to complete both options. The above options refer to Steps 2 and 3 of the "Tool for demonstration and assessment of additionality".

Additionality shall be demonstrated using the latest version of the "Tool for demonstration and assessment of additionality". Project participants can use either investment analysis or barrier analysis step. They may, if they wish so, use both the investment and barrier analysis steps.

OPTION 1. INVESTMENT ANALYSIS

Project proponents shall apply the latest version of the "Tool for demonstration and assessment of additionality" i.e., shall determine whether the proposed project activity is not:

(a) The most economical or financially attractive, or;

(b) Not economically attractive.

The indicator to be applied shall be either IRR, or the unit cost of producing electricity, thermal energy for steam and hot water.

The selection of the benchmark IRR shall be carried out according to the latest version of the "Tool for demonstration and assessment of additionality".

Where the unit cost of energy is the chosen indicator, the benchmark to be applied to the steam and/or hot water will depend on whether the project customer is:

a) A centralized steam and/or hot water generating facility purchasing steam and/or hot water from the project facility, in which case the benchmark is the unit purchase price or tariff of the thermal energy offered by the district heating plant to the project developer;

b) An importer of steam and or hot water from the grid, in which case the benchmark shall be the unit cost of thermal energy paid by the project customer which imports steam and or hot water from the grid.

In providing any benchmarks, the DOE shall be presented with supporting evidence, such as energy purchase agreements (in cases where the project customer is the central steam and or hot water generating facility), actual energy invoices or contracts (in the case of a project customer that imports thermal energy from the grid) where it is indicated in a transparent manner what the benchmark value is.

Calculation of the indicator

IRR

If IRR is chosen as the indicator then, the IRR calculation shall be applied to assess the additionality of the project activity following the guidance given in the latest version of the “Tool for demonstration and assessment of additionality”.

Unit cost of energy

Where unit cost of energy us the chosen indicator, the unit cost of electricity, steam and or heat to be provided by the project activity shall be calculated taking into account the investment, operation and maintenance costs, and the revenues excluding carbon but possibly including other sources of revenue as mentioned in the “Tool for Demonstration and Assessment of Additionality” and compared with that of the baseline scenario alternatives which provide those utilities. The approach used in such calculations shall be presented in a transparent manner in accordance with the “Tool for Demonstration and Assessment of Additionality”, in a way that shall enable the DOE to assess their appropriateness and reproduce the results presented by the project proponents. The calculations used to determine such indicators shall be presented to the DOE.

Present a clear comparison between the indicator values obtained for the various baseline scenario alternatives and the benchmark.

a) If the value of indicator for the project activity is such that it is not the most attractive amongst various baseline scenario options to produce the similar services and outputs, then the project activity shall be deemed additional.

b) If the indicator for the project activity is less favorable than the benchmark then the project activity cannot be considered the financially attractive or the most financially attractive and can be thus regarded as additional.

Sensitivity analysis

A sensitivity analysis shall be included to show whether the conclusion regarding the financial/economic attractiveness of the project activity without VCS is robust to reasonable variations in the critical assumptions. The investment analysis provides a valid argument in favor of additionality only if it consistently supports (for a realistic range of assumptions) that the project activity without VCS credits is unlikely to be the most financially/economically attractive option to the project developer.

The project proponent, who applies the new VCS methodology, shall provide evidences for the figures applied and used in the excel work sheets in order to be able to fully retrace the assumptions and calculations made under the investment analysis.

Determination of the most plausible baseline scenario

The most plausible baseline scenario shall be considered to be either of the following:

- the most economically attractive of the realistic and credible baseline scenario alternatives identified in Substep 1 b above that is in compliance with existing regulations, provided the emissions that would result from its implementation would be less than those resulting from the "continuation of existing practice" or "business-as-usual" baseline scenario alternative. If this is not the case, the baseline scenario shall be considered to be the continuation of the existing practice;

- the continuation of existing practice, in cases in which the only other possible baseline scenario alternative is for a project developer to invest in the project activity, but which has been determined not to be the most likely baseline scenario given the outcome of the investment analysis described above.

OPTION 2. BARRIER ANALYSIS

Determine whether the proposed project activity faces barriers that:

a) prevent the implementation of this type of project activity; and

b) do not prevent the implementation of at least one of the alternatives

The identified barriers are only sufficient grounds for demonstration of additionality if they would prevent the project developer from carrying out the proposed project activity undertaken without being registered as a VCS project activity. Barriers that prevent customers from purchasing the Electricity and thermal energy which the project activity produces are taken as barriers which the developer must also overcome.

The following sub-steps shall be used

Substep 2a: Identify the barriers that would prevent the implementation of the proposed VCS project activity

(1) Identify realistic and credible barriers that would prevent the implementation of the proposed project activity from being carried if the project activity was not

registered as a VCS project. Barriers must be addressed for both the project developer and the project customer (s).

(a) Investment barriers, other than economic/financial barriers in Step 2 above, inter alia:

   i. similar cogeneration activities have been implemented, but only through grants or other non commercial terms. Similar activities being those that rely on a broadly similar technology or practices, are of a similar scale, take place in a comparable energy sector environment with respect to the regulatory framework and are undertaken in the relevant country/region

   ii. no private capital is available from domestic or international capital markets due to real or perceived risks, as demonstrated by the country credit ratings or other country investment reports of a reputed origin

   iii. the investment required to deliver the energy produced by the project facility to the project customer (e.g. power lines, steam and hot water piping) is significant and the project developer is unable or unwilling to undertake it

(b) Technological barriers, inter alia:

   i. Skilled and/or properly trained labor to operate and maintain the technology are not available in the relevant country/region, which leads to an unacceptably high risk of equipment disrepair and malfunctioning or other underperformance.

   ii. Lack of infrastructure for implementation and logistics for maintenance of the technology.

   iii. Risk of technological failure: the technology failure risk in the local circumstances is significantly greater than for other technologies that provide the electricity, steam and/or hot water in quantities, grades and quality as those of the proposed project activity, as demonstrated by relevant scientific literature or technology manufacturer information. This is risk being a concern to both the project developer and the project customer.

(c) Barriers due to prevailing practice

   i. the project is the “first of its kind” either from a technological or business standpoint

(d) Barriers that prevent project customers from purchasing electricity, steam and/or hot water from the project facility

(e) Other barriers that the project developer or the project customer may face

Substep 2b. Show that the identified barriers would not prevent the implementation of at least one of the baseline scenario alternatives besides the propose project activity

(2) if the identified barriers also affect other baseline scenario alternatives identified as part of step 1, explain in what way those baseline scenario alternatives are less strongly affected by them than the proposed VCS project activity is. In other words, demonstrate that the identified barriers do not prevent the implementation of at least one of the baseline scenario alternatives. Any baseline scenario alternative that would be prevented by any barriers indicated above cannot be considered a "viable" alternative to the proposed project activity and shall thus be eliminated from further consideration.

Determination of additionality and the most plausible baseline scenario

- if there is only one baseline scenario alternative that is not prevented by any of the identified barriers and this scenario is not the project activity without being registered under the VCS, then this baseline scenario alternative shall be taken as the most plausible baseline scenario. In this case it shall be explained as indicated in the "Combined tool to identify the baseline scenario and demonstrate additionality" by using qualitative or quantitative arguments, how the registration of the VCS project activity will alleviate the barriers that prevent the proposed project activity from occurring.

- if there are more than one baseline scenario alternatives that are not prevented by any of the barriers, and these alternatives do not include the project activity without taking into account VERs, the project proponent shall explain how the registration of the VCS project activity will alleviate the barriers that prevent the proposed project activity from occurring.

  If the VCS alleviates those barriers, the project proponent may apply investment analysis to identify the most economically attractive of the baseline scenario alternatives that are not prevented by any of the barriers that the project activity faces. If the most economically attractive baseline scenario is a more carbon intensive alternative than the continuation of current practice then the project proponents may proceed to the following sections of this methodology, provided the baseline scenario is taken to be production of electricity by grid connected power sources and the production of steam and/or hot water is obtained from existing generating facilities. If on the other hand, it is determined that the most economically attractive scenario is a less GHG intensive alternative than the continuation of existing practice, then the methodology cannot be a applied.

Step 2.2: Common practice analysis

Demonstrate that the project activity is not common practice in the relevant country and sector by applying STEP 4 "Common Practice Analysis" as described in the latest version of the "Tool for the demonstration and assessment of additionality"

The relevant geographical area for undertaking the common practice analysis should in principle be the host country of the proposed CDM project activity. A region within the country could be the relevant geographical area if the framework conditions vary significantly within the country.

PROJECT BOUNDARY

The project boundary includes the site of the project facility(s) and the sites of the project customer(s).

CALCULATION OF EMISSION REDUCTIONS FROM THE PROJECT ACTIVITY

The emissions sources are given in table one below.

Table 1: Emissions sources included in or excluded from the project boundary

	Source	Gas	Included	Explanation/Justification
Baseline	Combustion of fossil fuels to produce electricity, steam and/or hot water at the project customer(s)' site, which provide steam and or hot water to the project customer site, and the power generating facilities connected to the grid.	CO_2	Yes	Main emissions source in the combustion of fossil fuel.
		CH_4	No	Excluded for simplification
		N_2O	No	Excluded for simplification.
Project activity	Combustion of natural gas to produce electricity, steam and/or hot water at the site of the project activity.	CO_2	Yes	Main emissions source in the combustion of natural gas.
		CH_4	No	Excluded for simplification
		N_2O	No	Excluded for simplification.

PROCEDURE FOR ESTIMATING LIFETIME OF THE BOILER(S)

The following approaches shall be taken into account to estimate the remaining lifetime of the boilers that would provide steam and hot water in the absence of the project activity:

a) The typical average technical lifetime of the type of equipment may be determined taking into account common practices in the sector and country (e.g. based on industry surveys, statistics, technical literature, etc.);

b) The practices of the responsible company regarding replacement schedules may be evaluated and documented (e.g. based on historical replacement records for similar equipment).

The time to replacement of the existing equipment in the absence of the project activity should be determined in on a case-by-case basis thus taking into consideration local conditions, existing practices and possible barriers to implementation of new projects or regulatory acts relating to the continuation of existing practices regarding steam and hot water generating equipment.

If in any year of the crediting period, new steam or hot water generating equipment is installed at the project customer's installations or at the installations that supply steam and or hot water to the project customer, it shall be assumed that all steam and or hot water that is displaced by the project activity would have otherwise been produced by using equipment with such performance characteristics.

In other words, should such situations occur during the crediting period, the baseline emissions factor will be recalculated based on Option B given for steam and hot water production (equations 8, 15 and 20), to reflect the assumption that in the absence of the project activity, the steam and hot water which is produced by the project facility would have been produced by more efficient steam and hot water generation technology.

The project proponents may opt to assume though that new more efficient equipment would have been installed to generate steam and hot water. In this case they shall assume that best available fossil fuel based steam or hot water generation technology would have been used. Or if they prefer, may opt to assume that the thermal generation efficiency of the equipment that would be installed is 100%. Either option may only be applied though in cases where the project proponents can demonstrate that the use of biomass is not likely to constitute a viable alternative to produce the heat that the project activity displaces

CALCULATION OF THE BASELINE EMISSIONS

The following approach to calculate the baseline emissions is only applicable to projects in which the most plausible baseline scenario has been identified to be the continuation of the existing practice, i.e. electricity supplied by the grid and steam and/or hot water produced by a district heating plant or sourced from a district heating plant.

The baseline scenario shall indicate what the baseline fuels are. The project proponent shall assess the potential for fuel switching and energy efficiency improvements under the baseline scenario as indicated below.

For the purpose of establishing the baseline emissions the project developer shall consider any changes that may impact on the baseline alternatives CO_2e intensity of the steam and/or hot water which it displaces. In this sense attention shall be paid to:

Fuel switching

- fuel switching taking place in the centralized steam and/or hot water generating facility that provides these sources of energy to the steam and hot water grids:

    - the project proponent first determines if the fuel changes are technically feasible using existing thermal energy generating equipment. This exercise is not carried out for electricity generation. For instance the proponents shall determine if the existing equipment is capable of utilizing more that one fuel, without major capital investment. This can be verified during validation. If not, then no additional considerations need to be undertaken in the crediting period and it will be assumed that the same fuel would have been used as has been in the past. If a fuel switch constitutes a possibility given the existing equipment, the project proponent shall monitor this on a yearly basis.

    - Alternatively, the project proponents may assume that natural gas is being used as the baseline fuel, in which case no monitoring in this respect shall be required. The project proponent may apply this default approach during the entire crediting period or for any specific year of the crediting period. This shall be clearly indicated in the monitoring reports presented the verifier.

Energy efficiency improvements

Energy efficiency improvements in thermal energy generation (when the project customer is a district heating plant) and transport of thermal energy to the project customer’s factory gate (when the project customer is an end user) include:

- energy efficiency measures and projects the improve the efficiency with which thermal energy is generated at the thermal energy generating facility;

- improvements to the steam transport system from the point of generation to the point of delivery to a customer connected to the grid that lead to a reduction in the amount of energy losses, and hence CO_2 emissions per unit of thermal energy delivered to the point at which the project activity steam and or hot water are delivered to the project customer. This needs to be considered in cases in which the project proponents chose to apply a GHG intensity factor which is based on measured data;

- activities that increase the amount heat returned to the central generating system boiler house in the form of hot condensate and flash steam, which therefore reduce the CO_2 intensity of the steam which is produced.

The impact of such measures on the baseline emissions are dealt with in the baseline emissions calculation and monitoring sections of this methodology. Alternatively, the project proponents may apply default factors as suggested in this methodology. In either case the DOE shall verify the appropriateness of the data/factors applied.

This methodology is only applicable to situations in which the baseline scenario is the continuation of the current practice for producing electricity and heat from fossil fuel

The baseline emissions for this particular methodology are the sum of emissions from resulting from the generation of electricity, steam and hot water.

$$BE_y = BE_{el,y} + BE_{th,y} \quad (1)$$

Where:

$BE_{el,y}$ Baseline emissions resulting from electricity generation in the year y (in tonnes of CO_2e). Calculated below as per equation (2);

$BE_{th,y}$ Baseline emissions resulting from the production of steam and/or hot water supplied to project customer i in the year y (in tonnes of CO_2). Calculated below as per equation (3).

BASELINE EMISSIONS FROM ELECTRICITY GENERATION

Baseline emissions from electricity generation are calculated by multiplying the net electricity generated at the project plant ($EG_{P,y}$) with a baseline electricity grid CO_2 emission factor ($EGEF_{BL,CO_2,y}$) as follows:

$$BE_{el,y} = EG_{P,y} \cdot EGEF_{BL,CO_2,y} \quad (2)$$

For construction of large new power capacity additions under the CDM, there is a considerable uncertainty relating to which type of other power generation is substituted by the power generation of the project plant. As a result of the project activity, the construction of an alternative power generation technology could be avoided, or the construction of a series of other power plants could simply be delayed. Furthermore, if the project were installed sooner than these other projects might have been constructed, its near-term impact could be largely to reduce electricity generation in existing plants. This depends on many factors and assumptions (e.g. whether there is a supply deficit) that are difficult to determine and which change over time. In order to address this uncertainty in a conservative manner, project participants shall use for ($EGEF_{BL,CO_2,y}$) the lowest emission factor among the following options:

For the first crediting period:

Option 1 The build margin, calculated according to “Tool to calculate emission factor for an electricity system”; and

Option 2 The combined margin, calculated according to “Tool to calculate emission factor for an electricity system”, using a 50/50 OM/BM weight.

BASELINE EMISSIONS FROM HEAT GENERATION

The baseline emissions from heat production ($BE_{th,y}$) are the sum of emissions from steam generation and hot water generation for sale to project customers:

$$BE_{th,y} = BE_{st,y} + BE_{hw,y} \tag{3}$$

Where:

$BE_{st,y}$ Baseline emissions resulting from the production of steam supplied to project customer i in the year y (in tonnes of CO_2). Calculated below as per equation (4);

$BE_{hw,y}$ Baseline emissions resulting from the production of hot water supplied to project customer i in the year y (in tonnes of CO_2). Calculated below as per equation (11).

The maximum amount of thermal energy in the form of steam and/or hot water, which is produced by the project activity during year y and which can be used for the purpose of determining the emissions reductions upon which VERs can be claimed, is defined as the maximum annual amount of thermal energy produced in the form of steam and/or hot water that has been produced over the three most recent years for which data is available in the pre-project steam and or hot water production facilities.

I. Baseline emissions from production of steam that is supplied to project customer i in year y (in tonnes of CO_2):

$$BE_{st,y} = \sum_i \sum_j \left(SC_{BL,j,y} \cdot SEF_{BL,i,y} \right) \qquad (4)$$

Where:

$SC_{BL,j,y}$ The amount of energy consumed in the form of steam by the project customer i, which is supplied by the project facility j in year y (in TJ). It is further obtained from equation (5).

$SEF_{BL,i,y}$ The baseline emission factor corresponding to the steam produced in project customer i's steam generating plant or sourced from the produced in a steam generating plant that supplies steam to a project customer i (in t CO_2/TJ), and obtained from equation (6) below.

The amount of energy consumed in the form of steam by the project customer i which is supplied by the project facility j in year y is given by:

$$SC_{BL,j,y} = SP_{BL,j,y} \cdot SDEN_{BL,j,y} \qquad (5)$$

Where:

$SP_{BL,j,y}$ Quantity of steam produced by the project facility j and supplied to the project customer i for year y, (in tonnes)

$SDEN_{BL,j,y}$ Specific enthalpy of steam leaving the project facility j (in TJ/tonne of steam supplied). This data shall be obtained from steam tables, using temperatures and pressure of the steam purchased.

The following options are provided to determine the baseline CO_2 emissions factor, $SEF_{BL,i,y}$ for the steam produced by the project customer i or by a steam generating plant that supplies a project customer i with steam (in tonnes of CO_2/TJ of steam) produced in year y.

Option I.A.

When actual data for the amount of fuel consumed and steam generated by the project customer i's steam generating plant or by the steam generating plant that supplies steam to a customer i is available, the baseline emission factor for the steam generated may be calculated as:

$$SEF_{BL,i,y} = \frac{44}{12} \cdot \frac{\sum_i \left(CEF_{FF,i,y} \cdot HEC_{BL,FF,st,i,y} \right)}{\sum_i HSC_{BL,i,y}} \qquad (6)$$

Where:

$CEF_{FF,i,y}$ Carbon emission factor in year y corresponding to fossil fuel used by project customer i to generate steam or that which is used in a given steam generating plant to produce the steam which is sourced by the project customer i (in tonnes of C/TJ), shall be determined from the technical literature, from the project customer i, or the steam generating plant which supplies steam to the project customer i.

$HEC_{BL,FF,st,i,y}$ The energy associated with the fossil fuel consumed by the project customer i or the steam generating facility that supplied steam to the project customer i, in year y (in TJ). Calculated below in equation (7).

$HSC_{BL,i,y}$ The amount of energy contained in the steam generated by the customer i or the steam generating facility that supplied steam to the project customer i by burning fossil fuel (in TJ) in year y.

The present methodology offers two options upon which to establish $HEC_{BL,FF,st,i,y}$:

Option I.A.a.

The energy associated with the fossil fuel that was consumed by the project customer i for self-generation of steam or by the steam generating facility that supplied steam to the project customer is given by:

$$HEC_{BL,FF,st,i,y} = HFC_{BL,FF,st,i,y} \cdot NCV_{FF,i,y} \qquad (7)$$

Where:

$HFC_{BL,FF,st,i,y}$ The quantity of fossil fuel consumed for steam generation by project customer i or that which was consumed by the steam generating plant that provided steam to the project customer i in year y (in tonnes)

$NCV_{FF,i,y}$ Net calorific value of the fossil fuel used by the project customer i in the scenario of self-generation or used by the steam generating plant that supplied steam to the project customer i in year y. Specific data may be provided by the project customer or from the technical literature (TJ/tonne)

Option I.A.b.

Alternatively, $HEC_{BL,FF,st,i,y}$ may be calculated from records of steam produced and the temperature and pressure conditions at which boiler feed water is supplied to and the steam generated from the boilers, as follows:

$$HEC_{BL,FF,st,i,y} = \frac{(HSC_{BL,i,y} - HSP_{BL,i,y} \cdot HSEN_{w,y}) \cdot 100}{\eta_{BL,st,i}} \quad (8)$$

Where:

$HSC_{BL,i,y}$	The amount of energy contained in the steam which was generated by the customer i or that which was generated by the steam generating facility that provided steam to the project customer i, and which was obtained by burning fossil fuel (in TJ) in year y.
$HSEN_{w,y}$	The specific enthalpy of water entering the boiler at project customer i's steam generating facilities or the water entering the boiler at the steam generating facilities which supplied steam to the project customer i in year y.
$HSP_{BL,i,y}$	The quantity of steam produced by the project customer i or that which was produced by the generating facility that supplied the steam to the project customer i in year y (in tonnes of steam produced).
$\eta_{BL,st,i}$	The efficiency of project customer i's boiler or the efficiency of the boiler that supplied steam to the project customer i based on NCV (in %). This parameter shall be one of the following:

i) the highest measured value of boiler efficiency recorded over full range boiler test;

ii) the boiler's peak thermal efficiency as per manufacturer's information;

iii) efficiencies of boilers of similar design;

iv) a default boiler efficiency of 100%;

Note: heat losses associated with the transmissions and distribution of steam are assumed to be zero

Energy content (in TJ) of the steam generated by customer i or by the facility that supplied steam to the project customer i is given by:

$$HSC_{BL,i,y} = HSP_{BL,i,y} \cdot HSEN_{BL,i,y} \quad (9)$$

Where:

$HSP_{BL,i,y}$	The quantity of steam produced by the project customer i or produced by the steam generating facility that supplied steam to the project customer i in year y (in tonnes of steam produced)
$HSEN_{BL,i,y}$	The specific enthalpy of the steam produced by project customer i or by the steam generating facilities that supplied steam to the project customer i in year y (in TJ/ tonne of steam produced).

Note for monitoring during the crediting period.

Option 1.A

Changes may be made to certain elements of the project customer's steam system (e.g. the condensate recovery system) that could result in a lower baseline emissions factor during the years of the crediting period. Additionally, changes in the type of fuel used may occur in any year y during the crediting period, which are likely to have occurred also in the absence of the project activity.

For the purpose of establishing the steam baseline emission factor in any given year y during the crediting period, the project proponent shall therefore:

a) establish the lowest specific heat consumption per unit of steam energy given by $\min(HEC_{BL,FF,st,i,y} / HSC_{BL,i,y})$ up till year y

b) multiply this value with the value of $\left(\frac{44}{12} \cdot CEF_{FF,i,y}\right)$ of the fuel used in year y

The baseline emissions factor for year y shall be the lowest between the value so calculated and that obtained from equation (6) above.

The purpose of this approach is to identify which year is the least energy intensive one, and assume that the improved performance would have not been lost over time. That is, in any year y it is always assumed that steam will be produced with the minimum amount of fossil fuel derived energy. It also aims to reflect the fact that changes in the fuel type being used in any year y may change to what has been previously the case, and that furthermore such changes would have also occurred in the absence of the project activity. If however in any year y, there is no fossil fuel consumption at the project customer's steam generating facility because all is displaced by the project activity, then the project proponent shall apply the lowest baseline emissions factor amongst the historical value for the three most recent years prior to the implementation of the project for which data is available and the values obtained during the years of the crediting period leading up to year y.

Note for cases in which a project customer uses steam produced by another steam generating plant:

Where the project customer is one that imports steam from generating facility, heat losses in transmission and distribution of that steam shall be considered nil. In other words, enthalpy data applied into the equations above shall be that which corresponds to the temperature and pressure conditions of the steam produced at the steam generating facility and not those existing of the steam at the point of off-take by the project customer. In this case, the steam baseline emissions factor shall be monitored as per the preceding note.

Option I.B.

The baseline CO_2 emissions factor per TJ of steam energy generated by customer i or by the steam generating facility that supplied steam to the project customer i, in the absence of the project activity can also be determined from boiler manufacturer's design data for customer i, and the fraction of heat recovered in the form of condensate, assuming no heat losses occur along the steam transmission and distribution lines, as follows:

$$SEF_{BL,i,y} = \frac{44}{12} \cdot \frac{CEF_{FF,i,y} \cdot (1 - X_{c,y}).100}{\eta_{BL,st,i}} \qquad (10)$$

Where:

$CEF_{FF,i,y}$ Carbon emission factor (in tonnes of C/TJ), corresponding to the fossil fuel consumption by customer i or the facility that provided steam to the project customer i in year y;

$\eta_{BL,st,i}$ Project customer i's boiler efficiency or the boiler efficiency of the steam generating plant that supplied steam to a project customer, based on NCV (in %).In the absence of boiler performance data, $\eta_{BL,st,i}$ can be determined by one of the following:

i) the highest measured value of boiler efficiency recorded over full range boiler test;

ii) the boiler's peak thermal efficiency as per manufacturer's information;

iii) efficiencies of boilers of similar design;

iv) a default boiler efficiency of 100%.

$X_{c,y}$ The fraction of the total energy contained in the steam which is produced by the steam generating facilities which is returned as hot condensate and flash steam where applicable, to the boiler house in year y. The values of $X_{c,y}$ can be obtained as follows:

Option 1. Based on historical/actual measured data

- from historical data:

Option 1a. When the mass of condensate and temperature and pressure conditions at which the condensate is returned to the boiler house condensate tank are known:

If this option is to be applied, then this calculation must be performed yearly during the crediting period to ensure that no improvements have been made that might lead to a further increase in the amount of energy recovered from the condensate. Should the value of the fraction so obtained in any year y be less than the historical maximum value (spanning the first year of the historical data used to establish the initial value of $X_{c,y}$ till year y-1 in the crediting period), the maximum value of $X_{c,y}$ during this period shall be taken. Energy returned to the boiler house in the form of hot condensate as well as from any flash steam recovered and thereafter used in a deaerator shall be accounted for.

Option 1.b When the mass of condensate recovered unknown, but temperature at which the condensate is returned to the condensate tank is known:

Calculate the heat recovered from the condensate entering the condensate tank by assuming that all the steam that condensed throughout the steam system is routed back to the boiler house condensate recovery tank, based upon the maximum temperature observed from historical records. In other words, assume that:

- no steam is used directly in a process
- all the steam that is condensed in heat exchangers is returned, i.e. no losses due to leaks (neither condensate nor live steam). Flash losses that occur across the steam traps are calculated by carrying out an enthalpy balance around

the condensate recovery tank at the tank's operating conditions

If this option is to be applied, then this calculation must be performed yearly to ensure that no improvements have been made that might lead to a further increase in the amount of energy recovered in the form of condensate that was present in the heat exchangers (e.g. if a condensate flash steam recovery project were to be implemented). Select the maximum condensate recovery temperature (at the condensate recovery tank) in the period spanning the first year of the historical data used to establish the initial value of $X_{c,y}$ till year y-1 in the crediting period, and use this value to establish the heat recovered from the condensate which is returned to the boiler in the form of condensate.

Option 2. Based on Default values

The following options assume that there are neither losses of condensate along the condensate piping nor losses to direct heating processes. The above assumptions overestimate the amount energy which can be recovered from this part of a steam system.

Option 2a If the existing condensate system is of the atmospherically vented condensate system type:

If the quantity and temperature at which the condensate is returned to the boiler house are not known, apply option 1b above but assume that the condensate which is obtained from the bottom of the condensate flash tank is pumped to the deaerator at 100°C to calculate the heat returned to the boiler in the form of hot condensate.

The proponents shall confirm annually if any changes to the design of the condensate system have been made that enable it to operate at a higher pressure, and thus recover more energy from the condensate routed to the condensate tank. Should this be the case, this default can no longer be applied.

Note: For such system condensate cannot exceed 100°C otherwise pump impeller cavitation /capitation would occur. Hence there is a practical limit to the amount of heat that can be recovered; in fact it would probably be somewhat lower than 100°C.

Option 2b. The project proponent may chose to calculate $X_{c,y}$ assuming that all the heat contained in the condensate in the heat transfer equipment is returned to the boiler. The calculation shall be performed based on enthalpy values of water, h_f, corresponding to the conditions at which the steam is generated according to the boiler manufacturer's design or the actual conditions.

II. Baseline emissions from production of hot water

The baseline emissions from the production of hot water in project customer i's installation or produced in the installation that supplied hot water to the project customer i are given by:

$$BE_{hw,y} = \sum_i \sum_j \left(HWC_{BL,j,y} \cdot HWEF_{BL,i,y} \right) \tag{11}$$

Where:

$HWC_{BL,j,y}$ The energy content in the hot water produced by the project facility j, which is purchased by project customer i in year y (in TJ);

$HWEF_{BL,i,y}$ The CO_2 baseline emissions factor corresponding to the hot water produced by the project customer i or produced by the hot water production plant that produces hot water which the project customer i uses in year y (in t CO_2/TJ)

The energy content in the hot water produced by the project facility j, which is purchased by project customer i in year y is obtained by the following equation:

$$HWC_{BL,j,y} = HWP_{BL,j,y} \cdot HWEN_{BL,j,y} \tag{12}$$

Where:

$HWP_{BL,j,y}$ The amount of hot water produced by project facility j and supplied to project customer i in year y (in tonnes);

$HWEN_{BL,j,y}$ The specific enthalpy of hot water produced by the project facility j in the year y (in TJ/tonne of water).

This part of the methodology considers situations in which a project customer i would have produced or obtained hot water from a hot water production plant. This hot water in the absence of the project activity would have been derived from either of the following sources of energy:

- fossil fuel, in directly fired hot water boilers, hwb (Option II.A.)

- steam, in steam to water heat exchangers, sthx (Option II.B.)

Option II.A. Hot water produced in boilers firing fossil fuels

The following alternatives are provided to determine the baseline CO_2 emissions factor associated to the production hot water in tonnes of CO_2/TJ where historical data is available.

Option II.A.a.

The baseline CO_2 emission factor associated with hot water production in boilers running on fossil fuel can be calculated as:

$$HWEF_{BL,i,y} = \frac{44}{12} \cdot \frac{\sum_i (CEF_{FF,i,y} \cdot HEC_{BL,FF,hwb,i,y})}{\sum_i HHWC_{BL,hwb,i,y}} \qquad (13)$$

$CEF_{FF,i,y}$ Carbon emission factor corresponding to the fossil fuel used by the project customer i to produce hot water or used by the plant which supplied hot water to a project customer i in year y (in tonnes of C/TJ). Obtained from the relevant hot water generating plant or from the technical literature.

$HEC_{BL,FF,hwb,i,y}$ The energy associated with the fossil fuel consumed by customer i to self-generate hot water in a hot water boiler or that consumed by a hot water production plant that provides the hot water to the project customer i (in TJ) in year y.

$HHWC_{BL,hwb,i,y}$ The energy contained in the hot water, which was generated by the customer i from burning natural gas (in TJ) or which was produced by the facility that provided hot water to the project customer i in year y.

The present methodology offers two options upon which to determine $HEC_{BL,FF,hwb,i,y}$:

Option II.A.a.i

The energy associated with the fossil fuel consumed by a customer i to self-generate hot water in a hot water boiler or that which is used to generate hot water in a facility that supplied hot water to a project customer i given by:

$$HEC_{BL,FF,hwb,i,y} = HFC_{BL,FF,hwb,i,y} \cdot NCV_{FF,i,y} \qquad (14)$$

Where:

$HFC_{BL,FF,hwb,i,y}$ The quantity of fossil fuel consumed for hot water generation in hot water boilers by the project customer i or by the plant that generated the hot water which customer i used for year y. This can be reported as mass units of the baseline fuel or in units of volume if data is provided on the mass density of the fossil fuel used (in tonnes)

$NCV_{FF,i,y}$ Net calorific value of the fossil fuel used in the hot water generating plant, whether this is the project customer i's facility or the plant that generated the hot water which the project customer i used, whichever is applicable,or specific data to be provided by the project customer for year y

Option II.A.a.ii

Alternatively, in the absence of suitable historical data for fossil fuel consumption or if preferred, $HEC_{BL,FF,hwb,i,y}$ may be calculated as follows:

$$HEC_{BL,FF,hwb,i,y} = \frac{(HHWC_{BL,hwb,i,y} - HHWP_{BL,hwb,i,y} \cdot HSEN_{w,y}) \cdot 100}{\eta_{BL,hwb,i}} \quad (15)$$

Where:

$HHWC_{BL,hwb,i,y}$ The energy contained in the hot water, which was generated by the customer i or by the plant that provided the hot water to the project customer i, from burning fossil fuel (in TJ) in year y

$HSEN_{w,y}$ The specific enthalpy of water entering the hot water boiler in year y

$\eta_{BL,hwb,i}$ Customer i's hot water boiler's efficiency or that of the hot water generating plant that supplied hot water to the project customer i, based on NCV. The value of this parameter shall be one of the following:

a. the highest measured value of boiler efficiency recorded over full range boiler test;

b. the boiler's peak thermal efficiency as per manufacturer's information;

c. efficiencies of boilers of similar design;

d. a default boiler efficiency of 100%

The energy content of the hot water self-generated by project customer i, or by the hot water generating facility that supplies hot water to customer i, is given by:

$$HHWC_{BL,hwb,i,y} = HHWP_{BL,hwb,i,y} \cdot HHWEN_{BL,hwb,i,y} \tag{16}$$

Where:

$HHWP_{BL,hwb,i,y}$ The mass of hot water self-generated in hot water boilers by the project customer i or by the hot water generating plant that supplies hot water to customer i, in year y (in tonnes)

$HHWEN_{BL,hwb,i,y}$ The specific enthalpy of the hot water leaving project customer i's installation or that of the hot water leaving the facility that supplies hot water to the project customer i, in year y (in TJ/tonne of water)

Note for monitoring during the crediting period.

Option II Aa is based on actual performance data. However changes may be made to certain elements of the project customer's hot water system (e.g. the improved insulation) could result in a lower hot water baseline emissions factor during the years of the crediting period. Additionally, changes in the type of fuel used may occur in any year y during the crediting period, which are likely to have occurred also in the absence of the project activity.

The project proponents shall therefore:

a) establish the lowest specific heat consumption per unit of thermal energy given by $\min\left(HEC_{BL,FF,st,i,y} / HHWC_{BL,hwb,i,y}\right)$ up till year y

b) multiply the above value with $\left(\frac{44}{12} \cdot CEF_{FF,i,y}\right)$ of the fuel used in year y

The baseline hot water emissions factor for year y shall be the lowest between the value so calculated and that obtained from equation (13).

The purpose of this approach is to identify which year is the least energy intensive one, and assume that the improved performance would have not been lost over time. That is, in any year y it is always assumed that hot water will be produced with the minimum amount of fossil fuel derived energy. It also aims to reflect the fact that changes in the fuel type being used in any year y may change to what has previously been the case, and that furthermore such changes would have also occurred in the absence of the project activity. If however in any year y, there is no fossil fuel consumption at the project customer's hot water generating facility because all is displaced by the project activity, then the project proponent shall apply the lowest hot water baseline emissions factor amongst the one for the three most recent years prior to the implementation of the project for which data is available and the values obtained during the years of the crediting period leading up to year y.

Note for cases in which a project customer uses hot water produced by another hot water generating plant:

Where the project customer is one that imports hot water from a generating facility, heat losses in transmission and distribution of that hot water shall be considered nil. In other words, enthalpy data applied into the equations above shall be that which corresponds to the temperature of the water produced at the hot water generating facility and not those existing at the point of off-take by the project customer. In this case, the hot water emissions factor shall be monitored during the crediting period as per the preceding note.

Option II.A.b.

The baseline specific CO_2 emissions factor for a project customer "i" of the hot water generating facility that supplies hot water to a project customer i, can be determined from the hot water boiler manufacturer's design data and monitoring the difference between the boiler hot water outlet and inlet return temperatures as follows:

$$HWEF_{BL,i,y} = \frac{44}{12} \cdot \frac{CEF_{BL,i,y} \cdot 100}{\eta_{BL,hwb,i}} \cdot \frac{\Delta T_{P,i,y}}{\Delta T_{BL,i}} \qquad (17)$$

Where:

$CEF_{BL,i,y}$ Carbon emissions factor in tonnes CO_2/TJ corresponding to the fossil fuel used by customer i to produce the hot water, or by the hot water production plant that supplies the hot water which the project customer uses in year y

$\eta_{BL,hwb,i}$ Customer i's hot water boiler's efficiency or the efficiency of the facility that produces the hot water which project customer i uses, based on the NCV. The value of this parameter shall be one of the following:

a. the highest measured value of boiler efficiency recorded over full range boiler test;

b. the boiler's peak thermal efficiency as per manufacturer's information;

c. efficiencies of boilers of similar design;

d. a default boiler efficiency of 100%.

$\Delta T_{BL,i}$ — Temperature difference between the water exiting the boiler and the water returning to it. The value applied shall be the lowest mean annual temperature difference over the three most recent years for which historical data is available. Alternatively, the design annual mean temperature difference may be considered as a default;

$\Delta T_{P,i,y}$ — Temperature difference between the water exiting boiler and water returning in year y. The applied value shall be the lowest value during the historical period considered and the current year. Alternatively, the design annual mean temperature difference may be considered as a default.

Option II.B. Hot water produced from steam using heat exchangers

The following alternatives are provided to determine the baseline CO_2 emissions factor associated to the production hot water in tonnes of CO_2/TJ when this is produced from steam.

Option II.B.a.

The CO_2 baseline emission factor associated with hot water production in steam heat exchangers can be calculated based upon historical data as:

$$HWEF_{BL,i,y} = \frac{44}{12} \cdot \frac{\sum_i (SEF_{BL,i,y} \cdot HEC_{BL,st,sthx,i})}{\sum_i HHWC_{BL,sthx,i}} \tag{18}$$

$SEF_{BL,i,y}$ — The baseline emission factor for the production of steam which is used to produce the hot water (in tonnes CO_2/TJ), and obtained from equation (4).

$HHWC_{BL,sthx,i,y}$ — The energy contained in hot water self generated by project customer i from steam or by the supplier of the hot water to a project customer i in a steam-to-water heat exchanger (in TJ) in year y

$HEC_{BL,st,sthx,i,y}$ — The energy associated with the steam consumed by customer i to self-generate hot water or that which is consumed by the hot water production plant which produces the hot water that a project customer i uses, in a steam-to-water heat exchanger (in TJ) in year y

The energy contained in hot water self generated by project customer i from steam or obtained from the hot water generating plant that supplied this hot water to a project customer i, by means of a steam-to-water heat exchanger can be obtained by:

$$HHWC_{BL,sthx,i,y} = HHWP_{BL,sthx,i,y} \cdot HHWEN_{BL,hw,sthx,i,y} \quad (19)$$

$HHWP_{BL,sthx,i,y}$ The mass of hot water self-generated by the project customer i or by the hot water production plant that produced the hot water that a project customer i uses, by means of a steam-to-water heat exchanger during year y (in tonnes)

$HHWEN_{BL,hw,sthx,i,y}$ Specific enthalpy of water leaving the steam-to-water heat exchanger or exchangers of the project customer i, during year y.

The amount of energy consumed in the form of steam to produce hot water in the absence of the project activity (in TJ), $HEC_{BL,st,sthx,i,y}$, is given by:

Option II.B.a.i.

$$HEC_{BL,st,sthx,i,y} = HFC_{BL,NG,hwb,i,y} \cdot HHWEN_{BL,st,sthx,i,y} \quad (20)$$

$HFC_{BL,st,stbx,i,y}$ Quantity of steam consumed by the project customer i or the facility that generates the hot water which a project customer i used in year y (in tonnes)

$HHWEN_{BL,st,sthx,i,y}$ Difference of the specific enthalpy of steam entering and condensate leaving the heat exchanger in year y (in TJ/tonne of water)

Option II.B.a.ii.

Alternatively, in the absence of suitable actual steam consumption data, or if preferred, $HEC_{BL,st,sthx,i,y}$ may be calculated as follows:

$$HEC_{BL,st,sthx,i,y} = \frac{(HHWC_{BL,sthx,i,y} - HHWP_{BL,sthx,i,y} \cdot HSEN_{w,y}) \cdot 100}{\eta_{BL,sthx,i}} \quad (21)$$

Where

$HSEN_{w,y}$ The specific enthalpy of water entering the steam to water heat exchanger in year y

$\eta_{BL,sthx,i}$ The steam-to-water exchanger efficiency (%) of customer i's hot water generating plant or that of the hot water generating plant that provides hot water to customer i, based on one of the following:

a. the highest measured annual value of heat exchanger efficiency;

b. the design heat exchanger efficiency;

c. efficiencies of steam-to-water heat exchangers of similar design;

d. a default heat exchanger efficiency of 100%.

Note for monitoring during the crediting period.

Changes may be made during the crediting period to elements of the hot water distribution system (e.g. improved insulation) that may reduce the amount of steam required to meet the thermal loads), which in turn will lead to changes in the baseline emissions factor of the hot water produced.

Changes may also occur to elements of the steam system from which the heat exchangers are fed, which may also lead to changes in the baseline emissions factor of the steam, and hence impact the baseline emissions factor for the hot water.

In establishing the value of the hot water baseline emissions factor to be applied in year y the project proponents shall therefore:

c) establish the lowest specific heat consumption per unit of thermal energy given by $\min(HEC_{BL,st,sthx,i,y} / HHWC_{BL,sthx,i,y})$ up till year y

d) multiply the above value with $SEF_{BL,i,y}$ corresponding to the year y

The baseline hot water emissions factor for year y shall be the lowest between the value so calculated and that obtained from equation (18).

The purpose of this approach is to identify which year is the least energy intensive one, and assume that the improved performance achieved in the hot water system would have not been lost over time. That is, in any year y it is always assumed that hot water will be produced with the minimum amount of steam energy.. If however in any year y, there is no steam consumption in the steam – hot water heat exchanger at the project customer's hot water generating facility because all of it is displaced by the project activity, then the project proponent shall apply the lowest hot water baseline emissions factor amongst the one obtained from the average of the three most recent years prior to the implementation of the project for which data is available and the values obtained during the years of the crediting period leading up to year y.

The project proponent shall ensure the steam baseline emissions factor is monitored annually and updated accordingly when applied to the above equations. The value for the baseline emissions factor of the steam to be applied in any year y shall be that obtained as per Section I above.

Option II.B.b.

The baseline CO_2 emissions factor for a customer i can be determined without having to resort to historical data of steam and/or hot water production from the steam-to-water heat exchanger manufacturer design data as follows:

$$HWEF_{BL,i,y} = \frac{44}{12} \cdot \frac{SEF_{BL,i,y} \cdot 100}{\eta_{BL,sthx,i}} \qquad (22)$$

Where:

$SEF_{BL,i,y}$ The baseline emission factor corresponding to the steam that is utilized either by the project customer i or the hot water production plant that supplies hot water to customer i in year y, whichever is the case (in tonnes CO_2/TJ). Obtained from equation 4.

$\eta_{BL,sthx,i}$ The efficiency of steam-to-water exchanger efficiency at customer i's installations or at the facility which supplies hot water to customer i, based on one of the following:

a. the highest measured annual value of heat exchanger efficiency;

b. the design heat exchanger efficiency;

c. efficiencies of heat exchangers of similar design;

d. a default heat exchanger efficiency of 100%.

Note for monitoring during the crediting period

Changes may be made during the crediting period to elements of the steam system from which the heat exchangers are fed may lead to changes in the baseline emissions factor of the steam used, and hence impact the baseline emissions factor for the hot water which is produced.

Therefore, the project proponent shall ensure the steam baseline emissions factor is monitored annually and updated accordingly when applied to the above equations. The value for the baseline emissions factor of the steam to be applied in year y shall be that obtained as per Section I above.

CALCULATION OF THE PROJECT EMISSIONS

Project emissions within the project boundary result from the combustion of natural gas within the project boundary:

$$PE_y = PE_{NG,P,y} \quad (23)$$

Where:

$PE_{NG,P,y}$ Project emissions resulting from combustion of natural gas within the project boundary (in t CO_2e) for the year y.

Those project emissions are respectively calculated as follows:

$$PE_{NG,P,y} = FC_{NG,P,y} \cdot NCV_{NG} \cdot EF_{NG,CO2,p} \quad (24)$$

Where:

$FC_{NG,P,y}$ Natural gas consumed within the project facility "j" (in tonnes/ normal m^3) in the year y.

NCV_{NG} Lower heating value of the natural gas combusted (in TJ/t or TJ/normal m^3). As per certificates from the natural gas supplier or from IPCC figures.

$EF_{NG,CO2,p}$ CO_2 emission factor for the combustion of natural gas (in t CO2/TJ). As per certificates from the natural gas supplier or from IPCC figures.

When calculating the term $FC_{NG,P,y}$, the project proponent may resort to using the formula below:

$$FC_{NG,P,y} = FC_{NG,P,C,y} + FC_{NG,P,H,y} \quad (25)$$

Where:

$FC_{NG,P,C,y}$ Natural gas consumed by the main equipment within the boundaries of the project facility j in year y (in tonnes/ normal m^3)

$FC_{NG,P,H,y}$ Natural gas consumed for supplementary firing within the boundaries of the project facility j in year y (in tonnes/ normal m^3).

CALCULATION OF THE LEAKAGE EMISSIONS

The project proponent should estimate the size of leakage emission from electricity consumption and assess if those leakages are higher than 1% of the calculated emission reductions from that project activity, in the event that the project activity were to draw electricity from the grid. If that is the case, those leakage emissions should be included in the leakage calculations.

Upstream emissions from fuel extraction, processing, liquefaction, transportation and regasification of Natural Gas (to be considered only when the project fuel is Natural Gas)

In this methodology, the following leakage emission sources shall be considered:

- Fugitive CH_4 emissions associated with fuel extraction, processing, liquefaction, transportation, regasification and distribution of natural gas used in the project plant and fossil fuels used in the grid in the absence of the project activity ($LE_{CH_4,y}$).
- In the case LNG is used in the project plant: CO_2 emissions from fuel combustion/electricity consumption associated with the liquefaction, transportation, re-gasification and compression into a natural gas transmission or distribution system ($LE_{LNG,CO_2,y}$).

$$LE_{US,y} = LE_{CH_4,y} + LE_{LNG,CO_2,y} \qquad (26)$$

Where:

$LE_{CH_4,y}$	Leakage emissions due to fugitive upstream CH4 emissions in the year y in t CO2e
$LE_{LNG,CO_2,y}$	Leakage emissions due to fossil fuel combustion / electricity consumption associated with the liquefaction, transportation, re-gasification and compression of LNG into a natural gas transmission or distribution system during the year y in t CO2e

Fugitive methane emissions

For the purpose of determining fugitive methane emissions associated with the production – and in case of natural gas, the transportation and distribution of the fuels – project participants should multiply the quantity of natural gas consumed in all element processes i with a methane emission factor for these upstream emissions ($EF_{NG,upstream,CH_4}$), and subtract for all fuel types k which would be used in the absence of the project activity the fuel quantities multiplied with respective methane emission factors ($EF_{NG,upstream,CH_4}$), as follows:

$$LE_{CH_4,y} = \left[FF_{\Pr oject,y} \cdot NCV_{NG,y} \cdot EF_{NG,upstream,CH_4} - \sum_k FF_{Baseline,k,y} \cdot NCV_{NG,k} \cdot EF_{NG,upstream,CH_4} \right] \cdot GWP_{CH_4} \quad (27)$$

Where:

$LE_{CH_4,y}$	Leakage emissions due to upstream fugitive CH4 emissions in the year y in t CO2e
$FF_{\Pr oject,y}$	Quantity of natural gas combusted in all element processes during the year y in m³
$NCV_{NG,y}$	Average net calorific value of the natural gas combusted during the year *y* in /m³
$EF_{NG,upstream,CH_4}$	Emission factor for upstream fugitive methane emissions from production, transportation and distribution of natural gas in t CH4 per TJ fuel supplied to final consumers
$FF_{Baseline,k,y}$	Quantity of fuel type *k* (a coal or oil) that would be combusted in the absence of the project activity in all element processes during the year *y* in a volume or mass unit
$EF_{NG,upstream,CH_4}$	Emission factor for upstream fugitive methane emissions from production, transportation and distribution of natural gas in t CH4 per TJ fuel supplied to final consumers
GWP_{CH_4}	Global warming potential of methane valid for the relevant commitment period

Where reliable and accurate national data on fugitive CH4 emissions associated with the production, and in case of natural gas, the transportation and distribution of the fuels is available, project participants should use this data to determine average emission factors by dividing the total quantity of CH4 emissions by the quantity of fuel produced or supplied respectively. Where such data is not available, project participants may use the default values provided in Table 2 below. In this case, the natural gas emission factor for the location of the project should be used, except in cases where it can be shown that the relevant system element (gas production and/or processing/transmission/distribution) is predominantly of recent vintage and built and operated to international standards, in which case the US/Canada values may be used.

Note that the emission factor for fugitive upstream emissions for natural gas ($EF_{NG,upstream,CH_4}$) should include fugitive emissions from production, processing, transport and distribution of natural gas, as indicated in the Table 2 below. Note further that in case of coal the emission factor is provided based on a mass unit and needs to be converted in an energy unit, taking into account the net calorific value of the coal.

Table 2: Default emission factors for fugitive CH_4 upstream emissions

Activity	Unit	Default emission factor	Reference for the underlying emission factor range in Volume 3 of the *1996 Revised IPCC Guidelines*
Coal			
Underground mining	t CH4 / kt coal	13.4	Equations 1 and 4, p. 1.105 and 1.110
Surface mining	t CH4 / kt coal	0.8	Equations 2 and 4, p.1.108 and 1.110
Oil			
Production	t CH4 / PJ	2.5	Tables 1-60 to 1-64, p. 1.129 - 1.131
Transport, refining and storage	t CH4 / PJ	1.6	Tables 1-60 to 1-64, p. 1.129 - 1.131
Total	t CH4 / PJ	4.1	
Natural gas			
USA and Canada			
Production	t CH4 / PJ	72	Table 1-60, p. 1.129
Processing, transport and distribution	t CH4 / PJ	88	Table 1-60, p. 1.129
Total	t CH4 / PJ	160	
Eastern Europe and former USSR			
Production	t CH4 / PJ	393	Table 1-61, p. 1.129
Processing, transport and distribution	t CH4 / PJ	528	Table 1-61, p. 1.129
Total	t CH4 / PJ	921	
Western Europe			
Production	t CH4 / PJ	21	Table 1-62, p. 1.130
Processing, transport and distribution	t CH4 / PJ	85	Table 1-62, p. 1.130
Total	t CH4 / PJ	105	
Other oil exporting countries / Rest of world			
Production	t CH4 / PJ	68	Table 1-63 and 1-64, p. 1.130 and 1.131
Processing, transport and distribution	t CH4 / PJ	228	Table 1-63 and 1-64, p. 1.130 and 1.131
Total	t CH4 / PJ	296	

Note: The emission factors in this table have been derived from IPCC default Tier 1 emission factors provided in Volume 3 of the 1996 Revised IPCC Guidelines, by calculating the average of the provided default emission factor range.

CO_2 emissions from LNG

Where applicable, CO2 emissions from fuel combustion / electricity consumption associated with the liquefaction, transportation, re-gasification and compression of LNG into a natural gas transmission or distribution system ($LE_{LNG,CO_2,y}$) should be estimated by multiplying the quantity of natural gas combusted in the project with an appropriate emission factor, as follows:

$$LE_{LNG,CO_2,y} = FF_{Project,y} \cdot EF_{CO_2,upstream,LNG} \qquad (28)$$

Where:

$LE_{LNG,CO_2,y}$ Leakage emissions due to fossil fuel combustion / electricity consumption associated with the liquefaction, transportation, re-gasification and compression of LNG into a natural gas transmission or

	distribution system during the year y in t CO2e
$FF_{Project,y}$	Quantity of natural gas combusted in all element processes during the year *y* in m³
$EF_{CO_2,upstream,LNG}$	Emission factor for upstream CO2 emissions due to fossil fuel combustion/electricity consumption associated with the liquefaction, transportation, regasification and compression of LNG into a natural gas transmission or distribution system

CALCULATION OF THE EMISSION REDUCTIONS

The GHG emission reductions resulting from the project activity in the year y (ER_y) are calculated as in the equation below:

$$ER_y = BE_y - PE_y - LE_y \quad (29)$$

Where:

BE_y	Emissions in the baseline scenario for the year y. Calculated as in the equation given above.
PE_y	Emissions resulting from the project activity in the year y. Calculated as in the equation given above.
LE_y	Net leakage emissions resulting from the implementation and operation of the project activity. Calculated as in the equation given above.

The project proponent, who applies the new VCS methodology, should provide evidences for the figures applied and used in the excel work sheets in order to be able to fully retrace the assumptions and calculations made to determine the emissions reductions.

Data and parameters not monitored:

Data/parameter:	$SC_{BL,j,y}$
Data unit:	TJ
Description:	The amount of energy consumed in the form of steam by the project customer i, which is supplied by the project facility “j” in year y.
Source of data:	Calculated on the basis of the steam generation and the data for the steam enthalpy.

Measurement procedures (if any):	If applicable, energy content of steam can be directly measured.
QA/QC procedures	
Any comment:	-
Uncertainty level	Low: this parameter is calculated from variables which are monitored and subject to their own QA/QC procedures ($SP_{BL,j,y}$ and $SDEN_{BL,j,y}$). Alternatively, this could be measured by a heat meter, calibrated also following the QA/QC procedures applied in the data and parameters to be monitored section, which is similar also to that applied in other CDM approved methodologies such as AM0048.

Data/parameter:	$SEF_{BL,i,y}$
Data unit:	t CO_2/TJ
Description:	The baseline emission factor for the production of steam in project customer i for year y.
Source of data:	Actual performance data that is publicly available will be used for purpose. Otherwise, the project proponent may resort to historical data for the three most recent years for which data is available.
Measurement procedures (if any):	-
QA/QC procedures	-
Any comment:	
Uncertainty level	Low: two options are given in the meth to determine SEF: Option I.A., based on publicly available energy performance data on the amount of energy produced in the form of steam and energy consumed to produce it. The uncertainty level is in theory dependent mostly upon the how the amount of fossil fuel energy consumed is determined, namely $HEC_{BL,FF,st,i,y}$. The uncertainty level of this parameter is in turn considered to be low per se, and two options are given in turn to determine it as discussed in the table for $HEC_{BL,FF,st,i,y}$ Option I.B, based on default values and varying degrees of condensate recovery percentages with respect to the total amount of steam generated. Hence, the uncertainty level in this option is dependent primarily on how the fraction of heat recovered in the form of condensate is determined. This option relies on the use of efficiency values which are taken conservatively as those of the steam generating facilities of the project customers. It assumes that there are no transmission losses

	of heat. Such assumptions lead to a highly conservative estimate for the specific emissions because it assumes that once steam is generated from the boilers, there is no further loss of energy until the point of use. In practice, heat losses due to transmission tend to be of the order of 10%. The fossil fuel that needs to be burned to make up for these losses is ignored in our calculations, and this we feel is more than sufficient to compensate for even uncertainties, which as discussed we feel are low anyhow. Furthermore, all the options used to estimate the amount of energy recovered from the condensate that is formed assume that there are no condensate, nor heat losses between the point of condensate formation and entrance to the condensate recovery tank. This of course is highly conservative per se. There are two options given to determine Xc depending upon the availability of historical and actual data for quantity of condensate recovered and sent to the boiler house and condensate conditions of temperature and pressure. Where actual data is used, the maximum historical values are assumed, thereby assuming maximum energy recovery. The second option involves the use of default factors and requires annual verification to be carried out that the no changes have occurred that warrant a change in the applied default value.

Data/parameter:	$HEC_{BL,FF,st,i,y}$
Data unit:	TJ
Description:	The energy associated with the fossil fuel that was consumed by the project customer "i" during year y
Source of data:	Calculated on the basis of actual fuel consumption data that is publicly available.
Measurement procedures (if any):	-
QA/QC procedures	Ensure suitable standards for determining efficiency are applied if parameter is not determined from public sources. Check consistency with previously derived values and equipment design efficiency values
Any comment:	
Uncertainty level	There are two options given to determine $SEF_{BL,i,y}$, one based on a publicly reported data (Option 1 A) and the other based on default values (Option 1 B). Option 1A. The uncertainty level is considered to be low for this option if the central heating plant has to publicly report it heat production and fuel consumption figures to energy regulators. However if the central generating facility has only to report publicly its heat production figures and not its fossil fuel consumption ones, then in this case the uncertainty is potentially

	higher and additional measures need to be in place to ensure a low level of uncertainty. The methodology offers two alternatives to determine what the fossil energy consumption may be: Option I.A.a, which is based on publicly reported fuel consumption figures and fuel properties, which can be obtained from fuel suppliers, and which therefore is considered to be of low uncertainty Option I.A.b is based on the actual heat or steam production figures and conditions of boiler feedwater and steam, and the efficiency of the steam generating system. The efficiency of the steam generating equipment enables the project proponent to apply four options, each of which are more conservative than the other. Three of those options are: the manufacturer's quoted peak boiler efficiency, efficiencies of boilers of similar design, or a default value of 100% efficiency. The uncertainty level of these is low. The forth option is based on peak measured efficiencies, but this must be carried out by applying the standard procedures for boiler efficiency determinations. The use of a standard method, which relies on calibrated equipment and involves applying the highest value obtained over a full load range text in our opinion lead to a low level of uncertainty in the determination of the boiler efficiency in the event this option were to be applied. Option I B, which does not rely on reported energy production and consumption data but rather relies on similar boiler efficiency options given above. It offers an even lower uncertainty level In both cases above heat losses throughout the transmission system are ignored. Heat losses in steam transmission alone can amount to 5 – 10 % , and sometime even more in old systems, of energy produced by the generating facility. The calculations in the meth assume zero losses, and thus fuel to steam efficiency is significantly higher than what is in typical. Hence, the extra fossil fuel that needs to be burned to make up for these losses is not considered for the purpose of determining the amount of fossil fuel energy supplied to the steam generating facilities. This leads to a lower CO_2 emissions factor per unit energy of steam produced that will be the case in reality.

Data/parameter:	$HSC_{BL,i,y}$
Data unit:	TJ
Description:	The amount of energy contained in the steam which was generated by the customer i by burning fossil fuel during year y

Source of data:	Actual data that is publicly available will be used for purpose, or calculated using measured data (quantity of stem produced by customer i or the facility that supplies steam to customer i.
Measurement procedures (if any):	-
QA/QC procedures	Check for consistency with historical values if option involving the use of measured data is applied.
Any comment:	
Uncertainty level	Low: this data is publicly available and presented to energy authorities and the result of heat supplied to customers, or optional derived from monitored parameters subject to common QA/QC applied to measure similar parameters

Data/parameter:	$HFC_{BL,FF,st,i,y}$
Data unit:	tonnes
Description:	The quantity of fossil fuel consumed for steam generation by project customer i during year y.
Source of data:	Actual data that is publicly available will be used for this purpose.
Measurement procedures (if any):	-
QA/QC procedures	
Any comment:	
Uncertainty level	Low: if this is provided by the supplier of the steam as part of its duty to report this consumption to outside stakeholders. Data can also be crosschecked against historical data and compared to the amount of heat produced in the form of steam and supplied to the customers.

Data/parameter:	$\eta_{BL,st,i}$
Data unit:	**%**
Description:	Project customer i's boiler efficiency based on NCV (in %).
Source of data:	The highest measured value of boiler efficiency recorded over full range boiler test; the boiler's peak thermal efficiency as per manufacturer's information or a default boiler efficiency of 100%;
Measurement procedures (if any):	Full range boiler test if applicable
QA/QC procedures	Ensure suitable standards for determining efficiency are applied if relevant to the option chosen. Check consistency with similarly derived historical values and equipment design efficiency values
Any comment:	
Uncertainty level	Low: even in the case in which boiler efficiency is determined based measurements, these have to be done according to acceptable standards. It also involves taking the highest value of a full boiler efficiency load test which leads to a conservative determination of efficiency under this option. The remaining

	options involve an even higher degree of efficiency and to do not rely on any measured data, but rather on published data or very high conservative assumptions for boiler efficiency.

Data/parameter:	$HWC_{BL,j,y}$
Data unit:	TJ
Description:	The energy content in the hot water produced by the project facility j, which is purchased by project customer i in year y
Source of data:	If applicable, energy content of hot water can be directly measured.
Measurement procedures (if any):	-
QA/QC procedures	Where applicable meters shall be calibrated as per their data book. Measuring conditions shall be as per meters data book. Check consistency with historical monitored data. Crosscheck with invoices at project facility site
Any comment:	
Uncertainty level	Low: determined using QA/QC procedures commonly used in the CDM to temperature measurements.

Data/parameter:	$HWEF_{BL,i,y}$
Data unit:	t CO_2/TJ
Description:	The CO_2 emissions factor for the hot water produced in year y.
Source of data:	Actual data that is publicly available will be used for purpose.
Measurement procedures (if any):	-
QA/QC procedures	-
Any comment:	
Uncertainty level	Low: based partly on publicly reported data for heat production and fossil fuel consumption required to comply with energy legislation, or if applicable based on conservative and low level of uncertainty values of efficiency and publicly reported heat production figures, or in the absence of these on default values of low uncertainty level.

Data/parameter:	$HEC_{BL,FF,hwb,i,y}$
Data unit:	TJ
Description:	The energy associated with the fossil fuel consumed by customer i to self-generate hot water in a hot water boiler during year y.
Source of data:	Actual data that is publicly available will be used for purpose.
Measurement procedures (if any):	-
QA/QC procedures	-
Any comment:	

Uncertainty level	Low: same as for $HEC_{BL,FF,st,i,y}$ given above.

Data/parameter:	$HHWC_{BL,hwb,i,y}$
Data unit:	TJ
Description:	The energy contained in the hot water, which was generated by the customer i from burning fossil fuel during year y.
Source of data:	Actual data that is publicly available will be used for purpose.
Measurement procedures (if any):	-
QA/QC procedures	-
Any comment:	
Uncertainty level	Low: this data is publicly available and presented to energy authorities and the result of heat supplied to customers

Data/parameter:	$HFC_{BL,FF,hwb,i,y}$
Data unit:	tonnes
Description:	The quantity of fossil fuel consumed for hot water generation in hot water boilers by project customer i during year y. This can be reported as mass units of the baseline fuel or in units of volume if data is provided on the mass density of the natural gas used (in tonnes)
Source of data:	Actual data that is publicly available will be used for purpose.
Measurement procedures (if any):	-
QA/QC procedures	- .
Any comment:	
Uncertainty level	Low: if this is provided by the supplier of the hot water as part of its duty to report this consumption to outside stakeholders. Data can also be crosschecked against historical data and compared to the amount of heat produced in the form of steam and supplied to the customers.

Data/parameter:	$\eta_{BL,hwb,i}$
Data unit:	
Description:	Project customer i's hot water boiler's efficiency based on NCV.
Source of data:	The highest measured value of boiler efficiency recorded over full range boiler test; the boiler's peak thermal efficiency as per manufacturer's information or a default boiler efficiency of 100%
Measurement procedures (if any):	A full range boiler test if applicable.
QA/QC procedures	Ensure suitable standards for determining efficiency are applied if relevant to the option chosen. Check consistency with similarly derived historical values and equipment design efficiency values
Any comment:	

Uncertainty level	Low: even in the case in which boiler efficiency is determined based measurements, these have to be done according to acceptable standards. It also involves taking the highest value of a full boiler efficiency load test which leads to a conservative determination of efficiency under this option. The remaining options involve an even higher degree of efficiency and to do not rely on any measured data, but rather on published data or very high conservative assumptions for boiler efficiency.

Data/parameter:	$HHWC_{BL,sthx,i,y}$
Data unit:	TJ
Description:	The energy contained in hot water self generated by project customer i from steam, in a steam-to-water heat exchanger (in TJ) during year y.
Source of data:	Actual data that is publicly available will be used for purpose.
Measurement procedures (if any):	-
QA/QC procedures	-
Any comment:	
Uncertainty level	Low: if this data is publicly available and presented to energy authorities and the result of heat supplied to customers.

Data/parameter:	$HHWP_{BL,sthx,i,y}$
Data unit:	tonnes
Description:	The mass of hot water self-generated by the project customer i by steam-to-water heat exchanger during year y.
Source of data:	Actual data that is publicly available will be used for purpose.
Measurement procedures (if any):	-
QA/QC procedures	-
Any comment:	
Uncertainty level	Low: this data is publicly available and presented to energy authorities and quantifies the result of heat supplied to customers.

Data/parameter:	$HFC_{BL,st,stbx,i,y}$
Data unit:	tonnes
Description:	Quantity of steam consumed by the project customer for hot water production during year y.
Source of data:	Actual data that is publicly available will be used for this purpose.
Measurement procedures (if any):	-
QA/QC procedures	-
Any comment:	
Uncertainty level	Low: this data is publicly available and presented to energy

	authorities and quantifies the result of heat supplied to customers.

Data/parameter:	$\eta_{BL,sthx,i}$
Data unit:	
Description:	customer i's (in %) steam-to-water exchanger efficiency based on one of the following
Source of data:	The highest measured annual value of heat exchanger efficiency; the design heat exchanger efficiency or a default heat exchanger efficiency of 100%.
Measurement procedures (if any):	-
QA/QC procedures	Ensure suitable standards for determining efficiency are applied if relevant to the option chosen. Check consistency with similarly derived historical values and equipment design efficiency values if applicable.
Any comment:	
Uncertainty level	Low: provided suitable tests are conducted. Low: if any default value is chosen.

MONITORING METHODOLOGY

Monitoring procedures

Data for carbon content of fuel sources may be taken from IPCC. In the event that more recent or accurate scientific studies are produced and approved by the UNFCCC these data shall be used.

Official electricity generation and transmission company statistics is used to determine the grid electricity coefficient. This data is gathered from the utilities, whether on the national, regional or local level, as appropriate.

It is assumed that the data provided for the electricity grid and from individual facilities are available and transparent, in order to calculate the carbon coefficient of the electricity and steam and or hot water being displaced from project customers by the project activity.

Vintage and spatial level of data: the data is gathered on a national or regional power grid level to determine the combined margin.

As for the vintage of the data, the project developer should try and get three years of data prior to project implementation where to required in the baseline methodology. If three years of data is not available, then the project developer must use at least one complete year (two when it exists) and must demonstrate using evidence from credible sources to the DOE that additional data does not exist. Non-representative data is included unless there is a major outlying event. Should the project developer wish to exclude non-representative data they must be able to document why this is removed and this should be approved during validation.

When IPCC data is available, project proponents shall take into consideration that the Board agreed that the IPCC default values should be used only when country or project specific data are not available or difficult to obtain.

The project developer will have to ensure the completeness and accuracy of the data set during the baseline measurement year by installing, repairing, and calibrating meters as appropriate. Completeness/accuracy of data should be relatively easy to verify, and emissions reductions will not be included if the evidence does not demonstrate this point clearly. The project developer should obtain data on metering in the project and try and ascertain that the meter accuracy is 95% or greater – and that quality control procedures are in place to deal with defective meters and/or recalibrate them on a regular basis.

The project proponent shall also provided simplified diagrams illustrating the location of the monitoring points.

Data and parameters monitored

Data/parameter:	$EG_{P,y}$
Data unit:	MWh
Description:	Net electricity supplied to the power grid by the proposed project facility ‘j’ in year ‘y’(MWh/yr).
Source of data:	Electricity meter at the project facility ‘j’
Measurement procedures (if any):	Read electricity meter and store information until 2 years after the end of the crediting period.
Monitoring frequency	Monthly
QA/QC procedures	Meters shall be calibrated as per their data book. Measuring conditions shall be as per meters data book. Check consistency with historical monitored data. Crosscheck with invoices and electricity supply data at project facility site.
Any comment:	
Uncertainty level	Low, it follows QA/QC procedures and monitoring frequencies which are common to other CDM Monitoring methodologies such as AM0048

Data/parameter:	$CEF_{BL/P,FF,y}$
Data unit:	t C/TJ
Description:	Carbon emission factor corresponding to the fossil fuel used to produce steam or hot water as applicable. Carbon emission factor in year y corresponding to fossil fuel used by project customer i to generate steam/hot water or that which is used in a given steam/hot water generating plant to produce the steam/hot water which is sourced by the project customer i (in tonnes of C/TJ), shall be determined from the technical literature, from the project customer i, or the steam/hot water generating plant which supplies steam/hot water to the project customer i.
Source of data:	Obtained from the project customer ‘i’ / project facility ‘j’ or technical literature.
Measurement procedures (if any):	When IPCC data is available, project proponents shall take into consideration that the Board agreed that the IPCC default values should be used only when country or project specific data are not available or difficult to obtain.
Monitoring frequency	-
QA/QC procedures	-
Any comment:	-

Uncertainty level	Low, given external sources that provide it (fuel suppliers/government bodies, IPCC)

Data/parameter:	$EF_{BL,CO_2,y}$
Data unit:	t CO_2/MWh
Description:	Emission factor of the electricity grid to which the project facility "j" supplies the electricity generated. Determination of the emission factor will be made once at the validation stage based on an ex ante assessment, and once again at the start of each subsequent crediting period (if applicable). Regardless of whether option 1 (BM) or option 2 (CM) is chosen, the emission factor is also calculated ex-post as described in the "Tool to calculate emission factor for an electricity system".
Source of data:	Publicly available data on electricity generation within the respective power grid.
Measurement procedures (if any):	
Monitoring frequency	Calculated ex-post each year.
QA/QC procedures	As per "Tool to calculate emission factor for an electricity system"
Any comment:	-
Uncertainty level	Low, the data upon which the parameter is determined is obtained for official electricity sector statistics whilst the treatment of the data to the determine the parameter uses an approved CDM tool

Data/parameter:	$EF_{NG,upstream,CH_4}$
Data unit:	t CH_4/TJ
Description:	Emission factor for upstream fugitive methane emissions from production, transportation and distribution of natural gas.
Source of data:	Obtained from the project facility 'j' or table in the leakage section.
Measurement procedures (if any):	When IPCC data is available, project proponents shall take into consideration that the Board agreed that the IPCC default values should be used only when country or project specific data are not available or difficult to obtain.
Monitoring frequency	-
QA/QC procedures	-
Any comment:	-
Uncertainty level	Low, the source is an official third party (IPCC) or a host country official source

Data/parameter:	$EF_{CO_2,upstream,LNG}$
Data unit:	tCO_2/TJ

Description:	Emission factor for upstream CO_2 emissions due to fossil fuel combustion/electricity consumption associated with the liquefaction, transportation, regasification and compression of LNG into a natural gas transmission or distribution system
Source of data:	Where reliable and accurate data on upstream CO_2 emissions due to fossil fuel combustion / electricity consumption associated with the liquefaction, transportation, re-gasification and compression of LNG into a natural gas transmission or distribution system is available, project participants should use this data to determine an average emission factor. Where such data is not available, project participants may assume a default value of 6 tCO_2/TJ as a rough approximation
Measurement procedures (if any):	When IPCC data is available, project proponents shall take into consideration that the Board agreed that the IPCC default values should be used only when country or project specific data are not available or difficult to obtain.
Monitoring frequency	-
QA/QC procedures	-
Any comment:	-
Uncertainty level	Low, the source is an official third party (IPCC) or a host country official source

Data/parameter:	$SDEN_{BL,j,y}$
Data unit:	TJ/tonne
Description:	Specific enthalpy of steam leaving the project facility 'j' (in TJ/tonne of steam supplied).
Source of data:	This data shall be obtained from steam tables, using temperatures and pressure of the steam purchased.
Measurement procedures (if any):	Use monitored pressure and temperature of the steam to obtain specific enthalpy from steam tables.
Monitoring frequency	Monthly
QA/QC procedures	Meters shall be calibrated as per their data book. Measuring conditions shall be as per meters data book. Check consistency with historical monitored data.
Any comment:	-
Uncertainty level	Low, parameter is obtained from temperature and pressure data that is monitored and subject to QA/QC procedures applied in CDM monitoring methodologies such as AM0048 and AM0029, and publicly available steam tables

Data/parameter:	Steam temperature
Data unit:	°C
Description:	Temperature of steam purchased by project customer 'i'.

Source of data:	Temperature meters at project facility ‘j’
Measurement procedures (if any):	Read temperature meter daily and calculate monthly average. Store information until 2 years after the end of the crediting period.
Monitoring frequency	Daily measurements and monthly average.
QA/QC procedures	Meters shall be calibrated as per their data book. Measuring conditions shall be as per meters data book. Check consistency with historical monitored data.
Any comment:	-
Uncertainty level	Low, parameter is monitored and subject to QA/QC procedures applied in CDM monitoring methodologies such as AM0048

Data/parameter:	Steam pressure
Data unit:	MPa
Description:	Pressure of steam purchased by project customer ‘i’.
Source of data:	Pressure meters at project facility ‘j’
Measurement procedures (if any):	Read pressure meter daily and calculate monthly average. Store information until 2 years after the end of the crediting period.
Monitoring frequency	Daily measurements and monthly average.
QA/QC procedures	Meters shall be calibrated as per their data book. Measuring conditions shall be as per meters data book. Check consistency with historical monitored data.
Any comment:	-
Uncertainty level	Low, parameter is monitored and subject to QA/QC procedures applied in CDM monitoring methodologies such as AM0048

Data/parameter:	$FC_{NG,P,y}$
Data unit:	Tonnes or m^3
Description:	Natural gas consumed within the boundary of the project facility (in tonnes/normal m^3) in the year y.
Source of data:	Purchase records and fuel data logs.
Measurement procedures (if any):	Store information until 2 years after the end of the crediting period.
Monitoring frequency	Daily measurement and monthly recorded.
QA/QC procedures	Meters shall be calibrated as per their data book. Measuring conditions shall be as per meters data book. Check consistency with historical monitored data. Crosscheck with purchase records.
Any comment:	-
Uncertainty level	Low, parameter is monitored and subject to QA/QC procedures applied in CDM monitoring methodologies such as AM0029

Data/parameter:	GWP_{CH_4}
Data unit:	tCO_2/tCH_4
Description:	Global warming potential of CH_4 valid for the commitment period. Obtained from IPCC.
Source of data:	-
Measurement procedures (if any):	-
Monitoring frequency	-
QA/QC procedures	-
Any comment:	-
Uncertainty level	Low, given external source that provides it (IPCC)

Data/parameter:	NCV_{NG} / $NCV_{FF,i,y}$
Data unit:	TJ/t
Description:	Lower heating value of the natural gas/fossil fuel combusted (in TJ/t or TJ/10^3 normal m^3).
Source of data:	As per purchase certificates or IPCC default data.
Measurement procedures (if any):	-
Monitoring frequency	-
QA/QC procedures	-
Any comment:	-
Uncertainty level	Low, the source is a credible host country source such as the fuel supplier of an third part source such as the IPCC.

Data/parameter:	$HWEN_{BL,j,y}$
Data unit:	TJ/tonne
Description:	The specific enthalpy of hot water produced by the project facility j in the year y (TJ/ tonne).
Source of data:	This data shall be obtained using temperature of the hot water purchased measured at the project facility 'j' using data from the steam tables.
Measurement procedures (if any):	Use monitored temperature of the hot water produced by the project facility 'j' to obtain specific enthalpy.
Monitoring frequency	Monthly
QA/QC procedures	Meters shall be calibrated as per their data book. Measuring conditions shall be as per meters data book. Check consistency with historical monitored data.
Any comment:	If heat meter is available, separate temperature readings are not

	required.
Uncertainty level	Low, provided the given QA/QC procedures and monitoring frequencies are adhered to. Where the parameter is determined based on measured temperature the enthalpy is determined from steam tables. Hence uncertainty is also low.

Data/parameter:	Hot water temperature
Data unit:	°C
Description:	Temperature of hot water purchased by project customer 'i'.
Source of data:	Temperature meters at project facility 'j'.
Measurement procedures (if any):	Read temperature meter daily and calculate monthly average. Store information until 2 years after the end of the crediting period.
Monitoring frequency	Daily measurements and monthly average.
QA/QC procedures	Meters shall be calibrated as per their data book. Measuring conditions shall be as per meters data book. Check consistency with historical monitored data.
Any comment:	-
Uncertainty level	Low, parameter is monitored and subject to QA/QC procedures and monitoring frequency applied in CDM monitoring methodologies such as AM0048 to similar variables

Data/parameter:	Water return temperature
Data unit:	°C
Description:	Temperature of warm water returned to hot water generating facility.
Source of data:	Temperature meters at project facility 'j'.
Measurement procedures (if any):	Read temperature meter daily and calculate monthly average. Store information until 2 years after the end of the crediting period.
Monitoring frequency	Daily measurements and monthly average.
QA/QC procedures	Meters shall be calibrated as per their data book. Measuring conditions shall be as per meters data book. Check consistency with historical monitored data.
Any comment:	To be applied when using Option II.A.b.
Uncertainty level	Low, parameter is monitored and subject to QA/QC procedures and monitoring frequency applied in CDM monitoring methodologies such as AM0048 to similar variables

Data/parameter:	Steam condensate temperature
Data unit:	°C
Description:	Temperature of condensate from existing heat exchanger used by customer 'i ' to produce hot water or by the supplier of hot water

	to customer i
Source of data:	Temperature meters
Measurement procedures (if any):	Store information until 2 years after the end of the crediting period.
Monitoring frequency	Daily measurements and monthly average.
QA/QC procedures	Meters shall be calibrated as per their data book. Measuring conditions shall be as per meters data book. Check consistency with historical monitored data.
Any comment:	To be used when applying Option II.B.a.i
Uncertainty level	Low, parameter is monitored and subject to QA/QC procedures and monitoring frequency applied in CDM monitoring methodologies such as AM0048 to similar variables. Where defaults are used, the validity of these defaults is verified annually to determine if significant changes have been made to operating conditions (pressure) of the condensate system or if flash steam recovery system is added or it operating pressure increased.

Data/parameter:	$HWP_{BL,j,y}$
Data unit:	tonnes/yr
Description:	The amount of hot water produced by project facility ‘j’ and supplied to project customer ‘i’ in the year y (in tonnes)
Source of data:	Measured at the project facility ‘j’.
Measurement procedures (if any):	Read hot water meter and store information until 2 years after the end of the crediting period.
Monitoring frequency	Monthly
QA/QC procedures	Meters shall be calibrated as per their data book. Measuring conditions shall be as per meters data book. Check consistency with historical monitored data. Crosscheck with purchase receipts and hot water supply data at project site.
Any comment:	-
Uncertainty level	Low, the parameter is monitored and subject to QA/QC procedures which are common to those demanded in other CDM methodologies such as AM0029 and AM0048. It can be cross checked with billing information

Data/parameter:	$SP_{BL,j,y}$
Data unit:	tonnes/yr
Description:	Quantity of steam produced by the project facility ‘j’ and supplied to the project customer ‘i’ in the year y, (in tonnes)
Source of data:	Measured at the project facility ‘j’.
Measurement procedures (if any):	Read steam meter and store information until 2 years after the end of the crediting period.

Monitoring frequency	Monthly
QA/QC procedures	Meters shall be calibrated as per their data book. Measuring conditions shall be as per meters data book. Check consistency with historical monitored data. Crosscheck with invoices and steam supply data at project site.
Any comment:	-
Uncertainty level	Low, the parameter is monitored and subject to QA/QC procedures which are common to those demanded in other CDM methodologies such as AM0029 and AM0048. It can be cross checked with billing information

GUIDANCE TO THE APPLICATION OF THE METHODOLOGY AND THE PREPARATION OF THE VCS PROJECT DESCRIPTION

1. Project location including geographic and physical information allowing the unique identification and delineation of the specific extent of the project should be provided in the PDD.

2. In line with the requirements of the VCS PD format, the project proponent, who applies the new VCS methodology, should provide a detailed description of:

(a)The scenario existing prior to the start of the implementation of the project activity, with a list of the equipment(s) and systems in operation at that time;

(b) The scope of activities/measures that are being implemented within the project activity, with a list of the equipment(s) and systems that will be installed and/or modified within the project activity/activities.

The project implementation schedule (precise schedule of works) should be described in detail with indication of the current status. Project proponents should indicate the source for the technical data provided in the PDD.

3. The technical specifications of the equipment installed at the site of the project activity should be disclosed together with the consumption of fuel, electricity, net calorific value of the fuel used together with detailed information on quality and quantity of heat and power generated.

4. When designing the monitoring plan in the VCS PD the project proponent should provide where possible an organigram illustrating the monitoring and reporting system organizational structure. Where possible, names of the staff with monitoring and reporting functions should be included in the PD.

5. The project proponent who applies the VCS methodology should describe how staff responsible for monitoring, recording and maintenance and calibration of monitoring equipment shall be trained.

6. Project emissions which are not addressed in the new methodology shall be calculated and compared with 1% of the overall average annual emissions reductions. They can only be excluded from further analysis they represent less than 1% of the total expected emission reductions."

7. In cases where the project activity results in the decommissioning of a steam and/or hot water generating facility at the project customer's site, the project proponent shall describe if there is any possibility that this may result in leakage. If it is deemed that leakage may occur, then the project proponent shall describe a means of estimating in a conservative manner what such leakage may be.

If however it is argued that the project activity results in the replacement of equipment and that the leakage due to the use of the replaced equipment in another activity can be neglected because the replaced equipment is scrapped, then an independent monitoring of the scrapping of the replaced equipment shall be implemented. The monitoring should include a check to ensure that the name plate of the equipment scrapped corresponds to that which has been replaced. For this purpose, scrapped equipment should be stored until such correspondence has been checked. The scrapping of replaced equipment should be documented and independently verified.

Approved VCS Methodology

VM0003

Version 1.2

29 August 2013

Sectoral Scope 14

Methodology for Improved Forest Management Through Extension of Rotation Age (IFM ERA)

Methodology developed by:

ecotrust

721 NW Ninth Ave, Suite 200
Portland, OR 97209
www.ecotrust.org

Table of Contents

1 SOURCES

This methodology is based on elements from the following methodologies:

- AR-ACM0001 *Afforestation and reforestation of degraded land*
- The *Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities*

This methodology also refers to the latest approved versions of the following tools:

- The CDM Additionality Tests (available at: http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-01-v5.2.pdf)
- The UNFCCC *Tool for testing significance of GHG emissions in A/R project activities* (available at: http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-04-v1.pdf)
- The UNFCCC tool for the *Calculation of the number of sample plots for measurements within A/R CDM project activities* (available at: http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-03-v2.pdf)

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology quantifies the GHG emission reductions and removals generated from improving forest management practices to increase the carbon stock on land by extending the rotation age of a forest or patch of forest before harvesting. By extending the age at which trees are cut, projects increase the average carbon stock on the land and remove more emissions from the atmosphere.

3 DEFINITIONS

Terms

Clear Cut: The harvest of all trees in an area

Logging Slash: Branches, other dead wood residues, and foliage left on the forest floor after timber removal

Patch Cut: A clear cut on a small area (less than one hectare)

Seed Tree: A variant system on clear cut with limited mature trees being left to provide seeds for regeneration

Group Selection: A variant on clear cut with groups of trees being left for wildlife habitat, wind firmness, soil retention or other silvicultural goals

Tree: A perennial woody plant with a diameter at breast height > 5 cm and a height greater than 1.3 m.

List of acronyms

A/R	Afforestation/Reforestation (under CDM)
AFOLU Guidelines	Agriculture, Forestry and Other Land Uses section of the IPCC Guidelines for National Greenhouse Gas Inventories 2006.
CDM	Clean Development Mechanism
GPG LULUCF	Intergovernmental Panel on Climate Change's Good Practice Guidance for Land-Use Land Use Change and Forestry
IFM	Improved forest management
VCS	Verified Carbon Standard
VCU	Verified Carbon Unit
FSC	Forest Stewardship Council

4 APPLICABILITY CONDITIONS

This methodology is applicable to Improved Forest Management (IFM) project activities that involve an extension in rotation age (ERA).

The conditions under which the methodology is applicable are:

- Forest management in both the baseline and project scenariot involves harvesting techniques such as clear cuts, patch cuts, seed tree, continuous thinning or group selection practices.
- Forests which are not subject to timber harvesting, or managed without an objective for earning revenue through timber harvesting in the baseline scenario are not eligible under this methodology.
- Forests must be certified by the Forest Stewardship Council (FSC) by the start of the project crediting period. FSC certification must be demonstrated no later than at the time of the first verification event.
- Project proponents must define the minimum project length in their project description document.
- The project does not encompass managed peat forests and the proportion of wetlands are not expected to change as part of the project
- Project proponents must have a projection of management practices in both with and without project scenarios.
- If fire is used as part of forest management then fire control measures, such as installation of fire-breaks or back-burning, must be taken to ensure fire does not spread outside the project area—that is, no biomass burning must be permitted to occur beyond the project area due to forest management activities.
- There may be no leakage through activity shifting to other lands owned or managed by project proponents outside the bounds of the project area.

5 PROJECT BOUNDARY

5.1 GHG Sources and Sinks

The carbon pools included in or excluded from the project boundary are shown in Table 1.

Table 1: Selected Carbon Pools

Carbon pools	Selected (Yes or No)	Justification / Explanation of choice
Above-ground biomass	Yes	Major carbon pool subjected to the project activity.
Below-ground biomass	Yes	Below-ground biomass stock is expected to increase due to the implementation of the VCS IFM project activity. Belowground biomass subsequent to harvest is not assessed with the conservative assumption of immediate emission.
Dead wood	Conditional	Dead wood stocks can be conservatively excluded UNLESS the project scenario produces greater levels of slash than the baseline AND slash is burned as part of forest management. If slash produced in the project case is left in the forest to become part of the dead wood pool, dead wood may be conservatively excluded. Alternatively, project proponents may elect to include the pool (where included the pool must be estimated in both the baseline and with project cases) as long as the dead wood pool represents less than 50% of total carbon volume on the site in any given modeled year.
Litter	No	Changes in the litter pool will be *de minimis* as a result of rotation extension.
Soil organic carbon	No	Changes in the soil organic carbon pool will be *de minimis* as a result of rotation extension.

Wood products	Conditional	This stock may increase or decrease (when compared to baseline) due to implementation of the project activity. The methodology provides an approach for accounting for this pool, but it allows also for exclusion of the wood products pool if transparent and verifiable information can be provided that carbon stocks in wood products are rising faster in the project case than in the baseline or are decreasing faster in the baseline than in the project case.

The emission sources included in or excluded from the project boundary area shown in Table 2. Any one of these sources can be neglected, ie, accounted as zero, if the application of the most recent UNFCCC CDM *Tool for testing significance of GHG emissions in A/R project activities* (see section 10 References) leads to the conclusion that the emission source is insignificant.

Table 2: Emissions sources included in the project boundary

Sources	Gas	Included / Excluded	Justification / Explanation of choice
Burning of biomass	CO_2	Excluded	However, carbon stock decreases due to burning are accounted as a carbon stock change
	CH_4	Included	Non-CO_2 gas emitted from biomass burning
	N_2O	Excluded	Potential emissions are negligibly small

Following the guidance of the Executive Board of the CDM, emissions caused by combustion of fossil fuels and through the use of fertilizers are considered insignificant and are not considered here (UNFCCC CDM EB 44, UNFCCC CDM EB 42).

5.2 Project area and eligibility of land

The project area geographically delineates the improved forest management project activity under the control of the project proponents. The IFM project activity may contain more than one discrete area of land. At the time the project description is validated, the following must be defined:

- Each discrete area of land must have a unique geographic identification;
- Aggregation of forest properties with multiple landowners is permitted under the methodology with aggregated areas treated as a single project area;
- The project proponents must describe legal title to the forest, rights of access to the sequestered carbon (or avoided carbon emissions), current land tenure, and forest management for each discrete area of forest;

- The project proponents must justify that, during the project lifetime, each discrete area of land is expected to be subject to a change in forest management through activities under the control of the project proponents.

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

6.1 Selected Baseline Approach

“Changes in carbon stocks in the pools within the project boundary from the most likely land use at the time the project starts”.

6.2 Preliminary screening based on the starting date of the IFM project activity

In accordance to the *VCS Standard v3*, or latest version, the start date for AFOLU projects can be earlier than 1 January 2002, provided that project validation and verification against the VCS has been completed by 1 October 2011, the project proponent can verifiably demonstrate that it had been designed and implemented as a climate change mitigation project from its inception, and that prior to 1 January 2002 the project engaged independent verifiers/monitoring experts and applied methodologies that now conform to this VCS-approved methodology to assess and quantify the project’s baseline scenario, leakage and net emissions reductions/removals.

If the project proponents claim that the start date of the IFM project activity is before the date of validation, then the project proponents must:

- Provide evidence that the starting date of the IFM project activity was after 1 January 2002, and
- Provide evidence that the incentive from the planned sale of VCUs was seriously considered in the decision to proceed with the project activity. This evidence must be based on (preferably official, legal and/or other corporate) documentation that was available to third parties at, or prior to, the start of the project activity.

6.3 Determination of Baseline Scenario

Step 1a. Identify credible alternative forest management scenarios to the proposed VCS project activity

As per the applicability conditions the project must demonstrate a baseline that involves clear cut, patch cut, seed tree, continuous thinning or group selection forest management techniques, using such evidence as management plans, forest inventories, assessments by reputable forestry consultants, the common practice of alternative land owners and common practice in the region. If such a baseline cannot be demonstrated then this methodology cannot be applied. Baseline scenarios with no timber harvesting or management without a timber revenue objective must be excluded as per the methodology applicability conditions.

Identify realistic and credible land-use scenarios that would have occurred on the land within the proposed project area in the absence of the IFM project activity under the VCS.[1] The scenario should be feasible for the project

[1] For example, continuation of the pre-project land-use or switch to land-use typical for region where the IFM project is planned

proponents or similar project proponents taking into account relevant national and/or sectoral policies[2] and circumstances, such as historical land uses, practices and economic trends. The identified land use scenario must be limited to forested land uses. This process should clearly identify barriers and benefits of all potential scenarios.

The possible land-use scenarios to be evaluated must include:

- Continuation of the pre-project forest management (Historical Baseline),
- Legal requirements for forest management in the region (Legal Baseline),
- Common practice forest management in the region (Common Practice Baseline), and
- Forest management as modeled under the project but in the absence of registration as an IFM project activity.

For identifying realistic and credible land-use scenarios, land use records, field surveys, data and feedback from stakeholders, and information from other appropriate sources, including Participatory Rural Appraisal (PRA)[3] may be used as appropriate. All current land uses within the boundary of the proposed IFM project activity may be deemed realistic and credible.

Project proponents should use the following guidelines to define these possible land-use scenarios.

Guidance for Defining the Legal Baseline

The Legal Baseline is defined by the forest management scenario that maximizes net present value to the forest owner(s) through timber harvesting while reflecting all legal requirements for forest management. In many cases, the specific management practices defined by the project proponent in the Legal Baseline may not be explicitly addressed in the relevant forest practices regulations, and the legality and plausibility of these practices must be confirmed by an independent forest consulting entity.

Guidance for Defining the Common Practice Baseline

Common practice in the project region must be defined by an independent forest consulting entity and should consider the following elements of forest management:

1) Harvest rotations,

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to be located, establishing agricultural plantation, tourist resort, hunting area/farm, utilizing regionally typical forms of funds investment or other economically attractive activities.

[2] The Annex 3 to the report of the EB at its twenty-second meeting and the Annex 19 to the report of the EB at its twenty-third meeting clarify how the relevant national and/or sectoral policies must be taken into account during identification of a baseline scenario. See: http://cdm.unfccc.int/Reference/Guidclarif.

[3] Participatory rural appraisal (PRA) is an approach to the analysis of local problems and the formulation of tentative solutions with local stakeholders. It makes use of a wide range of visualisation methods for group-based analysis to deal with spatial and temporal aspects of social and environmental problems. This methodology is, for example, described in:

- Chambers R (1992): Rural Appraisal: Rapid, Relaxed, and Participatory. Discussion Paper 311, Institute of Development Studies, Sussex.
- Theis J, Grady H (1991): Participatory rapid appraisal for community development. Save the Children Fund, London.

2) Harvest methods,
3) Species harvested and planted,
4) No harvest zones,
5) Riparian management areas,
6) Areas of steep slope or unstable soils, and/or
7) Maximum patch cut areas.

Step 1b. Selection of a single baseline forest management scenario

IFM project proponents must evaluate the identified plausible baseline management regimes relative to:

- A documented history of the operator (eg, operator must have at least 20 years of management records to show normal historical practices). Common records to document history include data on timber cruise volumes, inventory levels, harvest levels, etc. on the property;
- The legal requirements for forest management and land use in the area; and,
- A common practice standard among similar landowners in the area.

In all cases these three scenarios must be described by the project proponent, then reviewed, and approved as plausible and accurate by an independent forest consulting entity. Requirements for forest consultant qualifications will vary by region, however, the verifier should consider the following elements when reviewing consultant qualifications:

1) In those regions where a legally recognized certified forester designation exists, the forest consulting entity must have that designation
2) In those areas where there are no legal certified forester designations, the consultant must have either:
    a. Accreditation under a widely recognized elective accreditation program that grants “certified forester” designation (eg, Society of American Foresters); or,
    b. Publicly filed management plans or harvest plans that demonstrate the participation of the consulting entity and their qualifications to review the required documentation. The alternative/land use scenario that is not prevented by any barrier or is the most financially viable must be identified as the baseline scenario.

IFM project proponents should use the following guidelines to select the most plausible baseline scenario to be modeled.

Historical Baseline

The Historical Baseline must be selected as the most plausible baseline scenario if the following documents exist for the forest property:

1) Historical records of forest management exist for 20 or more years preceding the project start date.

2) Historical records indicate that the management practices have surpassed the legal barriers provided by conforming with all local and regional forest legislation.

3) Historical records that indicate that the historical management surpasses financial barriers by providing above average market returns.[4]

If these documents do not exist, the project must be developed using the Legal or Common Practice Baselines.

Legal Baseline

If the Historical Baseline is not applicable based on the criteria above, the Legal Baseline must be selected as the most plausible baseline scenario if regulations of forest management practices exist and are readily enforced within the project region.

Regulations and/or other legally-binding restrictions on forest management must pertain to specific forest management practices (eg, diameter limit regulattions) to be considered as the foundation of a Legal Baseline. If forest management in the project area is constrained only by more general regulations which do not pertain to specific forest management practices (eg, the Endangered Species Act), the project must select the Common Practice Baseline. In any case, projects subject to regulation and enforcement of specific forest management practices (ie, those that would select the Legal Baseline) must still also incorporate any management restrictions stemming from more general regulations (eg, the Endangered Specids Act) into the Legal Baseline.

An independent forest consulting entity must confirm that the practices defined in the Legal Baseline by the project proponent are plausible considering verifiable evidence. During validation the forest consultant must share with the validation/verification body evidence for their determination of the plausibility of the Legal Baseline. Such evidence must in all situations be considered confidential and must not be published or shared by the validation/verification body. Such evidence may include, for example: management plans, records of timber sales or harvesting by the project proponent within the project area or in other properties under their control; management plans, records of timber sales, or harvesting by other entities similar to the project proponent in the region; national or regional government statistics on forest management in the region; published data and analyses on forest management in the region; and/or spatial analyses on management options and/or carbon stocks in the focal region. As needed, the validation/verification body may consult additional independent forest consulting entities to verify the opinion provided by the independent forest consulting entity selected by the proponent and to determine that the Legal Baseline is plausible.

Common Practice Baseline

The Common Practice Baseline must be selected as the most plausible baseline scenario whenever there is insufficient documentation to utilize the Historical Baseline and where regulations pertaining to specific forest management practices do not exist or are not readily enforced in the project region.

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[4] Below-market returns must be defined as 80% or less of the current prevailing internal rate of return for forestland investment in comparable forest types and locations, after considering the full array of timber, non-timber and ecosystem service net revenues associated with the property, averaged over the last five years. Forestland investment in comparable forest types and locations must be defined as the common practice management.

It is possible that the Common Practice Baseline and project scenarios are the same, in which case the project scenario would not be considered additional.

During validation the forest consultant must share with the validation/verification body evidence for their determination of common practice. Such evidence must in all situations be considered confidential and must not be published or shared by the validation/verification body. Such evidence may include, for example: management plans, records of timber sales or harvesting by the project proponent within the project area or in other properties under their control; management plans, records of timber sales, or harvesting by other entities similar to the project proponent in the region; national or regional government statistics on forest management in the region; published data and analyses on forest management in the region; and/or spatial analyses on management options and/or carbon stocks in the focal region.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

The project proponent must test the additionality of the project using the current UNFCCC CDM *Tool for the demonstration and assessment of additionality* (see Section 10). In application of the Additionality Tool the project scenario as described ex-ante using this methodology and monitored using this methodology mustmust be evaluated alongside the baseline scenario identified in Step 1. If a financial analysis or a demonstration of barriers does not lead the preclusion of the project scenario then the project mustmust be considered non-additional.

8 QUANTIFICATION OF EMISSION REDUCTIONS AND REMOVALS

8.1 Stratification

If the project area is not homogeneous, stratification must be carried out to improve the accuracy and precision of carbon stock estimates. Different stratifications may be required for the baseline and project scenarios in order to achieve optimal accuracy and precision of the estimates of net GHG emissions reductions or GHG removal by sinks.

For estimation of baseline carbon stocks strata must be defined on the basis of parameters that are key variables in any method used to estimate changes in managed forest carbon stocks, for example:

- Management regime,
- Site index / anticipated growth rates,
- Forest species, or
- Age class.

For this methodology it will be important to stratify by management regime so that all areas to be clear cut or patch cut within a given year or within the years between monitoring events must be a stratum with further division if differences exist in site index, species and/or age class.

The project area must be stratified *ex-ante*. Further stratification beyond the parameters given above is not usually warranted. However, other parameters (eg, soil type, climate) may be useful for *ex-post* stratification.

Note: In the equations used in this methodology, the letter i is used to represent a stratum and the letter M for the total number of strata: M_B is the number of *ex-ante* defined baseline strata as determined with the procedures above; M_B remains fixed. M_{PS} is the number of strata in the project scenario as determined *ex-ante*. *Ex-post* adjustments of the project scenario strata may be needed if unexpected disturbances occur during the project crediting period (eg, due to fire, pests or disease outbreaks), severely affecting different parts of an originally homogeneous stratum or stand, or when forest management (thinning, harvesting, replanting) occurs at different intensities, dates and spatial locations than originally planned. In such a situation the project area affected by the disturbance and / or variation in forest management may be delineated as a separate stratum for the purpose of monitoring the carbon stock changes.

8.2 Baseline Net GHG Removals by Sinks

The baseline net removals are averaged over a modeled 100 year period to remove fluctuations and the impact of fluctuations on the difference between the baseline and the project cases.

The baseline net GHG Removals by sinks will be determined as:

$$\Delta C_{BSL} = \Delta C_{BSL,P} - GHG_{BSL,E} \tag{1}$$

where:

ΔC_{BSL} Baseline net greenhouse gas removals by sinks; t CO_2-e

$\Delta C_{BSL,P}$ Carbon stock changes in all pools in the baseline; t CO_2-e

$GHG_{BSL,E}$ Greenhouse gas emissions as a result of forest management activities within the project area in the baseline; t CO_2-e

$$\Delta C_{BSL,P} = \Delta C_{BSL,tree} + \left(\Delta C_{BSL,DW}\right) + \left(\Delta C_{BSL,WP}\right) \tag{2}$$

where:

$\Delta C_{BSL,P}$ Carbon stock changes in all pools in the baseline; t CO_2-e

$\Delta C_{BSL,tree}$ Carbon stock changes in trees in the baseline; t CO_2-e

$\Delta C_{BSL,DW}$ Carbon stock changes in dead wood in the baseline; t CO_2-e

$\Delta C_{BSL,WP}$ Carbon stock changes in wood products in the baseline; t CO_2-e

Dead wood may conservatively be excluded. Wood products may also conservatively be excluded if it can be shown that carbon stocks in the baseline scenario can be expected to decrease more or increase less, relative to the project scenario.

$$\Delta C_{BSL,tree} = \frac{\left(\sum_{i=1}^{M_B} \Delta C_{BSL,AG|BG,i,100} * \frac{44}{12} \right)}{100} * t^* \quad (3)$$

where:

$\Delta C_{BSL,tree}$	Carbon stock changes in above-ground and below-ground biomass of trees in the baseline; t CO_2-e
$\Delta C_{BSL,AG\|BG,i,100}$	Summed annual net carbon stock change in above-ground and below-ground biomass for stratum *i*, (summed over the 100 year modeled baseline); t C
i	1, 2, 3 …M_B strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the start of the IFM project activity
44/12	Ratio of molecular weight of CO_2 to carbon, t CO_2-e t C^{-1}

If dead wood is selected in Table 1:

$$\Delta C_{BSL,DW} = \frac{\left(\sum_{i=1}^{M_B} \Delta C_{BSL,DW,i,100} * \frac{44}{12} \right)}{100} * t^* \quad (4)$$

where:

$\Delta C_{BSL,DW}$	Carbon stock changes in dead wood in the baseline; t CO_2-e
$\Delta C_{BSL,DW,i,100}$	Summed annual net carbon stock change in dead wood for stratum *i*, (summed over the 100 year modeled baseline); t C
i	1, 2, 3 …M_B strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the start of the IFM project activity
44/12	Ratio of molecular weight of CO_2 to carbon, t CO_2-e t C^{-1}

If wood products are selected in Table 1:

$$\Delta C_{BSL,WP} = \frac{\left(\sum_{i=1}^{M_B} \Delta C_{BSL,WP,i,t} * \frac{44}{12}\right)}{100} * t^* \qquad (5)$$

where:

$\Delta C_{BSL,WP}$ Carbon stock changes in wood products in the baseline; t CO_2-e

$\Delta C_{BSL,WP,i,t}$ Baseline annual net carbon stock change in wood products for stratum *i*, at time *t*; t C yr^{-1}

i 1, 2, 3 …M_B strata in the baseline scenario

t 1, 2, 3, … t^* years elapsed since the start of the IFM VCS project activity

44/12 Ratio of molecular weight of CO_2 to carbon, t CO_2-e t C^{-1}

8.3 Carbon Stock Changes in the Baseline

$\Delta C_{BSL,AG|BG}$, $\Delta C_{BSL,DW}$ and $\Delta C_{BSL,WP}$ must be estimated using models of forest management across the baseline period. Modeling can be conducted with relative ease and confidence using a peer-reviewed forestry model. The PD must detail what model is being used and what variants have been selected. All model inputs and outputs must be available for inspection by the validator. The baseline must be modeled over 100 years.

The model must not assume the immediately release of carbon stock in the dead wood pool, as set out in the most recent version of the VCS *AFOLU Requirements*.

Examples of appropriate models include:

- US Forest Service's FVS: Forest Vegetation Simulator
- SPS: Stand Projection System
- FPS: Forest Projection System by Forest Biometrics
- CRYPTOS and CACTOS: California Conifer Timber Output Simulator

Models must be:

- Peer reviewed in a process involving experts in modeling and biology/forestry/ecology
- Used only in scenarios relevant to the scope for which the model was developed and evaluated
- Parameterized for the specific conditions of the project

In countries and regions where specific forestry models do not exist or are not available it is valid to employ a simple spreadsheet based model (including common simple growth models such as the Chapman Richards model of tree growth appropriately parameterized). Such models must be clearly labeled with all assumptions and justifications for assumptions presented. Spreadsheet models may also be necessary to extrapolate some growth models to include additional pools and harvest schedules.

It is inevitable that the input to models will be inventory data. However, the exact form of the input data is not prescribed here as this will vary by model but may include: cruised volumes, stand tables or plot data. The equations given in Section 5 must be used and detailed in full in the project description.[5]

The output of the models must be the annual changes in stocks of carbon in live aboveground tree biomass ($\Delta C_{BSL,AG|BG,i,t}$), dead wood ($\Delta C_{BSL,DW,i,t}$)and wood products ($\Delta C_{BSL,WP,i,t}$) by strata in the baseline scenario through the duration of the project.[6] If the model output is the annual stock (C) the change (ΔC) would be calculated as: $C_{t2} - C_{t1}$.

If the output for the tree is the volume then this must be converted to biomass and carbon using equations 13-18 in Section 5. If processing of alternative data on dead wood and wood products is necessary, equations 24-35 may be used.

8.4 Baseline Emissions

The GHG emissions in the baseline within the project area can be estimated as:

$$GHG_{BSL,E} = \sum_{t=1}^{t^*} \left(E_{BSL,BiomassBurn,t} \right) \quad (6)$$

where:

$GHG_{BSL,E}$ — Greenhouse gas emissions as a result of forest management activities within the project area in the baseline; t CO_2-e

$E_{BSL,\ BiomassBurn,t}$ — Non-CO_2 emissions due to biomass burning as part of forest management during the year t in the baseline; t CO_2-e

t — *1, 2, 3 …*t^* years elapsed since the start of the IFM project activity

GHG emission sources included or excluded from the project area can be neglected, ie, accounted as zero, if the application of the most recent version of the CDM Additionality Tools (see section 10 References) leads to the conclusion that the emission source is insignificant.

8.4.1 Estimation of baseline non-CO2 emissions due to biomass burning

The non-CO_2 emissions due to biomass burning as part of forest management ($E_{BiomassBurn}$) mustmust be estimated by:

5 Input data including precision bounds must be made available to verifying organizations

6 Where modeling produces changes in carbon stocks over five year periods the numbers must be annualized to give a stock change number for each year.

$$E_{BiomassBurn,t} = E_{BiomassBurn,CH_4,t} \qquad (7)$$

where:

$E_{BiomassBurn,t}$	Non-CO_2 greenhouse gas emission at time *t* as a result of biomass burning due to forest management; t CO_2-e
$E_{BiomassBurn,CH4,t}$	CH_4 emissions at time *t* as a result of forest management; t CO_2-e

Estimation of CH_4 emissions based on the carbon stock loss from biomass burning during forest management is based on the biomass of logging slash burned, *BS* calculated using equation 9. This is multiplied by factors that adjust for the mass of CH_4 versus carbon released, and for the global warming potential of CH_4.

$$E_{BiomassBurn,CH_4,t} = BS_{BSL,t} * ER_{CH_4} * \frac{16}{12} * GWP_{CH_4} \qquad (8)$$

where:

$E_{BiomassBurn,CH4,t}$	CH_4 emissions at time *t* as a result of forest management; t CO_2-e
$BS_{BSL,t}$	Carbon stock in logging slash subject to burning as part of forest management; t C
ER_{CH4}	Emission ratio for CH_4 (if local data on combustion efficiency is not available or if combustion efficiency can not be estimated from fuel information, use IPCC default value, 0.012[7]); kg C as CH_4 (kg C burned)$^{-1}$
GWP_{CH4}	Global warming potential for CH4 (IPCC default: 21 for the first commitment period of the Kyoto Protocol); t CO_2-e (t CH_4)$^{-1}$
16/12	Ratio of molecular weights of CH_4 and C; mol mol^{-1}
t	1, 2, 3, … t years elapsed since the start of IFM VCS project activities

If logging slash is not burned as part of forest management then:

$BS_{BSL,t} = 0$, otherwise:

$$BS_{BSL,t} = \sum_{j=1}^{S_{BSL}} \sum_{l=1}^{N_{j,t}} \left(\left(\left(f_j(DBH,H) \right) - \left(V_{l,j,t} * D_j \right) \right) * CF_j \right) \qquad (9)$$

[7] Table 3A.1.15, Annex 3A.1, GPG-LULUCF (IPCC 2003)

where:

$BS_{BSL,t}$	Carbon stock in logging slash subject to burning as part of forest management; t C
$V_{l,j,t}$	Harvested merchantable volume of tree *l* of species *j* at time *t,* m^3
D_j	Basic wood density of species *j*; t d.m.m^{-3}
$f_j(DBH,H)$	Allometric equation for species *j* linking diameter at breast height (*DBH*) and possibly height (*H*) to above-ground biomass of living trees; t d.m. $tree^{-1}$
CFj	Carbon fraction of biomass for tree species *j*; t C t^{-1} d.m. (IPCC default value = 0.5 t C t^{-1} d.m.)
l	Sequence number of trees harvested
j	*1, 2, 3 …* S_{BSL} tree species in the baseline scenario
t	1, 2, 3, … t years elapsed since the start of IFM VCS project activities

8.5 Project net GHG removals by sinks

The actual net greenhouse gas removals mustmust be estimated using the equations in this section. When applying these equations for the *ex-ante* calculation of net anthropogenic GHG removals by sinks, project participants mustmust provide estimates of the values of those parameters that are not available before the start of monitoring activities.[8] Project proponents must retain a conservative approach in making these estimates.

$$\Delta C_{ACTUAL} = \Delta C_P - GHG_E \tag{10}$$

where:

ΔC_{ACTUAL}	Actual net greenhouse gas removals by sinks; t CO_2-e
ΔC_P	Sum of the changes in above-ground biomass, dead wood and wood products in the project scenario; t CO_2-e
GHG_E	Increase in GHG emissions as a result of the implementation of the proposed IFM project activity within the project area; t CO_2-e

Note: In this methodology Equation (14) is used to estimate actual net greenhouse gas removals by sinks for the period of time elapsed between project start (*t* = 1) and the year *t* = *t**, *t** being the year for which actual net

[8] For the ex-ante estimation of changes in above-ground biomass, dead wood and wood products in the project scenario projects must model the expected changes in stocks through the with-project management scenario using methods as described in Section 4.1

greenhouse gas removals by sinks are estimated. The “stock change” method must be used to determine annual, or periodic values.

8.5.1 Estimation of changes in the carbon stock

The verifiable changes in the carbon stock in tree above-ground biomass, dead wood and wood products are estimated using the following approach[9]:

$$\Delta C_P = \sum_{t=1}^{t^*} \Delta C_t * \frac{44}{12} \qquad (11)$$

where:

ΔC_P Sum of the changes in above-ground biomass, dead wood and wood products in the project scenario; t CO_2-e

ΔC_t Annual change in carbon stock in all selected carbon pools for year *t*; t C yr^{-1}

t *1, 2, 3* … t^* years elapsed since the start of the IFM project activity

44/12 Ratio of molecular weights of CO_2 and carbon; t CO_2 t^{-1} C

ΔC_t mustmust be estimated using the following equation:

$$\Delta C_t = \sum_{i=1}^{M_{PS}} \left(\Delta C_{AG,i,t} + \Delta C_{BG,i,t} + \Delta C_{DW,i,t} + \Delta C_{WP,i,t} \right) \qquad (12)$$

where:

ΔC_t Annual change in carbon stock in all selected carbon pools for year *t*; t C yr^{-1}

$\Delta C_{AG,i,t}$ Annual carbon stock change in above-ground biomass of trees for stratum *i*, (possibly average over a monitoring period); t C yr^{-1}

$\Delta C_{BG,i,t}$ Annual carbon stock change in below-ground biomass of trees for stratum *i*, (possibly average over a monitoring period); t C yr^{-1}

$\Delta C_{DW,i,t}$ Annual change in the dead wood carbon pool for stratum *i*, (possibly average over a monitoring period); t C yr^{-1}

[9] IPCC GPG-LULUCF 2003, equation 3.2.3

$\Delta C_{WP,i,t}$	Annual change in the wood products carbon pool for stratum *i*, (possibly average over a monitoring period); t C yr^{-1}
i	*1, 2, 3 …* M_{PS} strata in the project scenario
t	*1, 2, 3 …* t^* years elapsed since the start of the IFM project activity

Changes in carbon pools that are conservatively excluded from accounting mustmust be set equal to zero.

8.5.1.1 Tree Biomass

The mean carbon stock in aboveground biomass per unit area is estimated based on field measurements in sample plots. Plots may be permanent or temporary[10], they may have a defined boundary or be variable radius plots. Two methods are available: the Biomass Expansion Factors (*BEF*) method, and the Allometric Equations method.

Method 1: BEF method

Step 1: Determine based on available data, eg, volume tables (*ex-ante*) and measurements (*ex-post*), the diameter (*DBH*, at typically 1.3 m [4.5 ft] above-ground level), and also preferably height (*H*), of all the trees above some minimum *DBH* in the sample plots.

Step 2: Estimate the volume of the commercial (merchantable) component of trees based on available equations or yield tables (if locally derived equations or yield tables are not available use relevant regional, national or default data as appropriate). It is possible to combine Steps 1 and 2 if there are field instruments (eg, a relascope) that measure the volume of each tree more directly.

Step 3: Choose *BEF*, and root-shoot ratio *R* – see Section II.8 for guidance on source of data. If relevant information is available the *BEF* and *R* should be adjusted for forest type or stand structure.

Step 4: Convert the volume of the commercial component of the trees into the mean plot level carbon stock biomass of the commercial component of trees via wood density and carbon fraction:

$$CV_{AB\_plot,i,t} = \sum_{j=1}^{S_{PS}} \sum_{l=1}^{N_{j,i,sp,t}} (V_{l,j,i,sp,t} * D_j * CF_j) \quad (13)$$

where:

$CV_{AB\_plot,sp,i\,t}$	Carbon stock of the commercial component of trees in plot *sp*, in stratum *i* at time *t*; t C
$V_{l,j,i,sp,t}$	Merchantable volume of tree *l* of species *j* in plot *sp* in stratum *i* at time *t,* m^3 (if necessary convert from ft^3 to m^3 by multiplying by 0.0283)

[10] Note that due to covariance tighter precision and hence fewer measurements can be used if permanent plots are elected. See guidance in IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry – Section 4.3. Available at: http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/Chp4/Chp4_3_Projects.pdf

D_j	Basic wood density of species *j*; t d.m.m^{-3}
CFj	Carbon fraction of biomass for tree species *j*; t C t^{-1} d.m. (IPCC default value = 0.5 t C t^{-1} d.m.)
l	Sequence number of trees on plot *sp*
i	*1, 2, 3, …*M_{PS} strata in the project scenario
j	*1, 2, 3 …* S_{PS} tree species in the baseline scenario
t	*1, 2, 3 … t* years elapsed since start of IFM project activity

Step 5: Calculate the carbon stock in the commercial component of the trees for each stratum:

$$CV_{AB,i,t} = \sum_{sp=1}^{P_i} \frac{10000}{Ap} * CV_{AB\_plot,i,t} \quad (14)$$

where:

$CV_{AB,i,t}$	Carbon stock of the commercial component of trees in stratum *i* at time *t*; t C ha^{-1}
$CV_{AB\_plot,sp,i\ t}$	Carbon stock of the commercial component of trees in plot *sp*, in stratum *i* at time *t*; t C
Ap	Area of sample plot; m^2 (if necessary convert from ft^2 to m^2 by multiplying by 0.0929)
sp	*1, 2, 3 … Pi* sample plots in stratum *i* in the project scenario
i	*1, 2, 3 …* M_{PS} strata in the project scenario
t	*1, 2, 3 … t* years elapsed since the start of the IFM VCS project activity

If point sampling/basal area prism sampling is used then under Step 4 each tree should be multiplied by the number of trees per acre that it represents and under Step 5 the – 10000/Ap – factor should be omitted.

Step 6: Convert the mean carbon stock in the commercial component of the trees for each stratum into the total carbon stock in aboveground biomass via the BEF:

$$C_{AB,i,t} = CV_{AB,i,t} * BEF \quad (15)$$

where:

$C_{AB,i,t}$	Carbon stock in above-ground biomass of trees in stratum *i* at time *t*; t C ha^{-1}
$CV_{AB,i,t}$	Carbon stock of the commercial component of trees in stratum *i* at time *t*; t C ha^{-1}

BEF	Biomass expansion factor for conversion of merchantable biomass to total above-ground tree biomass; dimensionless
i	*1, 2, 3, …*M_{PS} strata in the project scenario
t	*1, 2, 3 … t* years elapsed since the start of the IFM project activity

Step 7: Calculate the carbon stock in below-ground biomass of all trees present in stratum *i* at time *t*:

$$C_{BB,i,t} = C_{AB,i,t} * R \quad (16)$$

where:

$C_{AB,i,t}$	Carbon stock in above-ground biomass of trees in stratum *i* at time *t*; t C ha^{-1}
$C_{BB,i,t}$	Carbon stock in below-ground biomass of trees in stratum *i* at time *t*; t C ha^{-1}
R	Root-shoot ratio appropriate for biomass stock; dimensionless
i	*1, 2, 3 …* M_{PS} strata in the project scenario
t	*1, 2, 3 … t* years elapsed since the start of the IFM project activity

Alternatively, the equations of Cairns et al. (1997)[11] may be used to calculate below-ground biomass stock (t ha^{-1}) from aboveground biomass stock (t ha^{-1})

If an appropriate equation exists to calculate belowground biomass directly from DBH it would be equally valid in this step.

Step 8: Calculate the mean carbon stock in tree biomass for each stratum:

$$C_{tree,i,t} = A_i * (C_{AB,i,t} + C_{BB,i,t}) \quad (17)$$

where:

$C_{tree,i,t}$	Carbon stock in trees in stratum *i* at time *t*; t C
$C_{AB,i,t}$	Carbon stock in above-ground biomass of trees in stratum *i* at time *t*; t C ha^{-1}
$C_{BB,i,t}$	Carbon stock in below-ground biomass of trees in stratum *i* at time *t*; t C ha^{-1}
A_i	Area of stratum *i*; ha

[11] Cairns, M. A., S. Brown, E. H. Helmer, and G. A. Baumgardner. 1997. Root biomass allocation in the world's upland forests. Oecologia 111: 1-11

i   *1, 2, 3 …* M_{PS} strata in the project scenario

t   *1, 2, 3 … t* years elapsed since the start of the IFM project activity

Step 8: Calculate the mean carbon stock change:

$$\Delta C_{AG,i,t} + \Delta C_{BG,i,t} = \frac{C_{tree,i,t2} - C_{tree,i,t1}}{T} \quad (18)$$

where:

$\Delta C_{AG,i,t}$	Annual carbon stock change in above-ground biomass of trees for stratum *i*; t C yr^{-1}
$\Delta C_{BG,i,t}$	Annual carbon stock change in below-ground biomass of trees for stratum *i*; t C yr^{-1}
$C_{tree,i,t}$	Carbon stock in trees in stratum *i* at time *t*; t C
T	Number of years between monitoring time *t*1 and *t*2 (*T* = *t*2 – *t*1); yr
i	*1, 2, 3 …* M_{PS} strata in the project scenario
t	*1, 2, 3 … t* years elapsed since the start of the IFM VCS project activity

Method 2: Allometric method

Step 1: As with Step 1 of the *BEF* method.

Step 2: Select or develop an appropriate allometric equation (if possible species-specific, or if not from a similar species) – see Section II.8 for additional guidance.

Step 3: Estimate carbon stock in above-ground biomass for each individual tree *l* of species *j* in the sample plot located in stratum *i* using the selected or developed allometric equation applied to the tree dimensions resulting from Step 1, and sum the carbon stocks in the sample plot:

$$C_{AB\_tree,j,i,sp,t} = \sum_{l=1}^{N_{j,sp}} f_j(DBH,H) * CF_j \quad (19)$$

where:

$C_{AB\_tree,l,j,i,sp,t}$	Carbon stock in above-ground biomass of trees of species *j* in plot *sp* in stratum *i* at time *t*; t C $tree^{-1}$
CFj	Carbon fraction of biomass for tree species *j*; t C t^{-1} d.m. (IPCC default value = 0.5 t C t^{-1} d.m.)
$f_j(DBH,H)$	Allometric equation for species *j* linking diameter at breast height (*DBH*) and possibly height (*H*) to above-ground biomass of trees; t. d.m. $tree^{-1}$

i	*1, 2, 3, …*M_{PS} strata in the project scenario
j	*1, 2, 3 …* S_{PS} tree species in the baseline scenario
l	*1, 2, 3, …*$N_{j,sp}$ sequence number of individual trees of species *j* in sample plot *sp*
t	*1, 2, 3 … t* years elapsed since start of IFM project activity

Step 4: Convert the carbon stock in above-ground biomass to the carbon stock in below-ground biomass via root-shoot ratio, given by:

$$C_{BB\_tree,j,i,sp,t} = C_{AB\_tree,j,i,sp,t} * R \quad (20)$$

where:

$C_{BB\_tree,l,j,i,sp,t}$	Carbon stock in below-ground biomass of tree *l* of species *j* in plot *sp* in stratum *i* at time *t*, t C tree^{-1}
$C_{AB\_tree,l,j,i,sp,t}$	Carbon stock in above-ground biomass of tree *l* of species *j* in plot *sp* in stratum *i* at time *t*, t C tree^{-1}
R_j	Root-shoot ratio appropriate for biomass stock; dimensionless

If an appropriate equation exists to calculate belowground biomass directly from DBH it would be equally valid in this step.

Step 5: Calculate total carbon stock in the biomass of all trees present in the sample plot *sp* in stratum *i* at time *t*

$$C_{tree,i,sp,t} = \sum_{j=1}^{S_{PS}} \left(C_{AB\_tree,j,i,sp,t} + C_{BB\_tree,j,i,sp,t} \right) \quad (21)$$

where:

$C_{tree,i,sp,t}$	Carbon stock in trees in plot *sp* of stratum *i* at time *t*, t C
$C_{AB\_tree,l,j,i,sp,t}$	Carbon stock in above-ground biomass of tree *l* of species *j* in plot *sp* in stratum *i* at time *t*; t C tree^{-1}
$C_{BB\_tree,l,j,i,sp,t}$	Carbon stock in below-ground biomass of tree *l* of species *j* in plot *sp* in stratum *i* at time *t*, t C tree^{-1}
$N_{j,i,sp,t}$	Number of trees of species *j* in plot *sp* of stratum *i* at time t
i	*1, 2, 3, …*M_{PS} strata in the project scenario

j	*1, 2, 3 …* S_{PS} tree species in the baseline scenario
t	*1, 2, 3 …* t years elapsed since the start of the IFM project activity

Step 6: Calculate the mean carbon stock in tree biomass for each stratum:

$$C_{tree,i,t} = \frac{A_i}{Asp_i} \sum_{sp=1}^{P_i} C_{tree,i,sp,t} \tag{22}$$

where:

$C_{tree,i,t}$	Carbon stock in trees in stratum i at time t; t C
$C_{tree,i,sp,t}$	Carbon stock in trees in plot sp of stratum i at time t, t C
Asp_i	Total area of all sample plots in stratum i; ha
A_i	Area of stratum i; ha
sp	*1, 2, 3 …* P_i sample plots in stratum i in the project scenario
i	*1, 2, 3 …* M_{PS} strata in the project scenario
t	*1, 2, 3 …* t years elapsed since the start of the IFM project activity

Step 7: Calculate the mean carbon stock change:

$$\Delta C_{AG,i,t} + \Delta C_{BG,i,t} = \frac{C_{tree,i,t2} - C_{tree,i,t1}}{T} \tag{23}$$

where:

$\Delta C_{AG,i,t}$	Annual carbon stock change in above-ground biomass of trees for stratum i; t C yr^{-1}
$\Delta C_{BG,i,t}$	Annual carbon stock change in below-ground biomass of trees for stratum i; t C yr^{-1}
$C_{tree,i,t}$	Carbon stock in trees in stratum i at time t; t C
T	Number of years between monitoring time $t1$ and $t2$ ($T = t2 - t1$); yr
i	*1, 2, 3 …* M_{PS} strata in the project scenario
t	*1, 2, 3 …* t years elapsed since the start of the IFM project activity

Note that for permanent plots with tagged trees, change in carbon stocks are tracked directly through estimates of carbon stock increments in individual trees summed across plots and strata. For detailed guidance see Pearson et al 2005.[12]

8.5.1.2 Dead wood (if selected in Table 1)

Dead wood included in the methodology comprises two components only – *standing dead wood* and *lying dead wood* (that is, below-ground dead wood is conservatively neglected). Considering the differences in the two components, different sampling and estimation procedures mustmust be used to calculate the changes in dead wood biomass of the two components. In all cases, dead wood modeling must include a decay function that is a 10-year linear decay or a more conservative alternative for dead wood that reflects a pattern of carbon loss over time.

$$\Delta C_{DW,i,t} = \frac{C_{DW,i,t2} - C_{DW,i,t1}}{T} \tag{24}$$

where:

$\Delta C_{DW,i,t}$	Annual carbon stock change in dead wood for stratum *i*, (averaged over a monitoring period); t C yr^{-1}
$C_{DW,i,t2}$	Carbon stock of dead wood in stratum *i* at time *t=2*; t C
$C_{DW,i,t2}$	Carbon stock of dead wood in stratum *i* at time *t=1*; t C
T	Number of years between monitoring *t*2 and *t*1 (*T =t2-t1*); yr
i	*1, 2, 3* … M_{PS} strata in the project scenario
t	*1, 2, 3* … *t* years elapsed since the start of the IFM project activity

The methods to be followed in the measurement of the standing dead wood and the lying dead wood biomass are outlined below:

$$C_{DW,i,t} = (B_{SDW,i,t} + B_{LDW,i,t}) * CF_{DW} \tag{25}$$

where:

$C_{DW,i,t}$	Carbon stock of dead wood in stratum *i* at time *t*; t C
$B_{SDW,i,t}$	Biomass of standing dead wood in stratum *i* at time *t*; t d.m.
$B_{LDW,i,t}$	Biomass of lying dead wood in stratum *i* at time *t*; t d.m.

[12] Pearson, T., Walker, S. and Brown, S. 2005. Sourcebook for Land Use, Land-Use Change and Forestry Projects. Winrock International and the World Bank Biocarbon Fund. 57pp. Available at: http://www.winrock.org/Ecosystems/files/Winrock-BioCarbon_Fund_Sourcebook-compressed.pdf

CF_{DW} Carbon fraction of dry matter in dead wood; t C t^{-1} d.m.

i *1, 2, 3 …* M_{PS} strata in the project scenario

t *1, 2, 3 … t* years elapsed since the start of the IFM project activity

Method: Standing Dead Wood

Step 1: Standing dead trees mustmust be measured using the same criteria and monitoring frequency used for measuring live trees. The decomposed portion that corresponds to the original above-ground biomass is discounted. Stumps must be inventoried as if they are very short standing dead trees.

Step 2: The decomposition class of the dead tree and the diameter at breast height must be recorded and the standing dead wood is categorized under the following four decomposition classes:

- Tree with branches and twigs that resembles a live tree (except for leaves);
- Tree with no twigs but with persistent small and large branches;
- Tree with large branches only;
- Bole only, no branches.

Step 3: Biomass must be estimated using an allometric equation for live trees in the decomposition class 1. When the bole is in decomposition classes 2, 3 or 4, it is recommended to limit the estimate of the biomass to the main trunk of the tree.

If the top of the standing dead tree is missing, then the top diameter:

- May be assumed to be zero;
- May be measured if reachable or the broken top is identifiable on the ground or by using an instrument such as a relascope or laser inventory instrument;
- May be calculated proportionally to height assuming that the height of the intact dead tree would be equal to average height of all intact dead trees present in the same sample plot.

Step 4: The volume of dead wood is converted to biomass using the appropriate dead wood density class.

Method: Lying Dead Wood

The lying dead wood pool is highly variable, and stocks may or may not increase as the stands age depending if the forest was previously unmanaged (mature or unlogged) where it would likely increase or logged with logging slash left behind where it may decrease through time.

Step 1: Lying dead wood must be sampled using the line intersect method (Harmon and Sexton 1996).[13,14] Two 50-meter lines (164 ft) are established bisecting each plot and the diameters of the lying dead wood (≥ 10 cm diameter [≥ 3.9 inches]) intersecting the lines are measured.

Step 2: The dead wood is assigned to one of the three density states (sound, intermediate and rotten) using the 'machete test', as recommended by *IPCC Good Practice Guidance for LULUCF* (2003), Section 4.3.3.5.3.

Step 3: The volume of lying dead wood per unit area is calculated using the equation (Warren and Olsen 1964)[15] as modified by Van Wagner (1968)[16] separately for each density state:

$$V_{LDW,i,t} = \frac{\pi^2 * \left(\sum_{n=1}^{N} D_{n,i,t}{}^2 \right)}{8 * L} \quad (26)$$

where:

$V_{LDW,i,t}$	Volume of lying dead wood per unit area in stratum *i* at time *t*; m^3 ha^{-1}
$D_{n,i,t}$	Diameter of piece n of dead wood along the transect in stratum *i* at time *t*; cm (if necessary convert inches to cm by multiplying by 2.54)
N	Total number of wood pieces intersecting the transect; dimensionless
L	Length of the transect; m (if necessary convert ft to me by multiplying by 0.3048)
i	*1, 2, 3* … M_{PS} strata in the project scenario
t	*1, 2, 3* … *t* years elapsed since the start of the IFM project activity

To convert this to a mass per unit area multiply the volumes of each density state by their respective wood densities.

Step 4: Volume of lying dead wood must be converted into biomass using the following relationship:

$$B_{LDW,i,t} = A_i * \sum_{dc=1}^{3} V_{LDW,i,t} * D_{DW,dc} \quad (27)$$

[13] Harmon, M.E. and J. Sexton. (1996) Guidelines for measurements of wood detritus in forest ecosystems. US LTER Publication No. 20. US LTER Network Office, University of Washington, Seattle, WA, USA.

[14] A variant on the line intersect method is described by Waddell, K.L. 2002. Sampling coarse wood debris for multiple attributes in extensive resource inventories. Ecological Indicators 1: 139-153. This method may be used in place of Steps 1 to 3.

[15] Warren, W.G. and Olsen, P.F. (1964) A line intersect technique for assessing logging waste. *Forest Science* 10: 267-276.

[16] Van Wagner, C.E. (1968). The line intersect method in forest fuel sampling. *Forest Science* 14: 20-26.

where:

$B_{LDW,i,t}$ Biomass of lying dead wood per unit area in stratum *i* at time *t*; d.m. ha^{-1}

$V_{LDW,i,t}$ Volume of lying dead wood per unit area in stratum *i* at time *t*; m^3 ha^{-1}

$D_{DW,dc}$ Basic wood density of dead wood in the density class – sound (1), intermediate (2), and rotten (3); t d.m. m^{-3}

A_i Area of stratum *i*; ha

i *1, 2, 3 …* M_{PS} strata in the project scenario

t *1, 2, 3 … t* years elapsed since the start of the IFM project activity

8.5.1.3 Wood Products (if selected in Table 1)

The Wood Products pool is calculated through the following general steps for each harvest period *h*:

Step 1: Calculate the carbon in harvested timber removed from the project site based on wood densities and standard carbon conversions from biomass volumes

Step 2: Calculate the total carbon in harvested timber that will enter the wood products pool based on mill efficiencies and product disposition percentages

Step 3: Calculate the total carbon that will be stored for the short lived (≤3 years), medium lived (>3 years to 100 years) and long lived (100+ years)

The annual change in carbon stored in wood products is given in the following equation:

$$\Delta C_{WP,t1,t2} = \frac{C_{WP,t2} - C_{WP,t1}}{T} \tag{28}$$

where:

$\Delta C_{WP,t1,t2}$ Annual carbon stock change in wood products between time t1 and t2, (averaged over a monitoring period); t C yr^{-1}

$C_{WP,t2}$ Carbon stock of wood products at time *t=2*; t C

$C_{WP,t1}$ Carbon stock of wood products at time *t=1*; t C

T Number of years between monitoring *t*2 and *t*1 (*T =t2-t1*); yr

t *1, 2, 3 … t* years elapsed since the start of the IFM VCS project activity

To calculate wood products two methods are available. The direct (*1605b*) method is only applicable within the 48 contiguous United States and for limited vegetation types. The less direct (*Winjum et al.*) method can be applied to any vegetation types throughout the world.

Method 1: 1605b Method

The method uses the Forestry Appendix of the Technical Guidelines of the US Department of Energy's Voluntary Reporting of Greenhouse Gases Program (known as Section 1605(b)).[17] All harvested wood will be categorized by species and wood product (sawnwood or pulpwood). Wood density values for each species in the project area will be used to determine carbon volume for each cubic volume of wood delivered to processing facilities.

Regional data supplied in Table 1.4 and Table 1.5 of the 1605(b) document provide values to determine the percentage of harvested softwoods and hardwoods that will be converted to sawnwood and pulpwood.

Step 1: Calculate the total carbon in harvested timber removed from the project site. This is calculated by taking the biomass of the total volume extracted from the start of the project to date from within the project area with extracted timber differentiated into hardwood, softwood, sawnwood and pulpwood classes (if necessary convert volumes in ft^3 to m^3 by multiplying by 0.0283):

$$EXC_{WP,ty} = \sum_{h=1}^{H_{PS}} \sum_{j=1}^{S_{PS}} (V_{ex,h,s|p,j} * D_j * CF_j) \tag{29}$$

where:

$EXC_{WP,ty}$	The summed stock of extracted biomass carbon from within the project area by wood product disposition (hardwood sawnwood/hardwood pulpwood/softwood sawnwood/softwood pulpwood) *ty*; t C
$V_{ex,h,s\|p,j,}$	The volume of timber extracted from within the project area during harvest *h* by species *j* and wood product disposition *ty*; m^3
D_j	Basic wood density of species *j*; t d.m. m^{-3}
CFj	Carbon fraction of biomass for tree species *j*; t C t^{-1} d.m. (IPCC default value = 0.5 t C t^{-1} d.m.)
h	*1, 2, 3 …*number of harvests since the start of the IFM project activity
j	*1, 2, 3 …* S_{PS} tree species in the baseline scenario
s|p	Wood product disposition – defined here as sawnwood or pulpwood

[17] http://www.eia.doe.gov/oiaf/1605/Forestryappendix[1].pdf Also available as a US Forest Service General Technical Report at: http://www.fs.fed.us/ne/durham/4104/papers/ne_gtr343.pdf

Step 2: Calculate the total carbon that will enter the wood products pool. All projects must calculate the total carbon in harvested biomass that enters the wood products pool after deducting harvest slash left on site, bark biomass and waste calculated through mill efficiencies. For the purposes of this protocol Tables 1.4, 1.5 and 1.6 can be used to estimate these values for different regions within the United States. Examples 1.4 and 1.5 are given on pages 25-27 of the 1605(b) document which demonstrate the methods that can be followed with different existing data sets.

Step 3: Calculate the total amount of carbon stored in short lived, medium lived and long lived wood products. For the purposes of this methodology the proportion of harvested carbon stored in wood products is equivalent to the proportion listed in the "In Use" column of Table 1.6 of the 1605(b) document for any given year after harvest.

Each year's harvested carbon volume must be categorized into one of the following categories:

- Short lived wood products: harvested wood products and wood waste that will decay within 3 years.
- Medium lived wood products: harvested wood products and wood waste that will be retired between 3 and 100 years from the date of harvest.
- Long lived wood products: harvested wood products and wood waste that may be considered permanent (stored for 100 years or more).

To determine the proportion of harvested wood products that fall into each category, refer to the "In Use" column in the appropriate regional version of Table 1.6 of the 1605(b) document. For each harvested wood type (hardwood/softwood/pulpwood/sawnwood), two values are taken from the table: $P_{3\text{-year}}$, the percentage of total carbon stored in wood products after 3 years; and $P_{100\text{-year}}$, the proportion of harvested wood stored for 100 years. Three different values are calculated from this data, the short lived fraction (P_{SLF}), medium lived fraction (P_{MLF}), and long lived fraction (P_{LLF}):

$$P_{SLF} = 1-P_{3\text{-year}}$$

$$P_{MLF} = P_{3\text{-year}} - P_{100\text{-year}}$$

$$P_{LLF} = P_{100\text{-year}}$$

Each category of wood products will store carbon according to the following rules:

- Short lived wood products – immediate loss of all carbon upon harvest
- Medium lived wood products – no loss of carbon upon harvest, but carbon stored will decrease by $1/20^{th}$ for the next 20 years after harvest
- Long lived wood products – no loss of carbon

$$C_{WP,t,ty} = \sum_{h=0}^{t}((C_{Mill,ty,h} * P_{LLF}) + [(C_{Mill,ty.h} * P_{MLF}) * ((20-h)/20)] \quad (30)$$

Where:

$C_{WP,t,ty}$ The total carbon removed from the project site that remain stored in harvested wood products at Year *t* for harvest category *ty* (hardwood, softwood, sawnwood, pulpwood)

$C_{Mill,\ ty,h}$ the total carbon volume stored in wood products for harvest *h,* after deducting for mill efficiencies and product dispositions

h Year of harvest

$P_{SLF,MLF,LLF}$ The proportion of carbon stored in sawn hardwood/softwood or pulp hardwood/softwood "In Use" for the appropriate term. For short lived wood products this is 0. For medium lived wood products this must be reduced by 1/20 for 20 years after harvest. 20 years after harvest the medium lived term becomes zero. Long lived storage proportion is 1 for the 100 years of the project life.

Method 2: The Winjum et al. Method

Step 1: Calculate the biomass of the total volume extracted from the start of the project to date from within the project area (if necessary convert volumes in ft^3 to m^3 by multiplying by 0.0283).

$$EXC_{WP,ty} = \sum_{h=1}^{H_{PS}} \sum_{j=1}^{S_{PS}} (V_{ex,h,ty,j} * D_j * CF_j) \quad (31)$$

where:

$EXC_{WP,ty}$ The summed stock of extracted biomass carbon from within the project area class of wood product *ty*; t C

$V_{ex,h,ty,j,}$ The volume of timber extracted from within the project area during harvest *h* by species *j* and wood product class *ty*; m^3

D_j Basic wood density of species *j*; t d.m.m^{-3}

CFj Carbon fraction of biomass for tree species *j*; t C t^{-1} d.m. (IPCC default value = 0.5 t C t^{-1} d.m.)

h *1, 2, 3 …*number of harvests since the start of the IFM project activity

j *1, 2, 3 …* S_{PS} tree species in the baseline scenario

ty Wood product class – defined here as sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other

Step 2: Calculate the total carbon in harvested timber that will enter the wood products pool based on mill efficiencies and product disposition percentages. All factors are derived from Winjum et al.1998.[18]

$$C_{Mill,ty} = \sum_{s,w,oir,p}^{ty} EXC_{WP,ty} * (1 - WW) \qquad (32)$$

Where:

$C_{Mill,ty}$	Carbon in wood products after milling for category *ty*
$EXC_{WP,ty}$	Total extracted wood volumes over all types *ty*
WW	Wood waste fraction based on mill efficiency
s,w,oir,p	Wood product categories: sawnwood, woodbase panels, other industrial roundwood, paper and paperboard

<u>Wood waste fraction (WW):</u>

Winjum et al indicate that the proportion of extracted biomass that is oxidized (burning or decaying) from the production of commodities to be equal to 19% for developed countries, 24% for developing countries. *WW* is therefore equal to $EXC_{WP,ty}$ multiplied by 0.19 for developed countries and 0.24 for developing countries (Winjum et al., p. 278).

Step 3: Calculate the total carbon that will be stored for the short lived (≤3 years), medium lived (>3 years to 100 years) and long lived (100+ years).

Each year's harvested carbon volume must be categorized into one of the following categories:

- Short lived wood products: harvested wood products and wood waste that will decay within 3 years.
- Medium lived wood products: harvested wood products and wood waste that will be retired between 3 and 100 years from the date of harvest.
- Long lived wood products: harvested wood products and wood waste that may be considered permanent (stored for 100 years or more).

For each year's harvests, the calculation of carbon in wood products follows this formula:

$$C_{WP,ty} = \sum_{s,w,oir,p}^{ty} \left(\left(\left(C_{Mill,ty} \right) - SLF \right) + MLF \right) \qquad (33)$$

[18] Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284

where:

$C_{WP,ty}$	Total carbon for all wood product categories
$C_{Mill,ty}$	The summed stock of carbon remaining in wood products after milling from within the project area by class of wood product *ty*; t C
SLF	Fraction of wood products that will be emitted to the atmosphere within 3years of timber harvest; t C
MLF	Fraction of wood products in products stored between 3and 100 years that decay each year. This decay will be deducted linearly over 20 years from the year of harvest; t C
ty	Wood product class – defined here as sawnwood, wood-based panels, other industrial roundwood, paper and paper board
t	*1, 2, 3* … *t* years elapsed since the start of the IFM project activity

<u>Short-lived fraction (SLF)</u>

Winjum et al., 1998 defines the following proportions as the amount of carbon that each product category will lose over the first 5 years after harvest (applicable internationally):

Sawnwood	0.2
Woodbase panels	0.1
Other industrial roundwood	0.3
Paper and Paperboard	0.4

Assuming a linear decay rate, convert these values to annualized proportions as follows:

Sawnwood	0.04 annually
Woodbase panels	0.02 annually
Other industrial roundwood	0.06 annually
Paper and paperboard	0.08 annually

To convert this to 3 year percentage reductions as required by the AFOLU Requirements we multiply the annual values by 3 to come up with the final value for “short lived proportion” for each product category.

Sawnwood	0.12
Woodbase panels	0.06
Other industrial roundwood	0.18
Paper and paperboard	0.24

The methodology makes the assumption that this proportion of wood and all other classes of wood products are 100% oxidized immediately..

Therefore SLF will be equal to:

$$SLF = \left(C_{Mill,ty}\right) * slp \qquad (34)$$

where:

SLF Fraction of wood products that will be emitted to the atmosphere within 3 years of timber harvest; t C

$C_{WP,ty}$ The summed stock of extracted biomass carbon from within the project area by class of wood product *ty*; t C

slp Short-lived proportion -

ty Wood product class – defined here as sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other

<u>Medium lived fraction (MLF)</u>

Winjum et al., 1998 gives annual oxidation fractions for each class of wood products split by forest region (boreal, temperate and tropical). This methodology projects these fractions over 97 years to give the additional proportion that is oxidized between the 3rd and 100th years after initial harvest (Table 3):

Table 3: Proportion of remaining wood products oxidized between 3 and 100 years after initial harvest by wood product class and forest region (MLF)

Wood Product Class	*OF*		
	Boreal	**Temperate**	**Tropical**
Sawnwood	0.39	0.62	0.86
Woodbase panels	0.62	0.86	0.98
Other industrial roundwood	0.86	0.98	0.99
Paper and paperboard	0.39	0.62	0.99

To reflect a 20-year linear decay as required by the VCS AFOLU Requirements, the , 1/20th of these proportions must be deducted from the harvested wood products pools each year after harvest. 20 years after harvesting, the MLF term will be equal to zero.

However, for the first twenty years after each harvest cycle, the value of MLF for that harvest is therefore equal to

$$MLF = \left(\left(C_{Mill,ty}\right) - SLF\right) * ((20 - h)/20) * fo$$

(35)

where:

MLF	Fraction of wood products that is considered stored for the medium term and will be emitted to the atmosphere each year after harvest for twenty year; t C
$C_{Mill,ty}$	The summed stock of extracted biomass carbon after milling from within the project area by class of wood product *ty*; t C
SLF	Fraction of wood products that will be emitted to the atmosphere within 3 years of timber harvest; t C
fo	Fraction oxidized – see Table 3 for defaults; t C t C^{-1}
ty	Wood product class – defined here as sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other
h	year after harvest

8.5.2 Estimation of GHG emissions within the project area

The change in GHG emissions as a result of the implementation of the proposed IFM project activity within the project area can be estimated as:

$$GHG_{PS,E} = \sum_{t=1}^{t^*}\left(E_{PS,BiomassBurn,t}\right) \quad (36)$$

where:

$GHG_{PS,E}$	Greenhouse gas emissions as a result of forest management activities within the project area in the project scenario; t CO_2-e
$E_{PS, BiomassBurn,t}$	Non-CO_2 emissions due to biomass burning as part of forest management during the year *t* in the project scenario; t CO_2-e
t	*1, 2, 3 …*t^* years elapsed since the start of the IFM project activity

The monitoring of emissions by sources is only required if significant; if insignificant, evidence must be provided (eg, as relevant part of the monitoring of the project implementation) that the assumptions for the exclusion made in the *ex-ante* assessment still hold in the *ex-post* situation.

8.5.2.1 Estimation of non-CO2 emissions due to biomass burning

The non-CO_2 emissions due to biomass burning as part of forest management ($E_{BiomassBurn}$) must be estimated by:

$$E_{BiomassBurn,t} = E_{BiomassBurn,CH_4,t} \tag{37}$$

where:

$E_{BiomassBurn,t}$	Non-CO_2 greenhouse gas emission at time *t* as a result of biomass burning due to forest management; t CO_2-e
$E_{BiomassBurn,CH4,t}$	CH_4 emissions at time *t* as a result of forest management; t CO_2-e

Estimation of CH_4 emissions is based on the carbon stock loss from biomass burning during forest management is based on the biomass of logging slash burned, *BS* calculated using equation 30. This is multiplied by factors that adjust for the mass of CH_4 versus carbon released, and for the global warming potential of CH_4.

$$E_{BiomassBurn,CH_4,t} = BS_{PS,t} * ER_{CH_4} * \frac{16}{12} * GWP_{CH_4} \tag{38}$$

where:

$E_{BiomassBurn,CH4,t}$	CH_4 emissions at time *t* as a result of forest management; t CO_2-e
$BS_{PS,t}$	Carbon stock in logging slash subject to burning as part of forest management in the project scenario; t C
ER_{CH4}	Emission ratio for CH_4 (if local data on combustion efficiency is not available or if combustion efficiency can not be estimated from fuel information, use IPCC default value, 0.012[19]); kg C as CH_4 (kg C burned)$^{-1}$
GWP_{CH4}	Global warming potential for CH4 (IPCC default: 21 for the first commitment period of the Kyoto Protocol); t CO_2-e (t CH_4)$^{-1}$
16/12	Ratio of molecular weights of CH_4 and C; mol mol^{-1}
t	1, 2, 3, … t years elapsed since the start of IFM project activities

If logging slash is not burned as part of forest management then:

$BS_{PS,t} = 0$, otherwise:

[19] Table 3A.1.15, Annex 3A.1, GPG-LULUCF (IPCC 2003)

$$BS_{PS,t} = \sum_{j=1}^{S_{PS}} \sum_{l=1}^{N_{j,t}} \left(\left(\left(f_j(DBH, H) \right) - \left(V_{l,j,t} * D_j \right) \right) * CF_j \right) \qquad (39)$$

where:

$BS_{PS,t}$	Carbon stock in logging slash subject to burning as part of forest management; t C
$V_{l,j,t}$	Harvested merchantable volume of tree *l* of species *j* at time *t,* m^3
D_j	Basic wood density of species *j*; t d.m.m^{-3}
$f_j(DBH,H)$	Allometric equation for species *j* linking diameter at breast height (*DBH*) and possibly height (*H*) to above-ground biomass of living trees; t d.m. $tree^{-1}$
CFj	Carbon fraction of biomass for tree species *j*; t C t^{-1} d.m. (IPCC default value = 0.5 t C t^{-1} d.m.)
l	Sequence number of trees harvested
j	*1, 2, 3 …* S_{PS} tree species in the project scenario
t	1, 2, 3, … t years elapsed since the start of IFM project activities

8.6 Leakage

Under the applicability conditions of this methodology the type of leakage emissions to be calculated is: GHG emissions due to market effects resulting from a shift in harvest through time.[20]

Therefore, leakage must be estimated as follows:

$$LK = LK_{MarketEffects} \qquad (40)$$

where:

LK	Total GHG emissions due to leakage; t CO_2–e
$LK_{MarketEffects}$	Total GHG emissions due to impacts of project on timber supply and demand; t CO_2-e

Note: In this methodology the equation above is used to estimate leakage for the period of time elapsed between project start (*t*=1) and the year $t=t^*$, t^* being the year for which actual net greenhouse gas removals by sinks are estimated.

[20] GHG emissions through fossil fuel use outside the boundaries of the project are not considered based on guidance from the CDM Executive Board: http://cdm.unfccc.int/EB/044/eb44rep.pdf

8.6.1 Leakage due to Activity Shifting

As per the applicability conditions there may be no leakage due to activity shifting.

If the project is able to demonstrate that any decrease in wood products produced by the project relative to the baseline is less than 5% and any temporal displacement in the total production of wood products is less than 5 years then:

$$LK_{ActivityShifting} = 0 \tag{41}$$

If the project decreases wood product production by >5% relative to the baseline then the project proponent and all associated land owners must demonstrate that there is no leakage within their operations – ie, on other lands they manage/operate outside the bounds of the IFM project. Such a demonstration may include:

Historical records showing trends in harvest volumes paired with records from the with-project time period showing no deviation from historical trends forest management plans prepared ≥24 months prior to the start of the project showing harvest plans on all owned/managed lands paired with records from the with-project time period showing no deviation from management plans.

Leakage due to market effects is equal to the baseline emissions from logging multiplied by a leakage factor:

$$LK_{MarketEffects} = LF_{ME} * \left(\Delta C_{ACTUAL} - \Delta C_{BSL}\right) \tag{42}$$

Where:

$LK_{MarketEffects}$	Total GHG emissions due to market- effects leakage through decreased timber harvest; t CO_2-e
LF_{ME}	Leakage factor for market-effects calculations; dimensionless
ΔC_{ACTUAL}	Actual net greenhouse gas removals by sinks; t CO_2-e
ΔC_{BSL}	Baseline net greenhouse gas removals by sinks; t CO_2-e

The leakage factor is determined by considering where in the country logging will be increased as a result of the decreased supply of the timber caused by the project. If the areas liable to be logged have a higher carbon stock than the project area it is likely that the proportional leakage is higher and vice versa:

LF_{ME} = 0, where it can be demonstrated that no market-effects leakage will occur within national boundaries, (eg, if no new concessions are being assigned AND annual extracted volumes cannot be increased within existing national concessions AND illegal logging is absent (or *de minimis*) in the host country); or,

Where the project is able to demonstrate that any decrease in wood products produced by the project relative to the baseline is less than 5% and any temporal displacement in the total production of wood products is less than 5 years.

LF_{ME} $=$ 0.1, where rotations are moderately extended (5-10 years) leading to a shift in harvests across time periods but a change in total timber harvest equal to ≤25% over the project lifetime[21]

Where rotations are extended by >10 years and/or harvest is decreased by >25% over the project lifetime as per VCS AFOLU Requirements

The amount of leakage is determined by where harvesting would likely be displaced to. If in the forests to which displacement would occur a lower proportion of forest biomass in commercial species is in merchantable material than in project area , then in order to extract a given volume higher emissions should be expected as more trees will need to be cut to supply the same volume. In contrast if a higher proportion of the total biomass of commercial species is merchantable in the displacement forest than in the project forests then a smaller area would have to be harvested and lower emissions would result.

Each project thus must calculate within each stratum the proportion of total biomass in commercial species that is merchantable (PMP_i). This must then be compared to mean proportion of total biomass that is merchantable for each forest type (PML_{FT}).

Merchantable biomass is defined as: "Total gross biomass (including bark) of a tree 5 inches (12.7 cm) DBH or larger from a 1 foot (30.48 cm) stump to a minimum 4 inches top DOB of the central stem" *Definition from US Forest Service FIA Program*

The following deduction factors (LF_{ME}) must be used:

Where:

PML_{FT} *is equal (± 15%) to* PMP_i, $LF_{ME} =$ 0.4

PML_{FT} *is > 15% less than* PMP_i $LF_{ME} =$ 0.7

PML_{FT} *is > 15% greater than* PMP_i, $LF_{ME} =$ 0.2

Where:

PML_{FT} Mean merchantable biomass as a proportion of total aboveground tree biomass for each forest type; % (default values see parameter table)

PMP_i Merchantable biomass as a proportion of total aboveground tree biomass for stratum *i* within the project boundaries; %

LF_{ME} Leakage factor for market-effects calculations; dimensionless

[21] Defined here as the minimum project lifetime elected by project proponents in their project description document. If the project is extended beyond this time period harvests may not be decreased by more than 25% across through each additional crediting/baseline period

8.7 Summary of the GHG Emission Reduction and/or Removals

The net anthropogenic GHG removals by sinks is the actual net GHG removals by sinks minus the baseline net GHG removals by sinks minus leakage, therefore, the following general formula can be used to calculate the net anthropogenic GHG removals by sinks of a IFM project activity (C_{IFM}) in t CO_2-e.

$$C_{IFM} = \Delta C_{ACTUAL} - \Delta C_{BSL} - LK \quad (43)$$

where:

C_{IFM}	Net anthropogenic greenhouse gas removals by sinks; t CO_2-e
ΔC_{ACTUAL}	Actual net greenhouse gas removals by sinks; t CO_2-e
ΔC_{BSL}	Baseline net greenhouse gas removals by sinks; t CO_2-e
LK	Total GHG emissions due to leakage; t CO_2–e

8.7.1 Calculation of Uncertainty

Estimated carbon emissions and removals arising from AFOLU activities have uncertainties associated with the uncertainties associated with measures/estimates of: area or other activity data, carbon stocks, biomass growth rates, expansion factors, and other coefficients. It is assumed that the uncertainties associated with the estimates of the various input data are available, either as default values given in IPCC Guidelines (2006), IPCC GPG-LULUCF (2003), or estimates based of sound statistical sampling. Uncertainties arising from the measurement and monitoring of carbon pools and the changes in carbon pools must always be quantified.

Indisputably conservative estimates can also be used instead of uncertainties, provided that they are based on verifiable literature sources. In this case the uncertainty is assumed to be zero. However, this module provides a procedure to combine uncertainty information and conservative estimates resulting in an overall project uncertainty.

Uncertainty at all times is defined as the 90% confidence interval as a percentage of the mean.

<u>Planning to Diminish Uncertainty</u>

It is important that the process of project planning consider uncertainty. Procedures including stratification, and the allocation of sufficient measurement plots can help ensure that low uncertainty results and ultimately full crediting can result.

It is good practice to consider uncertainty at an early stage to identify the data sources with the highest uncertainty to allow the opportunity to conduct further work to diminish uncertainty.

<u>Estimation of Uncertainty for Pools and Emissions Sources</u>

For each measurement pool calculate both the mean and the 90% confidence interval. In all cases uncertainty should be expressed as the 90% confidence interval as a percentage of the mean.

For modeled results use the confidence interval of the input inventory data.

For wood products use the confidence interval of the stocks of extracted timber.

For biomass burning emissions use the confidence interval of the preburning stocks.

For both the baseline and the with-project case the total uncertainty is equal to the square root of the sum of the squares of each component uncertainty.

Total Uncertainty of the IFM Project

The total project uncertainty is calculated at the time of reporting through propagating the error in the baseline stocks and the error in the project stocks:

$$C_{IFM\_ERROR} = \sqrt{\mathrm{Uncertainty_{BSL}}^2 + \mathrm{Uncertainty_P}^2} \tag{44}$$

Where:

CIFM_ERROR Total uncertainty for IFMProject; %

UncertaintyBSL Total uncertainty in baseline scenario; %

UncertaintyP Total uncertainty in the with-project scenario; %

The uncertainty in the baseline and in the project should be defined as the square root of the summed errors in each of the measurement pools. The errors in each pool can be weighted by the size of the pool so that projects may reasonably target a lower precision level in pools that only form a small proportion of the total stock.

8.7.2 Uncertainty Deduction

If CIFMS_ERROR ≤ 10% of CIFM- then no deduction should result for uncertainty

If CIFM-_ERROR > 10% of CIFM- then the modified value for CIFM- to account for uncertainty should be:

$$= \frac{100 - C_{IFM\_ERROR}}{100} * C_{IFM} \tag{45}$$

Where:

CIFM- Net anthropogenic greenhouse gas removals by sinks; t CO2-e

CIFM-_ERROR Total uncertainty for IFMProject; %

8.7.3 Calculation of VCUs

To estimate the amount of VCUs that can be issued at time *t*=*t*2 (the date of verification) for monitoring period *T*=*t*2-*t*1, this methodology uses the following equation:

$$VCUs = \left(C_{IFM,t2} - C_{IFM,t1}\right) - BRR \qquad (46)$$

where:

VCUs	Number of Verified Carbon Units
CIFM-,t2	Net anthropogenic greenhouse gas removals by sinks, as estimated for t*=t2; t CO2-e
CIFM-,t1	Net anthropogenic greenhouse gas removals by sinks, as estimated for t*=t1; t CO2-e
BRR	Portion of carbon credits to be withheld as a buffer reserve

Buffer reserve should be calculated using *VCS Tool for AFOLU Non-Permanence Risk Analysis and Buffer Determination*.

The number of VCUs eligible for crediting in any one monitoring period may not exceed the ex-ante projected total number of VCUs for the defined project lifetime unless it can be demonstrated the ex-ante estimate created through modeling has been conservatively underestimated (eg, through growth rates in excess of projection or increases in harvest efficiency/decreases in harvest volumes).[22]

9 MONITORING

9.1 Data and Parameters Not Monitored

In addition to the parameters listed in the tables below, the provisions on data and parameters not monitored in the tools referred to in this methodology apply.

In choosing key parameters or making important assumptions based on information that is not specific to the project circumstances, such as in use of existing published data, project proponents must retain a conservative approach: that is, if different values for a parameter are equally plausible, a value that does not lead to over-estimation of net anthropogenic GHG removals by sinks must be selected.

Data / parameter:	$A_{BSL,i}$
Data unit:	Ha

[22] This requirement ensures through forest management rotations with growth and harvesting projects are not overcredited. Crediting should not occur to the peaks of growth if harvest is going to immediately follow.

Used in equations:	Implicitly used in Section 4.1
Description:	Area of baseline stratum, *i*
Source of data:	GPS coordinates and/or Remote Sensing data and/or legal parcel records
Measurement procedures (if any):	N/A
Any comment:	

Data / parameter:	*BEF*
Data unit:	Dimensionless
Used in equations:	15
Description:	Biomass expansion factor for conversion of annual net increment (including bark) in stem biomass to total above-ground tree biomass increment for species *j*
Source of data:	The source of data must be chosen with priority from higher to lower preference as follows: (a) Existing local and forest type-specific; (b) National and forest type-specific or eco-region-specific (eg, from national GHG inventory); (c) Forest type-specific or eco-region-specific from neighboring countries with similar conditions. Sometimes (c) might be preferable to (b); (d) Globally forest type or eco-region-specific (eg, IPCC literature: Table 3A.1.10 of GPG-LULUCF)
Measurement procedures (if any):	
Any comment:	- BEFs are age dependent, and use of average data may result in significant errors for both young and old stands – as BEFs are usually large for young stands and quite small for old stands.

Data / parameter:	*CF*
Data unit:	t C t^{-1} d.m.

Used in equations:	9, 10, 19, 29, 31, 39
Description:	Carbon fraction of dry matter
Source of data:	Default value 0.5 t C t^{-1} d.m. can be used, or species specific values from the literature
Measurement procedures (if any):	
Any comment:	

Data / parameter:	*D*
Data unit:	t d.m. m^{-3}
Used in equations:	9, 29, 31, 39
Description:	Basic wood density
Source of data:	The source of data must be chosen with priority from higher to lower preference as follows: (a) National and species-specific or group of species-specific (eg, from National GHG inventory); (b) Species-specific or group of species-specific from neighboring countries with similar conditions. Sometimes (b) may be preferable to (a); (c) Globally species-specific or group of species-specific (eg, IPCC GPG-LULUCF).
Measurement procedures (if any):	N/A
Any comment:	

Data / parameter:	D_{DW}
Data unit:	t d.m. m^{-3}
Used in equations:	27
Description:	Basic wood density of dead wood in the density class – sound (1), intermediate (2) and rotten (3)

Source of data:	The source of data must be chosen with priority from higher to lower preference as follows: (a) Research publications relevant to the project area; (b) National and species-specific or group of species-specific (eg, from National GHG inventory); (c) Species-specific or group of species-specific from neighboring countries with similar conditions. Sometimes (b) may be preferable to (a); (d) Globally species-specific or group of species-specific (eg, IPCC GPG-LULUCF).
Measurement procedures (if any):	Project-specific determination of density is most likely necessary
Any comment:	

Data / parameter:	$f_j(DBH,H)$
Data unit:	t d.m. tree^{-3}
Used in equations:	9, 19, 39
Description:	Allometric equation for species j linking diameter at breast height (DBH) and possibly height (H) to above-ground biomass of living trees
Source of data:	Whenever available, use allometric equations that are species-specific or group of species-specific, provided the equations have been derived using a wide range of diameters and heights, based on datasets that comprise at least 20 trees. Otherwise, default equations from IPCC literature, national inventory reports or published peer-reviewed studies may be used – such as those provided Tables 4.A.1 to 4.A.3 of the GPG-LULUCF (IPCC 2003).
Measurement procedures (if any):	
Any comment:	It is necessary to verify the applicability of equations used. Allometric equations can be verified by both: 1. Verification of equation conditions: Justification should be provided for the applicability of the equation to the project locations. Such justification should include identification of climatic, edaphic, geographical and taxonomic similarities between the project location and the location in which the equation was derived. Any equation used should have an r^2 value of greater than 0.5

	(50%) and a p value that is significant (<0.05 at the 95% confidence level). 2. Additional field verification For field verification either of the two methods below may be used: A. Destructive Sampling ▪ Selecting at least 5 trees covering the range of DBH existing in the project area, and felling and weighting the above-ground biomass to determine the total (wet) weight of the stem and branch components; ▪ Extracting and immediately weighing subsamples from each of the wet stem and branch components, followed by oven drying at 70^{o}C to determine dry biomass; ▪ Determining the total dry weight of each tree from the wet weights and the averaged ratios of wet and dry weights of the stem and branch components. B. Limited Measurements ▪ Select at least 10 trees per species distributed across the age range (but excluding trees less than 15 years old for which there is rarely a great relative inaccuracy in equations) ▪ Calculate volume of tree from basal and top diameters and tree height. Multiply by species-specific density to gain biomass of bole. Add an additional percentage to approximately cover biomass of branches: 15% for spruce/fir, 5% for pines and 20% for broadleaf forests[23] If the biomass of the harvested trees is within ±10% of the mean values predicted by the selected default allometric equation, and is not biased – or if biased is wrong on the conservative side (ie, use of the equation results in under- rather than over-estimate of project net anthropogenic removals by sinks) – then mean values from the equation may be used.

Data / parameter:	*OF,, WW*
Data unit:	kg kg^{-1}.
Used in equations:	32
Description:	WW = Fraction of extracted biomass effectively emitted to the atmosphere during production

[23] Calculated conservatively from the biomass expansion factors used to calculate total tree biomass from the biomass of the bole in IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry (2003), Table 3A.1.10.

Source of data:	The source of data is the published paper of Winjum et al. 1998[24]
Measurement procedures (if any):	
Any comment:	

Data / parameter:	PML_{FT}
Data unit:	%
Used in equations:	Leakage Section 6.2
Description:	Mean merchantable biomass as a proportion of total aboveground tree biomass for each forest type
Source of data:	The source of data must be chosen with priority from higher to lower preference as follows: 1. Peer-reviewed published sources (including carbon/biomass maps or growing stock volume[25] maps with a scale of at least 1km) 2. Official Government data and statistics 3. Original field measurements The forest types considered must be only those relevant for the specific market effects leakage ie. only forest types with active timber production. An appropriate source of data will be Government records on annual allowable cuts for the areas of commercial forests. Where volumes are used the source of data wood density is required to convert to merchantable biomass. The source of data on wood densities must be chosen with priority from higher to lower preference as follows: 1. Knowledge on commercial species and thus an appropriately weighted wood density derived from the density of these species 2. A region-specific mean wood density as given eg, in Brown 1997[26]

[24] Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284

[25] Volumes must be converted to merchantable biomass using wood densities/specific gravities. A weighted wood density must be used to convert multi-species data on growing stock volume to merchantable biomass

For the lower 48 US States the following defaults have been calculated[27] from the US Forest Service Forest Inventory Analysis Database and must be used where appropriate:

Forest Type Group	Merchantable Biomass as Proportion of Total Biomass
White Red Jack Pine	77%
Spruce Fir	58%
Longleaf Slash Pine	73%
Loblolly Shortleaf Pine	73%
Ponderosa Pine	64%
Oak Pine	71%
Oak Hickory	73%
Oak Gum Cypress	72%
Elm Ash Cottonwood	73%
Maple Beech Birch	76%
Aspen Birch	61%
Douglas Fir	70%
Western White Pine	62%
Fir-Spruce/Mountain Hemlock	62%
Lodgepole Pine	64%
Hemlock/Sitka Spruce	67%
Western Larch	66%
Redwood	43%
Western Oak	69%

[26] Brown, S. 1997. Estimating biomass and biomass change of tropical forests: a Primer. FAO Forestry Paper 134. http://www.fao.org/docrep/W4095E/W4095E00.htm

[27] The FIA mapmaker program (http://www.ncrs2.fs.fed.us/4801/fiadb/fim30/wcfim30.asp) was used. For the lower 48 states the total biomass and merchantable biomass by forest type were downloaded in order to calculate the proportions given here

Measurement procedures (if any):	
Any comment:	

Data / parameter:	*R*
Data unit:	kg kg^{-1}.
Used in equations:	16, 20
Description:	Root-shoot ratio appropriate for biomass increment of forest type / biome
Source of data:	The source of data must be chosen with priority from higher to lower preference as follows: (a) Research publications relevant to the project area; (b) National and forest type-specific or eco-region-specific (eg, from National GHG inventory); Sometimes (b) may be preferable to (a)[28] (c) Forest type-specific or eco-region-specific from neighboring countries with similar conditions.; (d) Globally forest type-specific or eco-region-specific (eg, IPCC GPG-LULUCF).
Measurement procedures (if any):	
Any comment:	Guidelines for Conservative Choice of Default Values: 1. If in the sources of data mentioned above, default data are available for conditions that are similar to the project (same vegetation genus; same climate zone; similar forest type), then mean values of default data may be use d and considered conservative. 2. Global values may be selected from Table 3A.1.8 of the GPG-LULUCF (IPCC 2003), or equivalently Table 4.4 of the AFOLU Guidelines (IPCC 2006), by choosing a climatic zone and species that most closely matches the project circumstances.

[28] (b) must only be used instead of (a) when the dataset is significantly larger and the relationship between root and shoot tighter for National and forest type-specific or eco-region-specific (b). For example projects may elect to use IPCC defaults in the 2006 Guidelines for National Greenhouse Gas Inventories: Volume 4 AFOLU – Table 4.4. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_04_Ch4_Forest_Land.pdf

Data / parameter:	*SLF*
Data unit:	unitless
Used in equations:	30, 33, 34, 35
Description:	Short lived fraction - proportion of wood products that oxidize immediately in the first three years after harvesting
Source of data:	The Forestry Appendix of US Department of Energy's Technical Guidelines for The Voluntary Reporting of Greenhouse Gas Program (Section 1605b) http://www.eia.doe.gov/oiaf/1605/Forestryappendix[1].pdf Also available as a US Forest Service General Technical Report at: http://www.fs.fed.us/ne/durham/4104/papers/ne_gtr343.pdf Winjum et al,. 1998
Measurement procedures (if any):	
Any comment:	

Data / parameter:	*MLF*
Data unit:	unitless
Used in equations:	30, 33, 35
Description:	Medium lived fraction -- Proportion of wood products that decay over a 20 year period after harvest
Source of data:	The Forestry Appendix of US Department of Energy's Technical Guidelines for The Voluntary Reporting of Greenhouse Gas Program (Section 1605b) http://www.eia.doe.gov/oiaf/1605/Forestryappendix[1].pdf Also available as a US Forest Service General Technical Report at: http://www.fs.fed.us/ne/durham/4104/papers/ne_gtr343.pdf Winjum et al., 1998
Measurement procedures (if any):	

Any comment:	

Data / parameter:	*LLF*
Data unit:	unitless
Used in equations:	30
Description:	Long lived fraction - proportion of wood products that remain stored for 100 years after harvest
Source of data:	The Forestry Appendix of US Department of Energy's Technical Guidelines for The Voluntary Reporting of Greenhouse Gas Program (Section 1605b) http://www.eia.doe.gov/oiaf/1605/Forestryappendix[1].pdf Also available as a US Forest Service General Technical Report at: http://www.fs.fed.us/ne/durham/4104/papers/ne_gtr343.pdf Winjum et al., 1998
Measurement procedures (if any):	
Any comment:	

9.2 Description of Monitoring Plan

All data collected as part of monitoring must be archived electronically and be kept at least for 2 years after the end of the project. 100% of the data must be monitored if not indicated otherwise in tables below. All measurements must be conducted according to relevant standards. In addition, the monitoring provisions in the tools referred to in this methodology apply.

9.2.1 Monitoring of Project Implementation

Information must be provided, and recorded in the project description, to establish that:

i. The geographic position of the project area is recorded for all areas of land;
   - The geographic coordinates of the project area (and any stratification inside the boundary) are established, recorded and archived. This can be achieved by field survey (eg, using GPS), or by using georeferenced spatial data (eg, maps, GIS datasets, orthorectified aerial photography or georeferenced remote sensing images).

ii. Commonly accepted principles of forest inventory and management are implemented;

- Standard operating procedures (SOPs) and quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of SOPs already applied in national forest monitoring, or available from published handbooks, or form the *IPCC GPG LULUCF 2003*, is recommended;
- The forest management plan, together with a record of the plan as actually implemented during the project must be available for validation and verification, as appropriate.

9.2.2 Sampling Design and Stratification

Stratification of the project area into relatively homogeneous units can either increase the measuring precision without increasing the cost unduly, or reduce the cost without reducing measuring precision because of the lower variance within each homogeneous unit. Project proponents must present in the project description an *ex-ante* stratification of the project area or justify the lack of it. The number and boundaries of the strata defined *ex-ante* may change during the project crediting period (*ex-post*).

Updating of strata

The *ex-post* stratification must be updated due to the following reasons:

- Unexpected disturbances occurring during the project crediting period (eg, due to fire, pests or disease outbreaks), affecting differently various parts of an originally homogeneous stratum;
- Forest management activities (cleaning, planting, thinning, harvesting, coppicing, re-planting) may be implemented in a way that affects the existing stratification.

Established strata may be merged if reasons for their establishing have disappeared.

9.2.3 Sampling framework

To determine the sample size and allocation among strata, this methodology uses the latest version of the UNFCCC tool for the "Calculation of the number of sample plots for measurements within A/R CDM project activities" (see section References) approved by the CDM Executive Board. The targeted precision level for biomass estimation across the project is +/- 10% of the mean at a 90% confidence level. In contrast to the CDM tool note that temporary plots are permissible under this methodology.

9.2.4 Data and Parameters Monitored

The following parameters must be monitored during the project activity. When applying all relevant equations provided in this methodology for the *ex-ante* calculation of net anthropogenic GHG removals by sinks, project proponents must provide transparent estimations for the parameters that are monitored during the project crediting period. These estimates must be based on measured or existing published data where possible and project proponents must retain a conservative approach: that is, if different values for a parameter are equally plausible, a value that does not lead to over-estimation of net anthropogenic GHG removals by sinks must be selected.

Future developments may allow remote sensing of carbon stocks and changes in carbon stocks, however, a new version of this methodology will be necessary to accommodate the currently unknown components of such future technology.

Data / parameter:	A_i
Data unit:	ha
Used in equations:	17, 22, 27
Description:	Area of stratum *i*
Source of data:	Monitoring of strata and stand boundaries must be done preferably using a Geographic Information System (GIS), which allows for integrating data from different sources (including GPS coordinates and Remote Sensing data).
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	It must be assumed ex-ante that stand boundaries and strata areas must not change through time

Data / parameter:	Ap
Data unit:	m^2
Used in equations:	14
Description:	Area of sample plot
Source of data:	Recording and archiving of size of sample plots
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	

Any comment:	Ex-ante the size of plots must be defined and recorded in the monitoring plan

Data / parameter:	$D_{n,i,t}$
Data unit:	cm
Used in equations:	26
Description:	Diameter of piece *n* of dead wood along the transect in stratum *i*, at time *t*
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	Lying dead wood must be sampled using the line intersect method (Harmon and Sexton 1996[29]). Two 50-meter lines are established bisecting each plot and the diameters of the lying dead wood (≥ 10 cm diameter) intersecting the lines are measured. Minimum measurement diameter for all sites must not be less than 10 cm.
Monitoring frequency:	
QA/QC procedures:	
Any comment:	Ex-ante the change in carbon stocks in all applicable pools will be modeled following the requirements in Section 4.1

Data / parameter:	*DBH*
Data unit:	cm
Used in equations:	9, 19, 38
Description:	Diameter at breast height of tree
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	Typically measured 1.3m above-ground. Measure all trees above some minimum *DBH* in the sample plots that result from the IFM project activity. The minimum *DBH* for all sites must not be more than 20cm.

[29] Harmon, M.E. and J. Sexton. (1996) Guidelines for measurements of woody detritus in forest ecosystems. US LTER Publication No. 20. US LTER Network Office, University of Washington, Seattle, WA, USA.

Monitoring frequency:	
QA/QC procedures:	
Any comment:	Ex-ante the change in carbon stocks in all applicable pools will be modeled following the requirements in Section 4.1

Data / parameter:	*H*
Data unit:	m
Used in equations:	9, 19, 38
Description:	Height of tree
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	Ex-ante the change in carbon stocks in all applicable pools will be modeled following the requirements in Section 4.1

Data / parameter:	*L*
Data unit:	m
Used in equations:	26
Description:	Length of the transect to determine volume of lying dead wood (default 100 m)
Source of data:	Field measurements
Measurement procedures (if any):	
Monitoring frequency:	

QA/QC procedures:	
Any comment:	Ex-ante the change in carbon stocks in all applicable pools will be modeled following the requirements in Section 4.1

Data / parameter:	*N*
Data unit:	Dimensionless
Used in equations:	26
Description:	Total number of wood pieces intersecting the transect
Source of data:	Field measurements
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	Ex-ante the change in carbon stocks in all applicable pools will be modeled following the requirements in Section 4.1

Data / parameter:	PMP_i
Data unit:	%
Used in equations:	Leakage section 6.2
Description:	Merchantable biomass as a proportion of total aboveground tree biomass for stratum *i* within the project boundaries
Source of data:	Within each stratum divide the summed merchantable biomass (defined as "Total gross biomass (including bark) of a tree 5" (12.7 cm) DBH or larger from a 1' (30.48 cm) stump to a minimum 4" (10.2 cm) top DOB of the central stem") by the summed total aboveground tree biomass
Measurement procedures (if any):	

Monitoring frequency:	At least every five years at the time of verification
QA/QC procedures:	
Any comment:	Ex-ante a time zero measurement must be made of this factor

Data / parameter:	*T*
Data unit:	yr
Used in equations:	18, 23, 24, 28
Description:	Number of years between monitoring time *t* and *t1* (*T* = *t2* – *t1*)
Source of data:	
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	Ex-ante the monitoring plan must detail the planned monitoring intervals through the project life

9.2.5 Conservative Approach and Uncertainties

To help reduce uncertainties in accounting of emissions and removals, this methodology uses, whenever possible, the proven methods from the GPG-LULUCF, GPG-2000, the IPCC's Revised 2006 Guidelines and the tools and methodologies of the CDM Executive Board. Tools and guidance from the CDM Executive Board on conservative estimation of emissions and removals are also used. Despite this, potential uncertainties still arise from the choice of parameters to be used. Uncertainties arising from, for example, biomass expansion factors (*BEFs*) or wood density, would result in uncertainties in the estimation of both baseline net GHG removals by sinks and the actual net GHG removals by sinks – especially when global default values are used.

It is recommended that project proponents identify key parameters that would significantly influence the accuracy of estimates. Local values that are specific to the project circumstances must then be obtained for these key parameters, whenever possible. These values must be based on:

- Data from well-referenced peer-reviewed literature or other well-established published sources[30]; or
- National inventory data or default data from IPCC literature that has, whenever possible and necessary, been checked for consistency against available local data specific to the project circumstances; or
- In the absence of the above sources of information, expert opinion may be used to assist with data selection. Experts will often provide a range of data, as well as a most probable value for the data. The rationale for selecting a particular data value must be briefly noted in the project description. For any data provided by experts, the project description must also record the expert's name, affiliation, and principal qualification as an expert (eg, that they are a member of a country's national forest inventory technical advisory group) – plus inclusion of a 1-page summary CV for each expert consulted, included in an annex.

In choosing key parameters of making important assumptions based on information that is not specific to the project circumstances, such as in use of default data, project proponents must select values that will lead to an accurate estimation of net GHG removals by sinks, taking into account uncertainties. If uncertainty is significant, project proponents must choose data such that it tends to under-estimate, rather than over-estimate, net GHG removals by sinks.

10 REFERENCES

Articles

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Harmon, M.E. and J. Sexton. (1996) Guidelines for measurements of woody detritus in forest ecosystems. US LTER Publication No. 20. US LTER Network Office, University of Washington, Seattle, WA, USA.

IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry – Section 4.3. Available at: http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/Chp4/Chp4_3_Projects.pdf

Pearson, T., Walker, S. and Brown, S. 2005. Sourcebook for Land Use, Land-Use Change and Forestry Projects. Winrock International and the World Bank Biocarbon Fund. 57pp. Available at: http://www.winrock.org/Ecosystems/files/Winrock-BioCarbon_Fund_Sourcebook-compressed.pdf

[30] Typically, citations for sources of data used should include: the report or paper title, publisher, page numbers, publication date, etc. (or a detailed web address). If web-based reports are cited, hardcopies should be included as Annexes in the project description if there is any likelihood such reports may not be permanently available

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UNFCCC Reports

UNFCCC CDM Additionality Tests (available at: http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-01-v5.2.pdf)

UNFCCC "Tool for testing significance of GHG emissions in A/R project activities" (available at: http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-04-v1.pdf)

UNFCCC tool for the "Calculation of the number of sample plots for measurements within A/R CDM project activities" (available at: http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-03-v2.pdf)

UNFCCC Executive Board of the Clean Development Mechanism 42nd Meeting Report (available at http://cdm.unfccc.int/EB/042/eb42rep.pdf)

UNFCCC Executive Board of the Clean Development Mechanism 44th Meeting Report (available at http://cdm.unfccc.int/EB/044/eb44rep.pdf)

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Version	Date	Comment
v1.0	13 May 2010	Initial version released. The initial version was developed by Ecotrust Forest Management, Inc., and assigned version '4 May 2010' for development purposes and assessed as version 4 May 2010 for reference in the first and second assessment reports. It has been redesignated version 1 for the purposes of finalization and approval by the VCSA.
v1.1	20 Nov 2012	The methodology was revised to account for the decay of carbon from the harvested wood products pool and to make explicit that the decay of the dead wood pool must not be assumed to be immediate. Revisions were made to Section 8.5.1.3. Other minor updates have also been incorporated into the methodology. Specifically, the applicability conditions were revised to clarify the types of forest management techniques which are eligible activities under this methodology and a modification was made with respect to the timing by which FSC certification must be in place to allow projects to achieve certification by the start of the project crediting period.
v1.2	29 Aug 2013	Clarified Section 6.3 with respect to selection of the most plausible baseline scenario.

VERIFIED CARBON STANDARD
A Global Benchmark for Carbon

Approved VCS Methodology VM0005

Version 1.2, 23 July 2013
Sectoral Scope 14

Methodology for Improved Forest Management: Conversion of Low Productive to High Productive Forest

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1 SOURCES

This methodology is written to conform with the VCS rules that apply to Improved Forest Management projects (conversion of low-productive forests to high-productive forests (LtHP)) and has been prepared by Silvestrum on behalf of Face the Future, both based in the Netherlands. The methodology draws on elements from VCS methodologies VM0007 and VM0011, and CDM methodology AR-ACM0002.

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology facilitates the quantification of the net GHG benefits of Improved Forest Management projects in natural Evergreen Tropical Rainforests that achieve carbon benefits in one of, or a combination of, two activities:

- Avoiding emissions from re-logging of already logged-over forest; and,
- Rehabilitation of previously logged-over forest by cutting climbers and vines, or liberation thinning, or enrichment planting, or a combination of these activities.

The baseline scenario therefore consists of a logged-over natural Evergreen Tropical Rainforest, normally with no or insignificant regrowth, that may or may not be relogged. To determine the emissions in the baseline, the following components are quantified: volume of timber removed during relogging (expanded to include emissions from total associated biomass losses); the amount of dead wood left after relogging; the carbon stored in harvested wood products; if absence of regrowth cannot be substantiated, regrowth of the residual stand; and, emissions associated with the establishment of infrastructure and fuel consumption.

Because baselines often become counter factual once the project gets implemented, this methodology facilitates the quantification of the above components in two ways:

- On the basis of a-spatial data in a pre-relogging situation in the project area, in combination with, for instance, logging information in a management plan; or,
- By the determination of the carbon stock components after relogging has occurred in a reference area for which similarity to the project area is demonstrated.

The relationship between the two baseline options and the project area is then established by analyzing the logging rates in the various strata in the baseline, determining the same strata in the project area, and applying the stratum-specific logging rates to the strata in the project area.

The methodology allows for the use of both approaches together, if either of the two cannot be supported with a complete set of information, with the following examples: (1) While obtaining spatially explicit post-relogging carbon stock data from a reference area through direct measurements, spatially explicit pre-relogging data based on direct measurements may be lacking. Once the similarity of the reference area and the project area has been ensured, pre-relogging carbon stock data may also be obtained from the project area. (2) If spatially explicit pre-relogging carbon stock data based on direct measurements is lacking, similarity between the reference area and the project area may be justified by reconstructing pre-relogging carbon stocks from the post-relogging data of the reference area and harvesting volumes from management files of the forest management unit, and comparing these with pre-relogging carbon stock data from the project area. The validity of reconstructed pre-relogging carbon stocks may be supported by other inventory data of the reference area (eg, inventories of commercial timber prior to relogging), the supporting data being subject to the scrutiny of the validator. (3) While using a-spatial data for assessing baseline carbon stock changes, carbon stocks in dead wood may be derived from a reference area.

While ensuring conservative results for net GHG project benefits, these options support the implementation of FM project activities in areas where data collection has not been organized in such a way that it facilitates compliance *a priori* with international carbon standards, which is very often the case.

The with-project scenario constitutes the avoidance of relogging, or rehabilitation of previously logged-over forest, or both. Rehabilitation, if any, is achieved by cutting climbers and vines, or liberation thinning, or enrichment planting, or a combination of these activities. To determine the emissions and removals in the with-project scenario, the following components are quantified: carbon stocks before the intervention; increases in carbon stocks over time; and emissions due to site preparation and project implementation.

An additional feature of this methodology is the determination of the regrowth of the residual forest in both the baseline and the with-project scenario. If regrowth occurs in the baseline scenario this is assumed to be small compared to regrowth in the with-project scenario.

The removal of herbaceous vegetation (including climbers and vines) is deemed an insignificant emissions source and therefore is not accounted for in the with-project scenario.

The methodology also provides for the quantification of leakage.

Finally, the methodology provides for the determination of the project's net GHG benefits and the resulting Verified Carbon Units (VCUs) that are generated. The methodology details the steps necessary to come to the final calculation of the project's net GHG benefits, represented by ΔC_{IFM}.

$$\Delta C_{IFM} = \Delta C_{BSL} - \Delta C_{WPS} - \Delta C_{LK} \quad (1)$$

Where:

Parameter	Description
ΔC_{IFM}	Total net GHG emission reductions from the IFM project activity
ΔC_{BSL}	Sum of the carbon stock changes and greenhouse gas emissions under the baseline scenario
ΔC_{WPS}	Sum of the carbon stock changes and greenhouse gas emissions under the with-project scenario

ΔC_{LK}	Sum of the carbon stock changes and greenhouse gas emissions due to leakage

Thus, the basis of the methodology is the estimation of total carbon benefits from the IFM project activity as the result of the total carbon loss in the baseline scenario (ΔC_{BSL}) avoided due to the project activity and the net removals through the enhancement of forest growth due to liberation thinning and enrichment planting (ΔC_{WPS}), minus any leakage (ΔC_{LK}) that might occur.

Additionality	Project Method
Crediting Baseline	Project Method

3 DEFINITIONS

This methodology does not use any methodology-specific definitions.

4 APPLICABILITY CONDITIONS

This methodology is applicable to Improved Forest Management (IFM) activities, as defined by the VCS rules.

Only areas that have been designated, sanctioned or approved for such activities (eg, as logging concessions) by the national or local regulatory bodies are eligible for crediting under this VCS Improved Forest Management (IFM) category.

In particular, this methodology is applicable to improved forest management practices that achieve the conversion of low-productive forest to high-productive forest (LtHP) through the protection of logged-over, degraded forest from further logging or the adoption of silvicultural techniques increasing the density of tree vegetation, or a combination of these activities.

This methodology is applicable to situations whereby the original forest is natural *Evergreen Tropical Rainforest*, using the FAO definition where the term “Evergreen Tropical Rainforest” is defined as follows: “Evergreen Tropical Rainforests occur where the annual rainfall is greater than 2,500 mm, where forests grow mostly at low elevations, are evergreen, luxuriant, predominantly of hardwood species, have a complex structure and are rich in both plants and animals. Soils tend to be mustow and poor in nutrients, features having a marked effect on forest management practices.”[1]

The applicability conditions for this methodology are the following:

- Project activities aim at the avoidance of relogging of logged-over, degraded natural Evergreen

[1] Source: http://www.fao.org/docrep/W8212E/w8212e03.htm#a definition of tropical forests

Tropical Rainforest, or the rehabilitation of logged-over natural Evergreen Tropical Rainforest through direct human intervention such as cutting of climbers and vines, liberation thinning and/or enrichment planting, or a combination of these activities;

- Land within the project area must have qualified as forest;
- In the baseline, the logged-over forest in the project area is unlikely to revert to normal regrowth patterns due to vines and climbers, which may include climbing bamboos, resulting from high-intensity logging operations in the past. In such cases, and subject to appropriate substantiation, regrowth of tree biomass before and following relogging in the baseline can be assumed to be zero. Where this is not the case, ex-ante estimates of regrowth must be made and monitoring of the baseline for ex-post confirmation of regrowth rates must be conducted;
- The soil carbon pool within the project boundary is either in a steady state at project commencement, or, if not, the soil carbon pool is only expected to increase more or decrease less in the with-project scenario in comparison to the baseline, and may therefore, conservatively be omitted;[2]
- Site preparation is carried out so as to avoid levels of soil disturbance or soil erosion sufficient to significantly reduce the soil carbon pool over the project lifetime;
- The use of nitrogen fertilizer in the project activities is prohibited;
- During the project crediting period, harvesting must not occur in the with-project scenario[3].
- Biomass burning, fuel gathering, removal of litter, or removal of dead wood do not occur in the baseline scenario and in the with-project scenario within the project boundary;
- A reference area may be used to derive relevant parameter values for the baseline scenario. This area must be of similar size as the project area, or larger (ie, 75% of the project area or more), for which similarity with the project area can be demonstrated using criteria outlined in this methodology, and for which it can be demonstrated that the management is not affected by its selection as a reference area; and,
- Flood irrigation or drainage of primarily saturated soils are not permitted as part of the project activity, so associated non-CO2 greenhouse gas emissions can be neglected.
- There is no peatland[4] within the project area or emissions associated with peatland are not significant.
- The methodology is not applicable to grouped projects.

[2] Project proponents must use the A/R CDM approved tool 6 to demonstrate insignificance.

[3] If harvesting is planned or expected to occur after the project crediting period, the associated carbon sink reversal will be addressed in the non-permanence risk assessment.

[4] See VCS definition.

5 PROJECT BOUNDARY

5.1 Land eligibility and Geographic boundaries

No land use change is occurring in the project area: it is forest land remaining forest land. Where the activity takes place in a country that has adopted a forest definition under the Kyoto Protocol, those thresholds must be adhered to. Otherwise, the definition used in the national GHG Inventory must be used.

Only areas that have been designated, sanctioned or approved for such activities (eg, as logging concessions or plantations) by the national or local regulatory bodies are eligible for crediting under the VCS Improved Forest Management (IFM) category. This will be determined according to the legally sanctioned logging laws, regulations and codes of practice of the relevant national or sub-national regulatory authority. These laws may be defined in absolute terms (hectares) or via prescription (relative per cent). Areas within the project area, where logging has been prohibited due to environmental, cultural or other reasons, must be determined through maps and spatial analysis and be excluded from the estimations of emission reductions or removals.

The boundary of the IFM activity must be clearly delineated and defined and include only land qualifying as “forest”.

Project proponents must clearly define the spatial boundaries of a project so as to facilitate accurate measuring, monitoring, accounting, and verifying of the project’s emissions reductions and removals.

The IFM project activity may contain more than one discrete area of land. Each discrete area of land must have a unique geographical identification.

When describing physical project boundaries (for both the project areas and, if any, the reference area), the following information must be provided per discrete area:

- Name of the project area (including compartment numbers, local name (if any)
- Unique identifier for each discrete parcel of land
- Map(s) of the area in digital format)
- Geographic coordinates obtained from a GPS or from a geo-referenced digital map)
- Total land area
- Details of forest land rights holder and user rights

Following the VCS definition of market leakage, the geographic boundaries for leakage from market effects are those of the country in which the project area occurs.

In this methodology, the project area (the geographic area in which the project activity is implemented) may exceed the area eligible for carbon accounting, ie, the forest area protected against relogging, rehabilited, or both. This may exclude areas that do not contain merchantable timber and/or that are inaccessible for legislative, technical or economic reasons. A justification for the in- or exclusion of areas within the project area must be provided in the project description of the actual project applying this methodology.

A reference area is an area that is representative of the project area in the baseline scenario and thus meets the criteria set out by the applicability conditions (minimum size) and those elaborated below (similarity to project area), where the volume of biomass that would have been removed from the project area over the lifetime of the project can be assessed.

5.2 Temporal boundaries

The temporal boundary for projects applying this methodology is equal to the project crediting period.

Project proponents must determine the project crediting period, the project crediting period start date and the project start date and provide verifiable evidence when the 1st monitoring period started and when the project begins to reduce or avoid GHG emissions.

5.3 Carbon pools

The carbon pools that must be included and that may be excluded from the project boundary are shown in Table 1.

Carbon pools and emissions sources may be neglected, ie, accounted as zero, if the application of the most recent version of the "Tool for testing significance of GHG emissions in A/R CDM project activities"[5] leads to the conclusion that the pool or emission source (see Table 2) is insignificant.

Table 1: Selection and justification of carbon pools

Carbon pools	Selected	Justification/Explanation of choice
Above-ground tree biomass	Yes	Major carbon pool assumed to significantly decrease in the baseline, or increase in the project, or both.
Above-ground non-tree biomass	No	Pool need not to be measured because it is not subject to significant changes or potential changes are transient in nature.
Below-ground biomass	Optional	Major carbon pool assumed to significantly decrease in the baseline, or increase in the project, or both. Not accounting for below-ground biomass is conservative.
Dead wood	Yes	Carbon pool likely to decrease as a result of the project

[5] Available at: http://cdm.unfccc.int/methodologies/ARmethodologies/tools/

		activity. Accounting for dead wood as zero in the with-project scenario is conservative. Accounting for dead wood occurring prior to re-logging as zero is conservative.
Litter	No	Conservative approach - unlikely to decrease as a result of the project activity, or increase in the baseline
Soil organic carbon	No	Conservative approach - unlikely to decrease as a result of the project activity, or increase in the baseline
Wood products	Yes	Carbon pool likely to decrease as a result of the project activity. Accounting for wood products as zero in the with-project scenario is conservative.

5.4 Greenhouse gases

The emissions sources included in or excluded from the project boundary are shown in Table 2. In addition, insignificance of sources can be determined by the tool referred to above.

Table 2: Gases considered from emissions by sources other than resulting from changes in stocks in carbon pools

Gas	Sources	Selected	Justification/explanation of choice
Carbon dioxide (CO_2)	Combustion of fossil fuel in vehicles / machinery	Yes or No	Included subject to materiality if relogging is the baseline activity
	Removal of herbaceous vegetation	No	Excluded based on VCS guidance
Methane (CH_4)	Combustion of fossil fuel in vehicles / machinery	Yes or No	Included as CO_2 equivalent emission if relogging is the baseline activity
	Burning of biomass	No	Not included – no burning allowed; not accounting for methane emissions in the baseline scenario is conservative
Nitrous oxide (N_2O)	Combustion of fossil fuel in vehicles / machinery	Yes or No	Included as CO_2 equivalent emission if relogging is the baseline activity
	Nitrogen based fertilizer	No	Not included – no use of fertilizer allowed

	Burning of biomass	No	Not included – no burning allowed; not accounting for N_2O emissions in the baseline scenario is conservative

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

The baseline scenario must reflect what most likely would have occurred in the absence of the project. It consists of a logged-over natural Evergreen Tropical Rainforest, normally with no or insignificant regrowth that may or may not be relogged.

The following information must be provided to prove that the project proponent meets the minimum acceptable standards outlined for this baseline scenario:

- A documented history of the operator (operator must have at least 5 years of management records to show logging intensities and normal historical practices). Common records would include data on timber cruise volumes, inventory levels, harvest levels, etc. on the property that demonstrate what the normal practice in the area is. The documented history must also indicate the periodicity in logging operations in the area and in management planning (eg, interval between two subsequent logging coupes according to management plans (past or current) and in reality); and

- The legal requirements for forest management and land use in the area; however if these are not enforced then this requirement does not have to be met; and

- Proof that their environmental practices equal or exceed those commonly considered a minimum standard among similar landowners in the area.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

The project proponent must demonstrate that the project is additional through the use of the latest version of the VCS Tool for the Demonstration and Assessment of Additionality in IFM Project Activities.

8 STRATIFICATION

If the project activity area at the start of the project is not homogeneous, stratification may be carried out to improve the accuracy and the precision of carbon stock estimates. Different stratifications may be required for the baseline and with-project scenarios in order to achieve optimal accuracy of the estimates of net GHG emissions or removal.

Strata must be spatially discrete and defined on the basis of forest carbon stocks or expected changes in forest carbon stocks. Stratum sizes must be known. Areas of individual strata must sum to the total project area. Strata must be identified with spatial data (eg, maps, GIS coverage, classified imagery, or sampling grids) from which the area can be determined accurately. Land use/land cover maps in particular must be ground-truthed and current, less than 10 years old. Strata must be discernible taking into account good practice in terms of the accuracy requirements for the definition of strata limits / boundaries. This must be indicated in the project description and the choice must be justified.

For estimation of baseline net GHG emissions or removals, or estimation of project net GHG emissions or removals, strata must be defined on the basis of parameters that are key entry variables used to estimate changes in biomass stocks.

The project area may be stratified *ex ante*, and this stratification may be revised *ex post* for monitoring purposes. Strata need only reflect consistent differences in biomass stocks and not for example species composition or ecological variables. Established strata may be merged if reasons for their establishment have disappeared or have proven irrelevant to key variables for estimating forest carbon stocks or changes in forest carbon stocks.

For baseline net GHG emissions or removals: Stratification is carried out according to pre-project carbon stocks. This stratification must be determined prior to the project activity. For each stratum, assumptions must be made as to how the carbon stocks would be affected in the business as usual scenario. In case of relogging, this must be based on the relogging that has taken place in an appropriately selected reference area or on the basis of reliable management or logging plans for the project area indicating anticipated logging intensities. The remaining carbon stocks per stratum must be determined.

For project net GHG emissions and removals. The *ex-ante* estimations must be based on the project plan, which must include a timetable for and scheduling of the silvicultural interventions, such as for example liberation thinning and enrichment planting. The *ex-post* stratification must be based on the actual implementation of the projected activities. The *ex-post* stratification may be affected by natural or anthropogenic impacts if they add variability to growth pattern in the treated project area.

Baseline stratification must occur only once and remain fixed for the lifetime of the project, unless baseline monitoring occurs in a reference area.

Stratification in the with-project scenario must be updated at the time of each and every monitoring campaign prior to verification based on recent developments.

For *ex-ante* and *ex-post* stratification, project proponents may optionally make use of remote sensing data and analysis platforms acquired close to the time the project commences.

9 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

9.1 Baseline Emissions

9.1.1 General Approach

The baseline scenario is characterized by emissions from relogging, which in the with-project scenario are avoided, or an absent or limited regrowth of the residual forest, which in the with-project scenario may be enhanced, or a combination of these two.

If relogging occurs in the baseline scenario, the volume of biomass that would have been removed from the project area over the lifetime of the project can either be determined by:

1. Harvesting levels, defined in terms of cubic meters, as determined in advance and reflected for example in management plans for the project area; or

2. Post-relogging carbon stocks in a reference area.

In the first case above, the baseline net GHG emissions are estimated based on available information on the volume of timber removed and damage to the residual stand due to relogging, carbon storage in dead wood and harvested wood products, regrowth and project emissions.

'Harvested volume' or 'volume of timber removed' ($V_{harvest,i,j}$:) is measured as cubic meters removed from the forest and as reported in available information mostly based on for instance truck loads of timber that have been transported off-site. Most often timber is measured at the landing / yard before loading and freight bills accompany the timber to the place where it is transported to. Volumes are normally measured by authorities such as the Forest Department, or as a minimum inspected by such authorities, after which volumes of timber are reported. Volumes are normally calculated on the basis of diameter measurement on both sides of the log at the landing / yard with calipers and the length of the log, and specified per species.

In the second case, net emissions are estimated as the pre-relogging carbon stock minus the post-relogging carbon stock in biomass, dead wood and harvested wood products, taking also into account regrowth and project emissions.

Regrowth, if any, of the residual stand may be estimated on the basis of existing, peer-reviewed literature, quantifying regrowth in comparable areas, or in a reference area.

If a reference area is used for the estimation of baseline net GHG emissions or removals, this area is selected through the identification of areas where degradation and loss of biomass from relogging is expected to be similar to what would occur in the project area. Justification must be provided in the project description that the selected reference area is representative for the project area in the baseline scenario, and that the management of the reference area is not affected by its selection as such. The latter can be based on documented evidence that the planning of relogging occurred prior to the assignment as reference area by the IFM project proponent.

Alternatively, a sample of reference areas can be taken. The reference areas together must meet the criteria set out by the applicability conditions (minimum size) and those elaborated in this section (similarity to project area).

If emissions due to avoided timber harvesting in the baseline are determined based on activity levels in a reference area, project proponents must demonstrate that the quantification of avoided emissions in the with-project scenario is taking into account:

a. Similarity of strata and timber quantities:

Similar strata in the project area and in the reference area will have similar quantities of timber, and therefore, it can reasonably be assumed that logging intensities in those strata in the project area are the same as the logging intensity that took place in the reference area;

b. Areas for infrastructure establishment:

The same percentages of land are likely to be liberated for roads and log landings in the project area compared with the reference area; and,

c. Areas that do not contain merchantable timber and/or, are inaccessible for legislative, technical or economic reasons:

Such areas must be excluded from the area for which the changes in carbon stocks are estimated because they would have remained untouched in the baseline in any case.

Similarity of the reference area(s) to the project area can be demonstrated through meeting the following conditions, based on own measurements, literature recourses, datasets or a combination of these:

- Supporting comparable quantities of pre-relogging carbon stocks in above-ground woody biomass, or tree biomass with $DBH \geq 5$ cm, and dead wood before relogging and comparable predicted yields of commercial timber (all ±20%). If project proponents conservatively choose not to account for dead wood in the with-project scenario, similarity for the dead wood carbon pools between the reference area and the project area does not need to be demonstrated. In case of a larger difference than 20%, the project proponent must demonstrate that due to a larger or smaller carbon stock in above-ground tree biomass and/or dead wood in the reference area compared to the project area the value for relogging carbon stock losses is at least underestimated and thus a conservative result for the net GHG benefits of the project is obtained (eg, if biomass in forest in the reference area is greater than in the project area and relogging rates will be the same). Supporting documentation may include geo-referenced data in one or more of the following: management and/or logging plans, measurement data, peer-reviewed literature, maps and/or remotely sensed footage; and

- Having been subjected to the same management regime for first-round logging, as evidenced in management and/or logging plans; and

- Having comparable legal rights and harvesting rights.

This methodology accounts for carbon stock in above-ground tree biomass (AGB), below-ground biomass (BGB – optional), dead wood (DW) and carbon stored in wood products (WP). However, $C_{BSLpre,i}$ and $C_{BSLpost,i}$ below refer only to the AGB and DW carbon pools. These stocks are estimated through fieldwork, possibly combined with carbon stock determination methods using aerial photography or remote sensing, or the use of peer-reviewed default factors for the project area. Below-ground biomass is not included in the calculation of $\Delta C_{REL,i,t}$ because that would result into an overestimation of CO_2 emissions due to relogging in the baseline scenario.

The net baseline GHG emissions and removals can be estimated through one of the two following approaches:

1. Using Pre-relogging A-spatial Data; and,

2. Using Post-relogging Mid to High Resolution Spatial Data.

In both cases, the net CO_2 equivalent emissions in the baseline will be determined as:

$$\Delta C_{BSL} = \sum_{t=1}^{t*} \sum_{i=1}^{M_{BSL}} \left(\Delta C_{REL,i,t} + \Delta C_{tree-exist,i,t}\right) + GHG_{BSL-E,t} \quad (2)$$

Where:

Parameter	Description	Unit
ΔC_{BSL}	Net CO_2 equivalent emissions in the baseline scenario up to year *t**	t CO_2-e
$\Delta C_{REL,i,t}$	Net carbon stock change due to relogging in the baseline scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}
$\Delta C_{tree-exist,i,t}$	Net carbon stock change in existing tree vegetation[6] in the baseline scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}
$GHG_{BSL-E,t}$	Greenhouse gas emissions as a result of relogging within the project boundary in stratum *i* at year *t*	t CO_2-e yr^{-1}
i	1, 2, 3 …M_{BSL} strata in the baseline scenario	
t	1, 2, 3, … t^* years elapsed since the project start	

9.1.2 Pre-relogging A-spatial Data for $\Delta C_{REL,i,t}$

Estimates of the levels of forest degradation and therefore biomass loss can be obtained based on a-spatial information contained in either management or logging plans, harvesting records, or in legal documentation for the concession. Preferably this information relates to the project area, but if such information is not available it can be obtained from a reference area, provided that similarity requirements as described above are met or that it results in an underestimated value of relogging carbon stocks losses and thus a conservative result for the net GHG benefits for the project. Loss of biomass is estimated through predicted volumes of timber removals per hectare combined with

6 With *DBH* ≥ 5 cm.

estimates of damage to the residual stand and carbon storage in wood products. The estimated post-relogging carbon stock in dead wood at year *t* is quantified as being emitted over 10 years with a linear decay function, following the procedure described in the VCS AFOLU Requirements v3.3, section 4.5.3.

$$\Delta C_{REL,i,t} = \begin{pmatrix} A_{REL,i,t} \times \left(C_{harvest,i} + \left(C_{damage,i} - C_{DW,i,t}\right) - \left(\mathrm{C}_{\mathrm{WP100,i}} + C_{WP20,i,t}\right)\right) \\ + \sum_{t-20}^{t}\left(A_{REL,i,t} \times C_{WP20,i,t} \times \frac{1}{20}\right) + \sum_{t-10}^{t}\left(A_{REL,i,t} \times C_{DW,i,t} \times \frac{1}{10}\right) \end{pmatrix} \times \frac{44}{12} \qquad (3)$$

Where:

Parameter	Description	Unit
$\Delta C_{REL,i,t}$	Net carbon stock change due to relogging in the baseline scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}
$A_{REL,i,t}$	Area relogged in baseline stratum *i* at year *t*	ha yr^{-1}
$C_{harvest,i}$	Carbon stock in harvested timber in stratum *i*	t C ha^{-1}
$C_{damage,i}$	Carbon loss due to damage to the residual stand in stratum *i*	t C ha^{-1}
$C_{DW,I,t}$	Post-relogging carbon stock in dead wood in the baseline scenario (stock emitted is quantified over 10 years with a linear decay function) in stratum *i* at year *t*	t C ha^{-1}
$C_{WP100,i}$	Post-relogging carbon stock stored in long-term wood products (stock remaining in wood products after 100 years) in the baseline scenario in stratum *i*	t C ha^{-1}
$C_{WP20,i,t}$	Post-relogging carbon stock stored in short-term and medium-term wood products (stock emitted is quantified over 20 years with a linear decay function) in the baseline scenario in stratum *i* at year *t*	t C ha^{-1}
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
44/12	The ratio of molecular weight of carbon dioxide to carbon	t CO_2-e t C^{-1}

If no relogging occurs, $\Delta C_{REL,i,t}$ is equal to zero and Equation 3 does not need to be used.

The actual or predicted volume of timber to be harvested from each stratum, is estimated via the below equations.

Carbon Stock in Harvested and Damaged Wood

$$C_{harvest,i} = \sum_{j=1}^{S} (V_{harvest,i,j} \times D_j \times CF) \quad (4)$$

Where:

Parameter	Description	Unit
$C_{harvest,i}$	Carbon stocks in harvested timber in the baseline scenario in stratum *i*	t C ha^{-1}
$V_{harvest,i,j}$	Volume of timber harvested in the baseline scenario of species *j* in stratum *i*	m^3 ha^{-1} yr^{-1}
D_j	Basic density of the harvested wood of species *j*	t d.m. m^{-3}
CF	Carbon fraction of dry matter[7]	t d.m.$^{-1}$
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
j	1, 2, 3 … *S* tree species	

$$C_{damage,i} = C_{harvest,i} \times f_{damage} \quad (5)$$

Where:

Parameter	Description	Unit
$C_{damage,i}$	Loss of carbon due to damage to the residual stand in the baseline scenario, in stratum *i*	t C ha^{-1}
$C_{harvest,i}$	Carbon stocks in harvested timber in the baseline scenario in stratum *i*	t C ha^{-1}
f_{damage}	Factor for damage to the residual stand caused by relogging	

[7] IPCC default value = 0.50

i	1, 2, 3 … M_{BSL} strata in the baseline scenario	

C_{damage} represents all carbon in damaged biomass, including dead wood, resulting from logging. Accounting for C_{damage} as zero in the baseline scenario is therefore conservative and in this case accounting for C_{DW} can be omitted as well. If project proponents want to account for C_{damage}, both C_{damage} and C_{DW} must be estimated.

f_{damage} must be determined using appropriate measurement techniques such as those described in the project description of the Noel Kempff Mercado Climate Action Project (NKM-CAP), version 02.02, dated 7/11/2005, or other similar established emission quantification approaches. Alternatively, peer reviewed literature may be used to derive f_{damage} from areas for which it can be shown that they are representative for the project area or general f_{damage} proxies for natural Evergreen Tropical Rainforests for conventional and/or Reduced Impact Logging (eg, Pulkki (1997)).

If C_{DW} for the project area cannot be derived from peer-reviewed literature, data can be obtained using appropriate measurement techniques applied in areas for which it can be shown that they are representative for the project area. The method for estimating the carbon stock in dead wood from field measurements is outlined below.

Harvested Wood Products

In line with the VCS guidelines on wood products, long-term storage in this pool is accounted for using the below equations. In case no reliable assumptions can be made as to the timber classes of the harvested wood and its end use, general information from Forest Departments from that area reflecting breakdown of timber classes as they are normally harvested from this forest type and area may be used (eg, plywood, round logs, sawn timber, etc.).

This methodology follows the conceptual framework detailed in Winjum *et al.* (1998).[8]

Step 1: Estimate the biomass carbon of the volume extracted by wood product type *ty* at year *t* from within the project boundary:

$$C_{XB,ty,i,t} = \frac{1}{A_i} \times \sum_{j=1}^{S} \left(V_{ex,ty,j,i,t} \times D_j \times CF \right) \tag{6}$$

8 Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284

Where:

Parameter	Description	Unit
$C_{XB,ty,i,t}$	Mean stock of extracted biomass carbon by class of wood product *ty* from stratum *i* at year *t*	t C ha^{-1}
A_i	Total area of stratum *i*	ha
$V_{ex,ty,j,i,t}$	Volume of timber extracted from within stratum *i* (does not include slash left onsite) by species *j* and wood product class *ty* at year *t*	m^3
D_j	Mean wood density of species *j*	t d.m.m^{-3}
CF	Carbon fraction of biomass	t C t^{-1} d.m.
t	1, 2, 3, … t^* years elapsed since the project start	
j	1, 2, 3 … *S* tree species	
ty	Wood product class – defined here as sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other	

Mean wood density of species (Dj)

Values for *Dj* can be taken from tables generally used in the local or regional timber and forest industry, or from peer-reviewed literature applicable to the region. If no species-specific values for *Dj* are available, the average value across all species can be used, increased by 20% to ensure a conservative (higher) estimate of $C_{WP100,i,t}$ and $C_{WP20,i,t}$ below.

Step 2: Estimate the proportion of biomass carbon extracted at year *t* that remains sequestered in long-term wood products after 100 years, and estimate the proportion of biomass carbon extracted at year *t* that is expected to be emitted from short-term and medium-term wood products over 20 years with a linear decay function.

$$C_{WP100,i,t} = \sum_{s,w,oir,p,o}^{ty} C_{XB,ty,i,t} \times (1 - ww_{ty}) - C_{WP20,i,t} \qquad (7a)$$

$$C_{WP20,i,t} = \sum_{s,w,oir,p,o}^{ty} \left(\left(C_{XB,ty,i,t} \times slp_{ty} \right) + \left(C_{XB,ty,i,t} \times \left(1 - slp_{ty} \right) \times fo_{ty} \right) \right) \qquad (7b)$$

Where:

Parameter	Description	Unit
$C_{WP100,i,t}$	Carbon stock in long-term wood products pool (stock remaining in wood products after 100 years) in stratum *i* at year *t*	t C ha^{-1}
$C_{WP20,i,t}$	Post-relogging carbon stock in short-term and medium-term wood products pool (stock emitted is quantified over 20 years with a linear decay function) in the baseline scenario in stratum *i* at year *t*	t C ha^{-1}
$C_{XB,ty,i,t}$	Mean stock of extracted biomass carbon by class of wood product *ty* from stratum *i* at year *t*	t C ha^{-1}
ww_{ty}	Wood waste fraction. The fraction immediately emitted through mill inefficiency	
slp_{ty}	Fraction of wood products that will be emitted to the atmosphere within 5 years of timber harvest	
fo_{ty}	Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years of timber harvest	
ty	Wood product class – defined here as sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other	
i	*1, 2, 3, …* M_{BSL} strata in the baseline scenario	
t	1, 2, 3, … t^* years elapsed since the project start	

Wood waste fraction (ww_{ty}):

Winjum *et al*. (1998) indicate that the proportion of extracted biomass ($C_{XB,ty}$) that is oxidized (burning or decaying) from the production of commodities to be equal to 19% for developed countries and 24% for developing countries. The fraction ww_{ty} is therefore equal to 0.19 for developed countries and 0.24 for developing countries.

Short-lived proportion (slp)

Winjum *et al.* (1998) give the following proportions for wood products with short-term (<5 yr) uses (*slp*) after which they are retired and oxidized (applicable internationally):

Wood Product Class	slp
Sawnwood	0.2
Woodbase panels	0.1
Other industrial roundwood	0.3
Paper and Paperboard	0.4

The methodology makes the assumption that all other classes of wood products are 100% oxidized within 5 years.

Additional oxidized fraction (fo)

Winjum *et al*. (1998) gives annual oxidation fractions for each class of wood products split by forest region. This methodology uses the fractions for tropical wood products, projected over 95 years to give the additional proportion that is oxidized between the 5th and 100th years after initial harvest:

Wood Product Class	*fo* (tropical)
Sawnwood	0.84
Woodbase panels	0.97
Other industrial roundwood	0.99
Paper and paperboard	0.99

9.1.3 Post-relogging Mid to High Resolution Spatial Data for $\Delta C_{REL,i,t}$

Where available, spatial data from a reference area that has undergone relogging can be combined with field sampling to produce post-relogging values of remaining biomass and dead wood. In case a sample of various reference areas is taken, the equation below provides for the calculations to be performed for each stratum *i* in these reference areas. The outcome of the equation must be the weighted average across similar strata in all reference areas, where the weighing factor is the total area of stratum *i* in each of the reference areas.

$$\Delta C_{REL,i,t} = \begin{pmatrix} A_{REL,i,t} \times \left(C_{BSLpre,i} - \left(C_{BSLpost,i} + \left(C_{DW,i,t} - C_{DWpre,i,t}\right) + \mathrm{C}_{\mathrm{WP100,i}} + C_{WP20,i,t}\right)\right) \\ + \sum_{t-20}^{t}\left(A_{REL,i,t} \times C_{WP20,i,t} \times \frac{1}{20}\right) + \sum_{t-10}^{t}\left(A_{REL,i,t} \times \left(C_{DW,i,t} - C_{DWpre,i,t}\right) \times \frac{1}{10}\right) \end{pmatrix} \times \frac{44}{12} \quad (8)$$

Where:

Parameter	Description	Unit
$\Delta C_{REL,i,t}$	Net carbon stock change due to relogging in the baseline scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}
$A_{REL,i,t}$	Area relogged in baseline stratum *i* at year *t*	ha yr^{-1}
$C_{BSLpre,i}$	Pre-relogging carbon stock in above-ground biomass in the baseline scenario in stratum *i*	t C ha^{-1}
$C_{DWpre,I,t}$	Pre-relogging carbon stock in dead wood (stock emitted is quantified over 10 years with a linear decay function) in stratum *i* at year *t*	t C ha^{-1}
$C_{BSLpost,i}$	Post-relogging carbon stock in above-ground biomass in the baseline scenario in stratum *i*	t C ha^{-1}
$C_{DW,i,t}$	Post-relogging carbon stock in dead wood in the baseline scenario (stock emitted is quantified over 10 years with a linear decay function in stratum *i* at year *t*	t C ha^{-1}
$C_{WP100,i}$	Carbon stock in long-term wood products pool (stock remaining in wood products after 100 years) in stratum *i* at year *t*	t C ha^{-1}
$C_{WP20,i,t}$	Post-relogging carbon stock in short-term and medium-term wood products pool (stock emitted over 20 years with a linear decay function) in the baseline scenario in stratum *i* at year *t*	t C ha^{-1}
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
44/12	The ratio of molecular weight of carbon dioxide to carbon	t CO_2-e t C^{-1}

If no relogging occurs, $\Delta C_{REL,i,t}$ is equal to zero and Equation 8 does not need to be used.

Pre-relogging Carbon Stocks in Above-ground Tree Biomass

Above-ground tree biomass carbon stocks prior to relogging ($C_{BSLpre,i}$) can be determined on the basis of previously conducted fieldwork or surveys or peer-reviewed proxies in the reference area. They can be estimated using the method outlined in Estimation of $\Delta C_{AGB,i,t}$.

In case data for $C_{BSLpre,i}$ cannot be obtained from the reference area (eg, because relogging has already occurred throughout the reference area), such information may also be obtained from parts of the project area that have not been treated with silvicultural techniques. Or, in case for the reference area data on $C_{BSLpost,i}$ and harvesting levels are available, $C_{BSLpre,i}$ can be approximated by the following equation:

$$C_{BSLpre,i} = C_{BSLpost,i} + C_{harvest,i} + C_{damage,i} \quad (9)$$

Values for $C_{harvest,i}$ and $C_{damage,i}$ must be obtained from management or logging plans, harvesting records and peer-reviewed literature as described previously.

Post-relogging Carbon Stocks in Above-ground Tree Biomass

$C_{BSLpost,i}$ can be estimated using the method outlined in Estimation of $\Delta C_{AGB,i,t}$ below.

Carbon Stock in Dead Wood

Estimating the baseline carbon stocks in dead wood as a result of relogging comprises of two components – *standing dead wood* and *lying dead wood*, both of which are estimated through field measurements within permanent sample plots. The methods for each of these two components are detailed below. Accounting for dead wood occurring prior to relogging as zero is conservative.

Standing Dead Wood

Step 1: Standing dead trees must be measured using the same techniques and criteria (eg, minimum *DBH*) used for measuring living trees, taking account of equations provided in Step 3. Stumps must be inventoried as if they are very short standing dead trees.

Step 2: The decomposition class (not to be confused with dead wood density class) of the dead tree must be recorded and the standing dead wood is categorized under two decomposition classes:

1. Tree with branches and twigs that resembles a live tree (except for leaves);

2. Tree with signs of decomposition (other than loss of leaves) including loss of twigs, branches, or crown.

Step 3: Biomass is estimated using an allometric equation or BEF calculation for live trees in the decomposition class 1; with no outward signs of decomposition (ie, twigs remaining) wood density is assumed to be comparable to live tree. Calculations for dealing with above-ground tree biomass are described above. In decomposition class 2, the estimate of biomass should be limited to the main trunk (bole) of the tree, in which case the biomass is calculated converting volume to biomass using the appropriate dead wood density class. Volume is estimated as either the volume of a cone if the top diameter cannot be measured (and is assumed to be zero), or a cylinder if the top diameter can be measured directly or by using an instrument such as a relascope or laser inventory instrument. Height/length is determined as either the total height in case of a standing bole or the height at the base of the crown if the crown is persistent[9].

[9] It is conservative and, therefore, acceptable to take the normal species' wood densities in case dead wood

For decomposition class 2, the biomass of standing dead trees is estimated as:

$$B_{SDW,l,sp,i,t} = \frac{1}{3} \times \pi \times \left(\frac{BDia_{SDW,l,sp,i,t}}{200} \right)^2 \times H_{SDW,l,sp,i,t} \times D_{DW,dc} \qquad (10)$$

Where:

Parameter	Description	Unit
$B_{SDW,l,sp,i,t}$	Biomass of standing dead tree *l* from sample plot *sp* in stratum *i* at year *t*;	t d.m.
$BDia_{SDW,l,sp,i,t}$	Basal diameter of standing dead tree *l* from sample plot *sp* in stratum *i* at year *t*;	cm
$H_{SDW,l,sp,i,t}$	Height of standing dead tree *l* from sample plot *sp* in stratum *i* at year *t*	m
$D_{DW,dc}$	Mean wood density of dead wood in the density class (dc) – sound (1), intermediate (2), and rotten (3);	t d.m. m^{-3}
sp	1, 2, 3 … P_i sample plots in stratum *i*	
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
t	1, 2, 3 … years elapsed since the start of the project activity	
l	1, 2, 3 … $N_{i,sp,t}$ standing dead trees in sample plot *sp* of stratum *i* at year *t*	

or (where top diameter is measured):

$$B_{SDW,l,sp,i,t} = \frac{BDia_{SDW,l,sp,i,t} + TD_{SDW,l,sp,i,t}}{200} \times H_{SDW,l,sp,i,t} \times D_{DW,dc} \qquad (11)$$

Where:

Parameter	Description	Unit
$B_{SDW,l,sp,i,t}$	Biomass of standing dead tree *l* from sample plot *sp* in stratum	t d.m.

density classes are not known.

	i at year *t*;	
$BDia_{SDW,l,sp,i,t}$	Basal diameter of standing dead tree *l* from sample plot *sp* in stratum *i* at year *t*;	cm
$TD_{SDW,l,sp,i,t}$	Top diameter of standing dead tree *l* from sample plot *sp* in stratum *i* at year *t*	cm
$H_{SDW,l,sp,i,t}$	Height of standing dead tree *l* from sample plot *sp* in stratum *i* at year *t*	m
$D_{DW,dc}$	Mean wood density of dead wood in the density class (dc) – sound (1), intermediate (2), and rotten (3);	t d.m. m^{-3}
sp	1, 2, 3 … P_i sample plots in stratum *i*	
I	1, 2, 3 … M_{BSL} strata in the baseline scenario	
T	1, 2, 3 … years elapsed since the start of the project activity	
I	1, 2, 3 … $N_{i,sp,t}$ standing dead trees in sample plot *sp* of stratum *i* at year *t*	

In selecting one of the 2 approaches provided above, project proponents must ensure that in the baseline scenario conservative estimates for dead wood are obtained.

Step 4: Estimate total carbon stock in standing dead trees present in the sample plot *sp* in stratum *i* at year *t*.

$$B_{SDW,sp,i,t} = \sum_{l=1}^{N_{sp,i,t}} B_{SDW,l,sp,i,t} \tag{12}$$

Where:

Parameter	Description	Unit
$B_{SDW,sp,i,t}$	Biomass of standing dead wood in sample plot *sp* in stratum *i* at year *t*;	t d.m
$B_{SDW,l,sp,i,t}$	Biomass of standing dead tree *l* in sample plot *sp* in stratum *i* at year *t*;	t d.m
sp	1, 2, 3 … P_i sample plots in stratum *i*	
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	

t	1, 2, 3 … *t** years elapsed since the start of the project activity	
$N_{sp,i,t}$	Number of standing dead trees in sample plot *sp* of stratum *i* at year *t*	
l	1, 2, 3 … $N_{i,sp,t}$ standing dead trees in sample plot *sp* of stratum *i* at year *t*	

Step 5: Estimate the mean biomass stock per unit area in standing dead wood for each stratum at year *t*:

$$B_{SDW,i,t} = \frac{1}{A_{sp,i,t}} \times \sum_{sp=1}^{P_i} B_{SDW,sp,i,t} \qquad (13)$$

Where:

Parameter	Description	Unit
$B_{SDW,i,t}$	Biomass of standing dead wood in stratum *i* at year *t*	t d.m. ha^{-1}
$B_{SDW,sp,i,t}$	Biomass of standing dead wood in sample plot *sp* in stratum *i* at year *t*	t d.m
$A_{sp,I,t}$	Total area of all sample plots in stratum *i* in year *t*	ha
sp	1, 2, 3 … P_i sample plots in stratum *i*	
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	

Lying Dead Wood

Step 1: Lying dead wood can be sampled using the line intersect method of Harmon and Sexton (1996)[10] or other peer reviewed and published methods. Harmon and Sexton prescribe two 50-meter lines to be established bisecting each sample plot and the diameters of the lying dead wood (≥ 10 cm diameter) intersecting the lines are measured.

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10 Harmon, M.E. and J. Sexton. (1996) Guidelines for measurements of wood detritus in forest ecosystems. US LTER Publication No. 20. US LTER Network Office, University of Washington, Seattle, WA, USA.

Step 2: The dead wood is assigned to one of the three density states (sound, intermediate and rotten) using the ‘machete test’, as recommended by *IPCC Good Practice Guidance for LULUCF* (2003), Section 4.3.3.5.3.

Step 3: The volume of lying dead wood per unit area is estimated using the equation (Warren and Olsen 1964)[11] as modified by Van Wagner (1968)[12] separately for each density state:

$$V_{LDW,i,t} = \frac{\pi^2 \times \left(\sum_{n=1}^{N} Dia_{n,i,t}{}^2 \right)}{8 \times L} \qquad (14)$$

Where:

Parameter	Description	Unit
$V_{LDW,i,t}$	Volume of lying dead wood per unit area in stratum *i* at year *t*	$m^3\ ha^{-1}$
$Dia_{n,i,t}$	Diameter of piece *n* of dead wood along the transect in stratum *i* at year *t*	cm
n	1, 2, 3 … *N* wood pieces intersecting the transect	
L	Length of the transect	m
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	

To convert this to a mass per unit area multiply the volumes of each density state by their respective wood densities as outlined below:

Step 4: Volume of lying dead wood must be converted into biomass using the following relationship:

$$B_{LDW,i,t} = \sum_{dc=1}^{3} V_{LDW,i,t} \times D_{DW,dc} \qquad (15)$$

[11] Warren, W.G. and Olsen, P.F. (1964) A line intersect technique for assessing logging waste. *Forest Science* 10: 267-276.

[12] Van Wagner, C.E. (1968). The line intersect method in forest fuel sampling. *Forest Science* 14: 20-26.

Where:

Parameter	Description	Unit
$B_{LDW,i,t}$	Biomass of lying dead wood per unit area in stratum *i* at year *t*	t d.m. ha^{-1}
$V_{LDW,i,t,}$	Volume of lying dead wood per unit area in stratum *i* at year *t*	m^3 ha^{-1}
$D_{DW,dc}$	Mean wood density of dead wood in the density class (dc) – sound (1), intermediate (2), and rotten (3)	t d.m. m^{-3}
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	

Total carbon stock in dead wood for each stratum is then calculated as the sum of standing and lying dead wood components.

$$C_{DW,i,t} = \left(\left(B_{SDW,i,t} + B_{LDW,i,t}\right) \times CF_{DW}\right) \quad (16)$$

Where:

Parameter	Description	Unit
$C_{DW,i,t}$	Carbon stock of dead wood in stratum *i* at year *t*	t C ha^{-1}
$B_{SDW,i,t}$	Biomass of standing dead wood in stratum *i* at year *t*	t d.m. ha^{-1}
$B_{LDW,i,t}$	Biomass of lying dead wood in stratum *i* at year *t*	t d.m. ha^{-1}
CF_{DW}	0.5 Default carbon fraction of dry matter in dead wood	t C t d.m.$^{-1}$
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	

Carbon stocks in Wood Products

The procedure to determine the carbon stocks stored in wood products in the baseline scenario is provided in the previous section.

9.1.4 Logging rate

To estimate the baseline net carbon loss for the entire project area, the total net loss of carbon in the baseline scenario for relogged strata as estimated using one of the above methods, must be multiplied with the rate at which logging would have occurred across the project area. Where a management plan exists outlining the phasing of logging activities for either the project area, or the reference area, that management plan may be used.

$$A_{i,t} = D\%_{i,t} \times A_{TOT,i} \tag{17}$$

Where:

Parameter	Description	Unit
$A_{i,t}$	Area logged in stratum *i* at year *t*	ha
$D\%_{i,t}$	Projected annual proportion of land that will be logged in stratum *i* at year *t*. If actual annual proportion is known and documented (eg, 25% per year for 4 years), set to proportion	% yr^{-1}
$A_{TOT,i}$	Total area logged in stratum *i*	ha
i	1, 2, 3 …M_{BSL} strata in the baseline scenario	
t	1, 2, 3, … t^* years elapsed since the project start	

Where no rate is available, it can be established through an examination of a reference area. This is done using the below equation:

$$D\%_{planned,i,t} = \sum_{pn=1}^{pn^*} \left(\left(D\%_{pn,i} / Yrs_{pn} \right) / n \right) \tag{18}$$

Where:

Parameter	Description	Unit
$D\%_{planned,i,t}$	Projected annual proportion of land that will be logged in stratum *i* at year *t*. If the actual annual proportion is known and documented (eg, 25% per year for 4 years), set to proportion	% yr^{-1}
$D\%_{pn,i}$	Percent of logged area in land parcel *pn* in stratum *i* of the	%

	reference area	
Yrs_{pn}	Number of years over which relogging occurred in land parcel *pn* in the reference area	yr
pn	1, 2, 3 … pn^* land parcels in the reference area	
n	Total number of land parcels examined	
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	

9.1.5 Forest Regrowth

If no or insignificant regrowth occurs following first and subsequent logging, eg, due to the complete colonization by climbers and vines, this must be demonstrated by sampling above-ground carbon stocks in woody biomass in a time series of logging coupes (eg, in tranversal studies). The length of the time series must not be shorter than 75% of the length of the project crediting period.

When accounting for regrowth*, ex-ante* estimates of tree biomass regrowth in the baseline can be based on peer-reviewed literature providing values for regrowth from comparable residual forest types in comparable areas.

If regrowth occurs in the baseline scenario this is assumed to be small compared to regrowth in the with-project scenario. Furthermore, regrowth in the relogged residual stand is assumed to be smaller than regrowth in the pre-relogged residual stand. Therefore, as a conservative approach, the regrowth in the baseline case is estimated as the regrowth of the pre-relogged residual forest applied to the entire area of the stratum, despite any relogging in that stratum.

Estimates of changes in carbon stocks due to regrowth of tree biomass in the baseline, can be obtained from a (part of a) reference area that has not been relogged, or from parts of the project area that have not been treated with silvicultural techniques, as follows:

$$\Delta C_{tree-exist,i,t} = A_{i,t} \times \sum_{j=1}^{S} \Delta C_{tree-exist,j,i,t} \qquad (19)$$

Where:

Parameter	Description	Unit
$\Delta C_{tree-exist,i,t}$	Change in carbon stock in existing tree vegetation[13] in the	$t\ CO_2\text{-e}\ yr^{-1}$

[13] With *DBH* ≥ 5 cm.

	baseline in stratum *i* at year *t*	
$A_{i,t}$	Area of baseline stratum *i* at year *t*	ha
$\Delta C_{tree\text{-}exist,j,i,t}$	Change in carbon stock in existing tree vegetation in the baseline in species *j* in stratum *i* at year *t*	t CO_2-e ha^{-1} yr^{-1}
j	1, 2, 3 … *S* tree species	
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
t	1, 2, 3, … t^* years elapsed since the project start	

$\Delta C_{tree\text{-}exist,j,i,t}$ is estimated as follows:

$$\Delta C_{tree-exist,j,i,t} = \Delta C_{tree-exist-AB,j,i,t} + \Delta C_{tree-exist-BB,j,i,t} \tag{20}$$

Where:

Parameter	Description	Unit
$\Delta C_{tree\text{-}exist,j,i,t}$	Change in carbon stock in existing tree vegetation in the baseline in species *j* in stratum *i* at year *t*	t CO_2-e ha^{-1} yr^{-1}
$\Delta C_{tree\text{-}exist\text{-}AB,j,i,t}$	Change in above-ground carbon stock in trees in the baseline in species *j* in stratum *i* at year *t*	t CO_2-e ha^{-1} yr^{-1}
$\Delta C_{tree\text{-}exist\text{-}BB,j,i,t}$	Change in below-ground carbon stock in trees in the baseline in species *j* in stratum *i* at year *t*	t CO_2-e ha^{-1} yr^{-1}
j	1, 2, 3 … *S* tree species	
i	1, 2, 3 … M_{BSL} strata in the baseline scenario	
t	1, 2, 3, … t^* years elapsed since the project start	

To estimate $\Delta C_{tree\text{-}exist\text{-}AB,j,i,t}$ see subsection: “Changes in C Stock in Above-ground Tree Biomass”. The inclusion of below-ground biomass is optional. If below-ground biomass is included, $\Delta C_{tree\text{-}exist\text{-}BB,j,i,t}$ can be estimated as in subsection: “Changes in C Stock in Below-ground Tree Biomass”.

9.1.6 Estimation of the Carbon Stock in Trees at t0

The carbon stock in tree biomass at t0 is defined as $C_{AGB,i,t}$ (plus optionally below-ground biomass by using a root:shoot ratio as defined above) at t0 and can be estimated as follows.

1. As $C_{BSL,pre,i}$
2. Based on an inventory of above-ground tree carbon stocks from Parts of the project area that have not been treated with silvicultural techniques.

9.1.7 Baseline Activity Emissions

A number of emission sources can arise from the implementation of baseline activities. Project proponents may choose to omit accounting for those sources as that leads to conservative estimates of the overall carbon benefits of the project.

Possible emission sources include, but may not be limited to: timber harvesting/logging operations, emissions due to infrastructure establishment, log extraction and transport of logs to the wharf for export or to the local sawmill or to the local depot for onwards sale.

This methodology does not foresee in the quantification of emissions due to timber procession, whether it is grid or generator powered.

Therefore, the emissions associated with activities in the baseline are estimated as:

$$GHG_{BSL\text{-}E,t} = E_{clearing,t} + E_{harvesting,t} + E_{extraction,t} + E_{transport,t} \quad (21)$$

Where:

Parameter	Description	Unit
$GHG_{BSL\text{-}E,t}$	Baseline emissions from sources in the baseline scenario at year *t*	t CO_2-e yr^{-1}
$E_{clearing,t}$	Emissions due to the new establishment of infrastructure such as the construction of roads or log landings for baseline logging at year *t*	t CO_2-e yr^{-1}
$E_{harvesting,t}$	Emissions due to the harvesting operations such as felling and debranching, etc. at year *t*	t CO_2-e yr^{-1}
$E_{extraction,t}$	Extraction of logs from the tree stump to the log landing at year *t*	t CO_2-e yr^{-1}
$E_{transport,t}$	Emissions due to transport of the logs from the log landing to the wharf for export, the sawmill, or to the depot for onward sale at year *t*	t CO_2-e yr^{-1}
t	1, 2, 3, … t^* years elapsed since the project start	

$E_{clearing,t}$: Emissions due to clearing of the area for infrastructure establishment

Emissions due to the establishment of infrastructure such as the construction of roads and log landings is estimated by considering the emissions due to the removal of biomass, the emissions from the equipment used to remove the biomass and the emissions from the equipment used to grade the roads (fuel emissions).

$$E_{clearing,t} = E_{biomass,t} + E_{felling,t} + E_{grading,t} \quad (22)$$

Where:

Parameter	Description	Unit
$E_{clearing,t}$	Emissions due to the establishment of infrastructure at year *t*	t CO_2-e yr^{-1}
$E_{biomass,t}$	Emissions due to the removal of the biomass itself at year *t*	t CO_2-e yr^{-1}
$E_{felling,t}$	Emissions due to the equipment use for felling the biomass (fuel emissions) at year *t*	t CO_2-e yr^{-1}
$E_{grading,t}$	Emissions due to the equipment used for the grading of the roads (fuel emissions) at year *t*	t CO_2-e yr^{-1}

To determine the emissions due to the removal of the biomass present at locations where infrastructure is being established, the area used for such purposes needs to be determined. This can be done on the basis of remote imagery (photographs or satellite) or by using a reported percentage that is typical for the area. Such a percentage has to be derived from peer-reviewed literature applicable to the area, or from Pulkki (1997) who reported for conventional logging in Evergreen Tropical Rainforests, a conservative percent of area cleared for infrastructure of 12%.[14]

To estimate the emissions from the removal of the biomass the area can be multiplied by an average carbon stock value per hectare that is representative of the project area.

Emissions due to the loss of biomass from felling is quantified as follows:

$$E_{biomass,t} = C_{biomass} \times A_{infrastructure,t} \times (44/12) \quad (23)$$

[14] Pulkki, R.E. (1997). Literature synthesis on logging impacts in moist tropical forests. FAO Working Paper GFSS/WP/06. Here a range of 12-17% is reported and hence for the baseline scenario a value of 12% is considered conservative.

Where:

Parameter	Description	Unit
$E_{biomass,t}$	Emissions due to the removal of the biomass on the area dedicated to infrastructure at year *t*	t CO_2-e yr^{-1}
$C_{biomass}$	Carbon in biomass lost due to the clearing for infrastructure	t C ha^{-1}
$A_{infrastructure,t}$	Area designated for infrastructure at year *t*	ha yr^{-1}
44/12	The ratio of molecular weight of carbon dioxide to carbon	t CO_2-e t C^{-1}

$C_{biomass}$ equals the area-weighed C_{BSLpre}, see Equation 45.

$E_{felling,t}$: emissions due to the use of equipment for the removal of the biomass

Emissions due to the use of equipment for the removal of biomass are quantified as follows:

$$E_{felling,t} = FC_{equip} \times EF_{fuel} \times V_{infrastructure,t} \qquad (24)$$

Where:

Parameter	Description	Unit
$E_{felling,t}$	Emissions due to the use of equipment for removal of the biomass on the area dedicated to infrastructure at year *t*	t CO_2-e yr^{-1}
FC_{equip}	Fuel consumption of equipment employed for felling	kL m^{-3}
EF_{fuel}	Fuel emission factor	t CO_2-e kL^{-1}
$V_{infrastructure,t}$	Volume of trees felled to clear the area designated for infrastructure at year *t*	m^3 yr^{-1}

$E_{grading,t}$: emissions due to the use of equipment for the grading of the roads

Emissions due to the use of equipment for grading roads are quantified as follows:

$$E_{grading,t} = FC_{grader} \times EF_{fuel} \times A_{infrastructure,t} \qquad (25)$$

Where:

Parameter	Description	Unit
$E_{grading,t}$	Emissions due to road grading at year *t*	t CO_2-e yr^{-1}
FC_{grader}	Fuel consumption of equipment employed for road grading	kL ha^{-1}
EF_{fuel}	Fuel emission factor	t CO_2-e kL^{-1}
$A_{infrastructure,t}$	Area designated for infrastructure at year *t*	ha yr^{-1}

$E_{harvesting,t}$: emissions due to the extraction of logs from the forest

Emissions are estimated as:

$$E_{harvesting,t} = FC_{equip} \times EF_{fuel} \times V_{harvested,t} \quad (26)$$

Where:

Parameter	Description	Unit
$E_{harvesting,t}$	Emissions due to harvesting at year *t*	t CO_2-e yr^{-1}
FC_{equip}	Fuel consumption of the equipment employed for harvesting	kL m^{-3}
EF_{fuel}	Fuel emission factor	t CO_2-e kL^{-1}
$V_{harvested,t}$	Volume harvested at year *t*	m^{-3} yr^{-1}

Volume harvested in the baseline is determined through Section 9.1.

This methodology in Section 9.1 facilitates the quantification of the volume harvested in two ways:

- On the basis of a-spatial data in a pre-relogging situation in the project area (for instance on the basis of information in a management plan); or,
- By the determination of the four components after relogging has occurred in a reference area for which similarity to the project area is demonstrated.

This quantification exercise determines amongst other the relationship between cubic meters of timber removed/harvested in the baseline. The correlation between the two baseline options and the project area is established by analyzing the logging rates in the various strata in the baseline, determination of the same strata in the project area, and the application of the stratum specific logging rates to the strata in the project area. This is a valid approach because the reference area is subjected to strict selection criteria that ascertain similarity to the project area. That parameter value determined by this approach is also used in this section as the harvested volume.

Alternatively, $E_{harvesting,t}$ can be determined on the basis of fuel consumed by the company for the purpose of its felling and debranching activities.

As default fuel consumption (FC) 1.28 – 1.73 liter per m^3 can be used. For new and efficient machinery the parameter value of 1.28 can be applied. For old and inefficient machinery 1.73 must be used.

$E_{extraction,t}$: emissions due to the extraction of the timber

Timber extraction from the forest to the log landing can be conducted with various types of machines. This methodology provides a quantification approach for extraction with medium sized bulldozers for transport to road side and trucks or trailers for transport to the log landings.

Emissions from log extraction and transport to log landing are estimated as:

$$E_{extraction,t} = (D_{extr\_total} / Eff_{fuel}) \times EF_{fuel} \quad (27)$$

$$D_{extr\_total} = D_{aver\ extrac} \times N_{trucks} \times 2 \quad (28)$$

$$N_{trucks} = V_{extr} / Cap_{truck} \quad (29)$$

Where:

Parameter	Description	Unit
$E_{extraction,t}$	Emissions due to extraction of timber from the forest to the log landings at year *t*	t CO_2-e yr^{-1}
D_{extr_total}	Total timber extraction distance	km
Eff_{fuel}	Fuel efficiency for medium-sized bulldozers/trucks/trailers	km kL^{-1}
EF_{fuel}	Fuel emission factor	t CO_2-e kL^{-1}
$D_{aver\ extrac}$	Average extraction distance of logs from stump to log landing	km
N_{trucks}	Number of trucks	
V_{extr}	Volume of timber extracted from the forest	m^{-3}
Cap_{truck}	Capacity of the truck	m^3 $truck^{-1}$

Default parameter values for medium sized bulldozers are estimated to be similar to those of truck and trailers. The defaults, including those for associated emission factors and fuel efficiency are derived from Kinjo et al. (2005) as cited in Carbon Planet (2009) and are: truck / trailer load capacity (10 m^3 $truck^{-1}$); EF_{fuel} (2.9 t CO_2-e kL^{-1}); and, Eff_{fuel} (3000 km kL^{-1}).

$E_{transport,t}$: emissions due to the transport of the logs from the log landing to the point of onward transport (eg, to a wharf in case of export) or point of (local) sale

Emissions from log extraction and transport to log landing are estimated as:

$$E_{transport,t} = (D_{trans\_total} / Eff_{fuel}) \times EF_{fuel} \quad (30)$$

$$D_{trans\_total} = D_{aver\ trans} \times N_{trucks} \times 2 \quad (31)$$

$$N_{trucks} = V_{trans} / Cap_{truck} \quad (32)$$

Where:

Parameter	Description	Unit
$E_{transport,t}$	Emissions due to the transport of the timber from the log landings to point of onward sale/transport at year *t*	t CO_2-e yr^{-1}
D_{trans_total}	Total timber transport distance	km
Eff_{fuel}	Fuel efficiency for medium-sized bulldozers/trucks/trailer	km kL^{-1}
EF_{fuel}	Fuel emission factor	t CO_2-e kL^{-1}
$D_{aver\ trans}$	Average transport distance of logs log landing to point of onward sale/transport	km
N_{trucks}	Number of trucks	
V_{trans}	Volume of timber transported	m^{-3}
Cap_{truck}	Capacity of the truck	m^3 $truck^{-1}$

9.2 Project Emissions

The net greenhouse gas emission reduction and removals in the with-project scenario must be estimated using the equations in this section. When applying these equations for the *ex-ante* estimation of total net GHG emission reduction by the IFM project activity, project proponents must provide estimates of the values of those parameters that are not available before the start of the project crediting period and commencement of monitoring activities. Project proponents must retain a conservative approach in making these estimates.

GHG emissions and removals in the with-project scenario are related to regrowth of the residual forest, silvicultural interventions such as climber cutting, liberation thinning, enrichment planting and/or harvesting, or a combination of these activities, and project implementation activities, such as the ones listed in Section 9.1.7.

Net CO_2 equivalent emissions in the with-project scenario (WPS) are estimated as:

$$\Delta C_{WPS} = \sum_{t=1}^{t*} \sum_{i=1}^{M_{WPS}} \Delta C_{P,i,t} + GHG_{WPS-E,t} \quad (33)$$

Where:

Parameter	Description	Unit
ΔC_{WPS}	Net CO_2 equivalent emissions in the with-project scenario up to year *t**	t CO_2-e yr^{-1}
$\Delta C_{P,i,t}$	Net carbon stock change due to forest regrowth and silvicultural interventions in the with-project scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}
$GHG_{WPS-E,t}$	Greenhouse gas emissions related to project implementation at year *t*	t CO_2-e yr^{-1}

9.2.1 Net carbon stock changes due to forest regrowth and silvicultural interventions

Estimation of $\Delta C_{P,i,t}$

Net carbon stock changes due to forest regrowth and silvicultural interventions in the with-project scenario are estimated as follows:

$$\Delta C_{P,i,t} = \Delta C_{AGB,i,t} + \Delta C_{BGB,i,t} + \Delta C_{DW,i,t} + \Delta C_{WP,i,t} - E_{biomassloss,i,t} \quad (34)$$

Where:

Parameter	Description	Unit
$\Delta C_{P,i,t}$	Net carbon stock change due to forest regrowth and silvicultural interventions in the with-project scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}
$\Delta C_{AGB,i,t}$	Net carbon stock change in above-ground tree biomass[15] in the with-project scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}

[15] With *DBH* ≥ 5 cm.

$\Delta C_{BGB,i,t}$	Net carbon stock change in below-ground tree biomass in the with-project scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}
$\Delta C_{DW,i,t}$	Net carbon stock change in dead wood in the with-project scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}
$\Delta C_{WP,i,t}$	Net carbon stock change in wood products in the with-project scenario in stratum *i* at year *t*	t CO_2-e yr^{-1}
$E_{biomassloss,i,t}$	Emissions due to site preparation for project activities in stratum *i* at year *t*	t CO_2-e yr^{-1}
t	1, 2, 3 … *t** years elapsed since the start of the project activity	
i	1, 2, 3 … M_{WPS} strata in the with-project scenario	

Accounting for dead wood in the with-project scenario as zero is conservative. Accounting for wood products in the with-project scenario as zero is conservative.

Estimation of $\Delta C_{AGB,i,t}$

The changes in the carbon stock in above-ground tree biomass within the project boundary are estimated using the following approach:

$$\Delta C_{AGB,i,t} = A_{i,t} \times (C_{AGB,i,t} - C_{AGB,i,t-T}) \times 44/12 / T \qquad (35)$$

Where:

Parameter	Description	Unit
$\Delta C_{AGB,i,t}$	Net carbon stock change in above-ground tree biomass in stratum *i* at year *t*	t CO_2-e
$C_{AGB,i,t}$	Carbon stock in above-ground tree biomass in stratum *i* at year *t*	t C ha^{-1}
t	1, 2, 3 … ***t**** years elapsed since the start of the project activity	
i	1, 2, 3 … M_{WPS} strata in the with-project scenario	
44/12	Ratio of molecular weights of CO_2 and carbon	t CO_2-e t C^{-1}

$A_{i,t}$	Area of stratum *i* at year *t*	ha
T	Number of years between monitoring times t_m *and* t_{m-1}	

Changes in C Stock in Above-ground Tree Biomass[16]

The mean carbon stock in above-ground tree biomass per unit area is estimated for each stratum on the basis of field measurements in permanent sample plots. Two methods are available: the Biomass Expansion Factors (*BEF*) method and the Allometric Equations method.

<u>BEF method</u>

Step 1: Determine on the basis of available data, eg, volume tables (*ex ante*) and measurements (*ex post*) the diameter at breast height (*DBH,* at typically 1.3 m above-ground level), and also preferably height (*H*), of all the trees above some minimum *DBH* in the permanent sample plots. The exact tree dimensions to be measured will be specified by the information obtained in Step 2.

Step 2: Estimate the stem volume of trees based on available equations or yield tables (if locally derived equations or yield tables are not available use relevant regional, national or default data as appropriate).

It is possible to combine Steps 1 and 2 if volume tables allow for deriving average volume of trees, or field instruments (eg, a relascope) that measure the volume of each tree directly are applied.

Step 3: Choose *BEF*

Step 4: Convert the stem volume of trees into carbon stock in above-ground tree biomass via basic wood density, the *BEF* and the carbon fraction:

$$C_{AGB,l,j,i,sp,t} = V_{l,j,i,sp,t} \times D_j \times BEF_j \times CF_j \quad (36)$$

[16] This section, with the Biomass Expansion Factors (*BEF*) method and the Allometric Equations method, including a number of additional steps to expand AGB to include below-ground biomass, etc., are part of several CDM EB approved methodologies, including for instance AR-ACM0002.

Where:

Parameter	Description	Unit
$C_{AGB,l,j,i,sp,t}$	Carbon stock in above-ground biomass of tree *l* of species *j* in plot *sp* in stratum *i* at year *t*	$t\ C\ tree^{-1}$
$V_{l,j,sp,t}$	Stem volume of tree *l* of species *j* in plot *sp* in stratum *i* at year *t*	$m^3\ tree^{-1}$
D_j	Basic wood density of species *j*	$t\ d.m.\ m^{-3}$
BEF_j	Biomass expansion factor for conversion of stem biomass to above-ground tree biomass for species *j*	
CF_j	Carbon fraction[17] of biomass for tree species *j*	$t\ C\ t\ d.m.^{-1}$
l	1, 2, 3 … $N_{j,i,sp,t}$ individual trees of species *j* in sample plot *sp* in stratum *i* at year *t*	
i	1, 2, 3 … M_{WPS} strata in the with-project scenario	
j	1, 2, 3 … S_{WPS} tree species in the with-project scenario	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	

Step 5: Calculate carbon stock in above-ground biomass of all trees present in plot *sp* in stratum *i* at time *t* (ie, summation over all trees *l* by species *j* followed by summation over all species *j* present in plot *sp*).

$$C_{AGB,i,sp,t} = \sum_{j=1}^{S_{WPS}} \sum_{l=1}^{N_{j,i,sp,t}} C_{AGB,l,j,i,sp,t} \qquad (37)$$

[17] IPCC default = 0.5

Where:

Parameter	Description	Unit
$C_{AGB,i,sp,t}$	Carbon stock in above-ground biomass of trees on plot *sp* of stratum *i* at time *t*	t C
$C_{AGB,l,j,i,sp,t}$	Carbon stock in above-ground biomass of tree *l* of species *j* in plot *sp* in stratum *i* at time *t*	t C tree^{-1}
l	1, 2, 3 … $N_{j,i,sp,t}$ individual trees of species *j* in sample plot *sp* in stratum *i* at year *t*	
i	1, 2, 3 … M_{WPS} strata in the with-project scenario	
j	1, 2, 3 … S_{WPS} tree species in the with-project scenario	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	

Step 6: Estimate the mean carbon stock in above-ground tree biomass for each stratum:

$$C_{AGB,i,t} = \frac{1}{A_{sp_i}} \sum_{sp=1}^{P_i} C_{AGB,i,sp,t} \tag{38}$$

Where:

Parameter	Description	Unit
$C_{AGB,i,t}$	Above-ground carbon stock in trees in stratum *i* at year *t*	t C ha^{-1}
$C_{AGB,i,sp,t}$	Above-ground carbon stock in trees on plot *sp* of stratum *i* at year *t*	t C
$A_{sp,i}$	Total area in all sample plots in stratum *i*	ha
sp	1, 2, 3 … *Pi* sample plots in stratum *i* in the with-project scenario	
i	1, 2, 3 … M_{WPS} strata in the project scenario	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	

Allometric Equations Method

Step 1: Proceed as in Step 1 of the *BEF* Method. The exact tree dimensions to be measured will be specified by the equation selected in Step 2.

Step 2: Select or develop an appropriate allometric equation (if possible species-specific, or if not, from a similar species).

If default allometric equations are available for conditions that are similar to the project (same vegetation genus; same climate zone; similar forest type), then the equation may be used and considered conservative. Otherwise, it is necessary either to use conservatively assessed values, or to verify the applicability of the equation if mean predicted values are to be used.

When allometric equations developed from a biome-wide database, such as those in Annex 4A.2, Tables 4.A.1and 4.A.2 of GPG LULUCF, or updated in IPCC 2006 Guidelines for AFOLU, are used, allometric equations can be verified by:

- Selecting at least 5 trees covering the range of *DBH* existing in the project area, and felling and weighing the above-ground tree biomass to determine the total (wet) weight of the stem and branch components;

- Determining the total dry weight of each tree from the wet weights and the averaged ratios of wet and dry weights of the stem and branch components.

If the biomass of the harvested trees is within about ±10% of the mean values predicted by the selected default allometric equation, and is not biased—or if biased is wrong on the conservative side (ie, use of the equation results in an under- rather than over-estimate of project net anthropogenic removals by sinks)—then mean values from the default equation may be used. (IPCC Good Practice Guidance for LULUCF, 2003, Section 4.3.3.5.1, under direct approach Step 3).

When allometric equations are used that are not developed from a biome-wide database as mentioned above, a one-sided t-test (with alpha = 0.05) should be applied to determine whether the biomass predicted by the allometric equation does not exceed the biomass from the harvested trees. To obtain biomass from the harvested trees, the same procedure as described above should be used.

Step 3: Estimate carbon stock in above-ground biomass for each individual tree *l* of species *j* in the sample plot located in stratum *i* using the selected or developed allometric equation applied to the tree dimensions determined in Step 1, and sum the carbon stocks in the sample plot:

$$C_{AGB,j,i,sp,t} = \sum_{l=1}^{N_{j,sp}} f_j(X, Y, ...) \times CF_j \tag{39}$$

Where:

Parameter	Description	Unit
$C_{AGB,j,i,sp,t}$	Carbon stock in above-ground biomass of trees of species *j* on sample plot *sp* of stratum *i* at year *t*;	t C
CF_j	Carbon fraction of dry matter for species or type *j*	t C t^{-1} d.m.

$f_j(X, Y, …)$	Allometric equation for species *j* linking measured tree dimension variables (eg, diameter at breast height (*DBH*) and possibly height (*H*)) to above-ground biomass of living trees	t d.m. $tree^{-1}$
i	1, 2, 3 … M_P strata in the with-project scenario	
j	1, 2, 3 … S_{WPS} tree species in the with-project scenario	
l	1, 2, 3 … $N_{j,i,sp,t}$ individual trees of species *j* in sample plot *sp* in stratum *i* at year *t*	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	

Step 4: Estimate the mean carbon stock in above-ground tree biomass for each stratum, as per the *BEF* method.

Estimation of $\Delta C_{BGB,i,t}$

The annual changes in below-ground tree biomass are estimated for each stratum on the basis of above-ground tree biomass. By using a root:shoot ratio, below-ground biomass is calculated from above-ground biomass, following Equation (40) below. Calculation of the parameter $\Delta C_{AGB,i,t}$ is described in "Estimation of $\Delta C_{AGB,i,t}$".

$$\Delta C_{BGB,i,t} = \Delta C_{AGB,i,t} \times R_j \quad (40)$$

Where:

Parameter	Description	Unit
$\Delta C_{BGB,i,t}$	Net carbon stock change in below-ground tree biomass in the with-project scenario in stratum *i* at year *t*	t CO_2 yr^{-1}
$\Delta C_{AGB,i,t}$	Net carbon stock change in above-ground tree biomass in the with-project scenario in stratum *i* at year *t*	t CO_2 yr^{-1}
R_j	Root:shoot ratio for tree species *j*	t root d.m. t^{-1} shoot d.m.
t	1, 2, 3 … ***t**** years elapsed since the start of the project activity	

i	1, 2, 3 … M_{WPS} strata in the with-project scenario	

9.2.2 Changes in carbon stocks in dead wood

Carbon stock changes in the project are monitored using the stock change method:

$$\Delta C_{DW,i,t} = (C_{DW,i,t} - C_{DW,i,t-T}) / T \quad (41)$$

Where:

Parameter	Description	Unit
$\Delta C_{DW,i,t}$	Annual net carbon stock change in dead wood for stratum *i*, at year *t*;	t CO_2-e ha^{-1} yr^{-1}
$C_{DW,i,t}$	Carbon stock in dead wood for stratum *i,* at year *t*;	t CO_2-e ha^{-1}
i	1, 2, 3 … M_P strata in the with-project scenario	
t	1, 2, 3 … *t** years elapsed since the start of the project activity	
T	Number of years between monitoring times t_m and t_{m-1}	

9.2.3 Changes in carbon stocks in wood products

Carbon stock changes in the project are monitored using the stock change method:

$$\Delta C_{WP,i,t} = (C_{WP,i,t} - C_{WP,i,t-T}) / T \quad (42)$$

Where:

Parameter	Description	Unit
$\Delta C_{WP,i,t}$	Annual net carbon stock change in wood products for stratum *i* at year *t*;	t CO_2-e ha^{-1} yr^{-1}
$C_{WP,i,t}$	Carbon stock in wood products for stratum *i* at year *t*;	t CO_2-e ha^{-1}
i	1, 2, 3 … M_P strata in the with-project scenario	

t	1, 2, 3 … t^* years elapsed since the start of the project activity	
T	Number of years between monitoring times t_m and t_{m-1}	

9.2.4 Emissions due to site preparation for project activities

If any site preparation occurs for liberation thinning and enrichment planting, then $E_{biomassloss}$ must be estimated when significant, using the most recent version of the CDM approved methodological tool "Estimation of emissions from clearing, burning and decay of existing vegetation due to implementation of an A/R CDM project activity"[18].

If however, the emissions due to changes in carbon stock in tree vegetation due to site preparation are insignificant they may be ignored. The removal of herbaceous vegetation (including climbers and vines) is deemed an insignificant emissions source and therefore is not accounted for in the with-project scenario.

9.2.5 GHG emissions as a result of the implementation of the project activity

There are various sources of emissions resulting from the general project implementation. These can include, but may not be limited to:

- Emissions due to administration, data-processing, and/or operating field station(s): grid or generator powered electricity;
- Emissions due to travel of project staff (ground transport, flights, etc.);
- Emissions due to travel and transport of external visitors (eg, auditing companies, consultants, etc.)

This will require information on kL fuel combusted, energy consumption or efficiency rates, km travelled, emission factors for various types of fuels, emissions associated with electricity generation, etc.

Approaches for estimating GHG_{WPS-E} are similar to those for GHG_{BSL-E}.

9.3 Leakage

9.3.1 Identification of sources of leakage

Leakage is defined as any increase in greenhouse gas emissions that occurs outside a project's boundary (but within the same country), that is measurable and attributable to the project activity. Its

18 Available at: <http://cdm.unfccc.int/>

effects on all carbon pools must be assessed and significant effects taken into account when estimating net emission reductions.

The applicability conditions determine that: “biomass burning, fuel gathering, removal of litter, or removal of dead wood do not occur in the baseline scenario and in the with-project scenario within the project boundary”. Therefore, this methodology only provides for the determination of leakage due to market effects.

$$\Delta C_{LK} = \Delta C_{LK\text{-}ME} \quad (43)$$

9.3.2 Quantification of leakage due to market effects

Option 1: This methodology applies to project activities, which reduce harvest levels in comparison with the baseline and possible reference areas. Therefore, the following leakage credit adjustment can be applied.

Project Action	Leakage Risk	Leakage credit adjustment (discount)
Substantially reduce harvest levels permanently (eg, RIL activity that reduces timber harvest by 25% or more across the project area; or, a forest protection/no logging project)	Moderate to High Depends on where timber harvest is likely to be shifted	Depends on where timber harvest is likely to be shifted to: • Similar carbon dense forests within the country: 40% • Less carbon dense forests within the country: 20% • More carbon dense forests within country: 70% • Out of country: 0% (according to stated VCS and CDM policy of not accounting for international leakage)

$$\Delta C_{LK\text{-}ME} = LF_{ME} \times \Delta C_{REL} \quad (44)$$

Where:

Parameter	Description	Unit
$\Delta C_{LK\text{-}ME}$	Total GHG emissions due to market-effects leakage	t CO_2-e
LF_{ME}	Leakage factor for market-effects calculations	

ΔC_{REL}	Emissions from relogging displaced through implementation of the project activities across strata	t CO_2-e

LF_{ME}, the leakage factor, depends upon where in the country logging might be increased, as a result of a decrease in timber supply from the project area.

$LF_{ME} = 0$ if it can be demonstrated to the verifier that no market-effects leakage will occur within national boundaries, eg, if no new concessions are being assigned AND annual extracted volumes per hectare in existing concessions have not increased in comparison to previously documented and projected and authorised extraction levels within existing concessions in the host country.

$LF_{ME} = 0.4$ if $C_{BSLpre} = NCS$

(if $C_{BSLpre} \leq NCS \times 1.15$ and $\geq NCS \times 0.85$)

$LF_{ME} = 0.7$ if $C_{BSLpre} < NCS \times 0.85$

$LF_{ME} = 0.2$ if $C_{BSLpre} > NCS \times 1.15$

Where:

Parameter	Description	Unit
LF_{ME}	Leakage factor for market-effects calculations	
NCS	The mean national forest carbon stock	t C ha^{-1}
C_{BSLpre}	Pre-relogging mean carbon stock in above-ground tree biomass across strata in the baseline scenario	t C ha^{-1}

Estimating C_{BSLpre} involves area-weighting the stocks across the strata:

$$C_{BSLpre} = \frac{\sum_{i=1}^{M_{BSL}} \left(C_{BSLpre,i} \times A_{REL,i} \right)}{\sum_{i=1}^{M_{BSL}} A_{REL,i}} \quad (45)$$

Where:

Parameter	Description	Unit
C_{BSLpre}	Mean carbon stock across strata in all pools selected in the	t C ha^{-1}

	baseline	
$C_{BSLpre,i}$	Carbon stock in all pools selected in the baseline in stratum *i*	t C ha^{-1}
$A_{REL,i}$	Area relogged in baseline stratum *i*	ha
I	1, 2, 3 …M_{BSL} strata in the baseline scenario	
M_{BSL}	The total number of strata in the baseline scenario	

ΔC_{REL} equals emissions from harvests displaced through implementation of the project activities as quantified in Sections 9.1.3 or 9.1.4, summed across strata.

Option 2: Instead of applying the default market leakage effect discount above, project proponents may opt to estimate the project's market leakage effect across the entire country and/or use analysis(es) from other similar projects to justify a different market leakage value.

9.4 Summary of GHG Emission Reduction and/or Removals

The total net GHG benefits from the IFM project activity (ΔC_{IFM}) are calculated as the result of the total carbon loss in the baseline scenario (ΔC_{BSL}) and the net removals through the enhancement of forest growth due to liberation thinning and enrichment planting (ΔC_{WPS}), minus any potential leakage (ΔC_{LK}) that might occur.

$$\Delta C_{IFM} = \Delta C_{BSL} - \Delta C_{WPS} - \Delta C_{LK} \quad (46)$$

Where:

Parameter	Description	Unit
ΔC_{IFM}	Total net GHG emission reductions from the IFM project activity up to year *t*	t CO_2-e
ΔC_{BSL}	Sum of the carbon stock changes and greenhouse gas emissions under the baseline scenario up to year *t*	t CO_2-e
ΔC_{WPS}	Sum of the carbon stock changes and greenhouse gas emissions under the with-project scenario up to year *t*	t CO_2-e
ΔC_{LK}	Sum of the carbon stock changes and greenhouse gas emissions due to leakage up to year *t*	t CO_2-e

ΔC_{IFM} must be corrected for uncertainty, as follows:

$$C_{IFM\_ERROR} = \sqrt{Uncertainty_{BSL}^{\ 2} + Uncertainty_{WPS}^{\ 2}} \tag{47}$$

Where:

Parameter	Description	Unit
C_{IFM_ERROR}	Total uncertainty for IFM project activity	%
$Uncertainty_{BSL}$	Total uncertainty in baseline scenario	%
$Uncertainty_{WPS}$	Sum of the carbon stock changes and greenhouse gas emissions under the with-project scenario up to year *t*	%

The procedure for estimating C_{IFM_ERROR} must be in accordance with the most recent version of the *Tool for Estimating Uncertainty in IFM Project Activities.*

If $C_{IFM\_ERROR} \leq 10\%$ of $\Delta C_{IFM,\,t}$ then no deduction must result for uncertainty.

If $C_{IFM\_ERROR} > 10\%$ of $\Delta C_{IFM,\,t}$ then the modified value for $\Delta C_{IFM,\,t}$ to account for uncertainty must be:

$$= \frac{100 - C_{IFM\_ERROR}}{100} \times C_{IFM,t} \tag{48}$$

Where:

Parameter	Description	Unit
$\Delta C_{IFM,\,t}$	Total net GHG emission reductions from the IFM project activity up to year *t*	$t\ CO_2$-e
C_{IFM_ERROR}	Total uncertainty for IFM project activity	%

Calculation of Verified Carbon Units

The number of Verified Carbon Units is calculated as follows:

$$VCU_{t2} = \left(\Delta C_{IFM,t2} - \Delta C_{IFM,t1}\right) \times \left(\frac{100 - C_{IFM\_ERROR}}{100}\right) - Bufferwithholding_{t2} \quad (49)$$

Where:

Parameter	Description	Unit
$VCU_{,t2}$	Number of Verified Carbon Units at year *t2*	
$\Delta C_{IFM,\ t1}$	Total net GHG emission reductions from the IFM project activity up to year *t1*	t CO_2-e
$\Delta C_{IFM,\ t2}$	Total net GHG emission reductions from the IFM project activity up to year *t2*	t CO_2-e
C_{IFM_ERROR}	Total uncertainty for IFM project activity	%
$Bufferwithholding_{t2}$	The number of VCU's to be withheld in the VCS AFOLU Pooled Buffer Account at year *t2*	

The percentage to be withheld in the VCS AFOLU Pooled Buffer Account is to be determined using the VCS Tool for AFOLU Non-Permanence Risk Analysis and Buffer Determination. This percentage is to be multiplied with the carbon stock changes within the project boundary at year *t2* in order to obtain the parameter $Bufferwithholding_{t2}$.

10 MONITORING

10.1 General

The monitoring plan must contain at least the following sections:

- Monitoring of stock changes and greenhouse gas emissions in the baseline (only under certain conditions)
- Monitoring of project carbon stock changes and greenhouse gas emissions
- Monitoring of leakage carbon stock changes and greenhouse gas emissions
- Estimation of ex-post total net carbon stock changes and greenhouse gas emissions.

This must include the following elements:

- A description of each monitoring task to be undertaken, and the technical requirements
- Parameters to be measured
- Data to be collected and data collection techniques
- Frequency of monitoring
- Quality Assurance and Quality Control (QA/QC) procedures
- Data archiving procedures
- Roles, responsibilities and capacity of monitoring team and management

All data collected as part of monitoring should be archived electronically and be kept at least for 2 years after the end of the last project crediting period. One hundred percent of the data should be monitored if not indicated otherwise in the tables below. All measurements should be conducted according to relevant standards. In addition, the monitoring provisions in the tools referred to in the most recent version of the CDM methodology AR-ACM0002, Version 1 or its replacement must apply.

Data archiving must take both electronic and paper forms, and copies of all data must be provided to each project participant. All electronic data and reports must also be copied on durable media such as CDs and copies of the CDs are stored in multiple locations. The archives must include:

- Copies of all original field measurement data, laboratory data, data analysis spreadsheet;
- Estimates of the carbon stock changes in all pools and non-CO2 GHG and corresponding calculation spreadsheets;

- GIS products;
- Copies of the measuring and monitoring reports

When applying all relevant equations provided in this methodology for the *ex-ante* estimation of net anthropogenic GHG removals by sinks, project proponents must provide transparent estimations for the parameters that are monitored during the project crediting period. These estimates must be based on measured or existing published data where possible and project proponents should retain a conservative approach: that is, if different values for a parameter are equally plausible, a value that does not lead to over-estimation of net anthropogenic GHG removals by sinks must be selected.[19]

10.2 Monitoring of Regrowth in the Baseline Scenario

When monitoring regrowth in the baseline scenario using a reference area, the monitoring plan must provide specific monitoring procedures. These procedures must follow the same approach as provided below for the monitoring of the with-project scenario. Thus, the monitoring plan is to provide (justifications for) sampling frequency, sample size and field procedures for monitoring regrowth of residual forest in the baseline scenario.

Data and Parameters Not Monitored in the Baseline

Data / parameter:	A_i
Data unit:	Ha
Description:	Area of stratum *i*
Source of data:	Equation (2)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	GHG_{BSL-E}
Data unit:	t CO_2-e yr^{-1}
Description:	Greenhouse gas emissions as a result of relogging within the project boundary

[19] AR-ACM0002, Version 1

	in stratum *i*
Source of data:	Equation (2)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$A_{REL,i}$
Data unit:	Ha
Description:	Area relogged in baseline stratum *i*
Source of data:	Equation (3)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$C_{harvest,i}$
Data unit:	$t\ C\ ha^{-1}$
Description:	Carbon stock in harvested timber in stratum *i*
Source of data:	Equation (3)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$C_{damage,i}$
Data unit:	$t\ C\ ha^{-1}$
Description:	Carbon loss due to damage to the residual stand in stratum *i*
Source of data:	Equation (3)

Measurement procedures (if any):	
Any comment:	Accounting for C_{damage} as zero in the baseline scenario is conservative

Data / parameter:	$C_{WP100,i,t}$
Data unit:	t C ha^{-1}
Description:	Post-relogging carbon stock stored in long-term wood products (stock remaining in wood products after 100 years) in the baseline scenario in stratum i
Source of data:	Equation (3),(7a) and (8)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$C_{WP20,i,t}$
Data unit:	t C ha^{-1}
Description:	Post-relogging carbon stock stored in short-term and medium-term wood products (stock is expected to be emitted over 20 years with a linear decay function) in the baseline scenario in stratum i at year t
Source of data:	Equation (3),(7b) and (8)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$C_{DW,I,t}$
Data unit:	t C ha^{-1}

Description:	Post-relogging carbon stock in dead wood in the baseline scenario (stock emitted is quantified over 10 years with a linear decay function) in stratum *i* at year *t*
Source of data:	Equation (3) and (8)
Measurement procedures (if any):	
Any comment:	If C_{DW} for the project area cannot be derived from peer-reviewed literature, data can be obtained using appropriate measurement techniques applied in areas for which it can be shown that they are representative for the project area.

Data / parameter:	$V_{harvest,j,i}$
Data unit:	$m^3\ ha^{-1}\ yr^{-1}$
Description:	Volume of timber harvested in the baseline scenario of species *j* in stratum *i*
Source of data:	Equation (4)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	D_j
Data unit:	t d.m. m^{-3}
Description:	Basic wood density for species *j*
Source of data:	Equation (4) Values for *Dj* can be taken from tables generally used in the local or regional timber and forest industry, or from peer-reviewed literature applicable to the region. If no species-specific values for *Dj* are available, the average value across all species can be used, increased by 20% to ensure a conservative (higher) estimate of $C_{WPi,t}$. The source of data must be chosen with priority from higher to lower

	preference as follows: (a) National and species-specific or group of species-specific (eg, from national GHG inventory); (b) (Group of) Species-specific from neighbouring countries with similar conditions. Sometimes b) might be preferable to a); (c) Globally species-specific or group of species-specific (eg, IPCC GPG-LULUCF 2003).
Measurement procedures (if any):	NA
Any comment:	

Data / parameter:	CF
Data unit:	t d.m.$^{-1}$
Description:	Carbon fraction of dry matter
Source of data:	IPCC default value 0.5
Measurement procedures (if any):	NA
Any comment:	

Data / parameter:	f_{damage}
Data unit:	Dimensionless
Description:	Factor for damage to the residual stand caused by relogging
Source of data:	Equation (5) Determined using appropriate measurement techniques such as those described in the project description of the Noel Kempff Mercado Climate Action Project (NKM-CAP), version 02.02, dated 7/11/2005, or other similar established emission quantification approaches. Alternatively, peer reviewed

	literature may be used to derive f_{damage} from areas for which it can be shown that they are representative for the project area or general f_{damage} proxies for natural Evergreen Tropical Rainforests for conventional and/or Reduced Impact Logging (eg, Pulkki (1997)).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$C_{XB,ty,i}$
Data unit:	t CO_2-e ha^{-1}
Description:	Mean stock of extracted biomass carbon by class of wood product *ty* from stratum *i*
Source of data:	Equation (6)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$V_{ex,ty,j,i}$
Data unit:	m^3
Description:	Volume of timber extracted from within stratum *i* (does not include slash left onsite) by species *j* and wood product class *ty*
Source of data:	Equation (6)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	ty
Data unit:	No dimension

Description:	Wood product class (eg, sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other)
Source of data:	Equation (6)
Measurement procedures (if any):	
Any comment:	Wood product classes are used to account for long-term storage of carbon in wood products. The share of timber ending up in the various wood product classes needs to be determined. In case no reliable assumptions can be made as to the timber classes of the harvested wood and its end use, general information from Forest Departments from that area reflecting breakdown of timber classes as they are normally harvested from this forest type and area may be used (eg, plywood, round logs, sawn timber, etc.).

Data / parameter:	ww_{ty}
Data unit:	No dimension
Description:	The fraction immediately emitted through mill inefficiency
Source of data:	Published paper of Winjum *et al*. 1998[20] (used in Equation (7a))
Measurement procedures (if any):	
Any comment:	

Data / parameter:	slp_{ty}
Data unit:	No dimension
Description:	Fraction of wood products that will be emitted to the atmosphere within 5 years of timber harvest

[20] Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284

Source of data:	Published paper of Winjum *et al*. 1998[24] (used in Equation (7b))
Measurement procedures (if any):	
Any comment:	

Data / parameter:	fo_{ty}
Data unit:	No dimension
Description:	Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years of timber harvest
Source of data:	Published paper of Winjum *et al*. 1998[24] (used in Equation (7b))
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$C_{BSLpre,i}$
Data unit:	t C ha^{-1}
Description:	Pre-relogging carbon stock in above-ground tree biomass in the baseline scenario in stratum *i*
Source of data:	Equation (8)
Measurement procedures (if any):	$C_{BSLpre,i}$ can be determined on the basis of previously conducted fieldwork or surveys or peer-reviewed proxies in the reference area or can be approximated in case of a reference area as follows: $C_{BSLpre,i} = C_{BSLpost,i} + C_{harvest,i} + C_{damage,I}$
Any comment:	

Data / parameter:	$C_{BSLpost,i}$
Data unit:	t C ha^{-1}

Description:	Post-relogging carbon stock in above-ground tree biomass in the baseline scenario in stratum *i*
Source of data:	Equation (8)
Measurement procedures (if any):	$C_{BSLpost,i}$ can be estimated using the method outlined in (Estimation of $\Delta C_{P,i,t}$).
Any comment:	

Data / parameter:	$B_{SDW,l,sp,i}$
Data unit:	t d.m.
Description:	Biomass of standing dead tree *l* from sample plot *sp* in stratum *i*
Source of data:	Equation (10) and (11)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	BDia
Data unit:	cm
Description:	Basal diameter of standing dead tree
Source of data:	Field measurements in sample plots. Used in Equation (10) and (11)
Measurement procedures (if any):	Measured at ground level. Measure all trees above some minimum *BDia* in the sample plots, typically $\geq$ 10 cm.
Any comment:	

Data / parameter:	TD_{SDW}
Data unit:	cm
Description:	Top diameter of standing dead tree / from sample plot *sp* in stratum *i*

Source of data:	Field measurements in sample plots. Used in Equation (10) and (11)
Measurement procedures (if any):	Height measured from ground level to either the top of a standing bole or to the base of crown if crown is persistent. Height is measured either directly or by using an instrument such as a clinometers, relascope or laser inventory instrument.
Any comment:	

Data / parameter:	H_{SDW}
Data unit:	cm
Description:	Height of standing dead tree
Source of data:	Field measurements in sample plots. Used in Equation (10) and (11)
Measurement procedures (if any):	Height measured from ground level to either the top of a standing bole or to the base of crown if crown is persistent. Height is measured either directly or by using an instrument such as a clinometers, relascope or laser inventory instrument.
Any comment:	

Data / parameter:	$D_{DW,dc}$
Data unit:	t d.m. m^{-3}
Description:	Mean wood density of dead wood in the density class (dc) – sound (1), intermediate (2), and rotten (3); t d.m. m^{-3}
Source of data:	Equation (10) and (11) The source of data must be chosen with priority from higher to lower preference as follows: (a) Research publications relevant to the project area; (b) National species-specific or group of species-specific (eg, from National GHG inventory); (c) Species-specific or group of species-specific from neighboring countries with similar conditions. Sometimes (b) may be preferable to (a); (d) Global species-specific or group of species-specific (eg, IPCC GPG-

	LULUCF). Species-specific dead wood densities may not always be available, and may be difficult to apply with certainty to decomposed wood and in the typically species rich forests of the humid tropics, hence it is acceptable practice to use dead wood densities developed for forest types.
Measurement procedures (if any):	Project-specific determination of density is most likely necessary, requiring collection of representative samples from 10-20 trees from each decomposition class. Dead wood samples are cut in discs and thickness and diameter measured to estimate green volume. Samples are oven dried (70^{o} C) to a constant weight in the laboratory, and density calculated as dry weight (g) per unit green volume (cm^3).
Any comment:	Basic wood density for dominant species *DS* when *j=DS*

Data / parameter:	V_{LDW}
Data unit:	m^3 ha^{-1}
Description:	Volume of lying dead wood per unit area in stratum *i*
Source of data:	Field measurements in sample plots. Used in Equation (14)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$Dia_{n,i,t}$
Data unit:	m^3 ha^{-1}
Description:	Diameter of piece *n* of dead wood along the transect in stratum *i*
Source of data:	Field measurements in sample plots. Used in Equation (14)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$B_{LDW,i,t}$
Data unit:	t d.m. ha^{-1}
Description:	Biomass of lying dead wood per unit area in stratum *i*
Source of data:	Field measurements in sample plots. Used in Equation (15)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$V_{LDW,i,t}$
Data unit:	m^3 ha^{-1}
Description:	Volume of lying dead wood per unit area in stratum *i*
Source of data:	Field measurements in sample plots. Used in Equation (15)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$D\%_{,i}$
Data unit:	% yr^{-1}
Description:	Projected annual proportion of land that will be logged in stratum *i* at year *t*. If actual annual proportion is known and documented (eg, 25% per year for 4 years), set to proportion
Source of data:	Used in Equation (17)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$E_{biomass}$
Data unit:	t CO_2-e yr^{-1}
Description:	Emissions due to the removal of the biomass itself at year *t*
Source of data:	Remote imagery (photographs or satellite) or by using a reported percentage that is typical for the area.
Measurement procedures (if any):	To estimate the emissions from the removal of the biomass area has to be multiplied by an average carbon stock value per hectare that is representative of the project area.
Any comment:	

Data / parameter:	$E_{felling}$
Data unit:	t CO_2-e yr^{-1}
Description:	Emissions due to the use of equipment for removal of the biomass on the area dedicated to infrastructure
Source of data:	Determined in Section 9.1
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$E_{grading}$
Data unit:	t CO_2-e yr^{-1}
Description:	Emissions due to road grading
Source of data:	Determined in Section 9.1
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$E_{harvesting}$
Data unit:	t CO_2-e yr^{-1}
Description:	Emissions due to harvesting
Source of data:	Determined in Section 9.1
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$E_{extraction}$
Data unit:	t CO_2-e yr^{-1}
Description:	Emissions due to extraction of timber from the forest to the log landings
Source of data:	Determined in Section 9.1
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$E_{transport}$
Data unit:	t CO_2-e yr^{-1}
Description:	Emissions due to the transport of the timber from the log landings to point of onward sale/transport
Source of data:	Determined in Section 9.1
Measurement procedures (if any):	
Any comment:	

Data and Parameters Monitored in the Baseline

Data / parameter:	$\Delta C_{tree\text{-}exist,i,}$
Data unit:	$t\ CO_2\text{-}e\ yr^{-1}$
Description:	Net carbon stock change in existing tree vegetation[21] in the baseline scenario in stratum *i*
Source of data:	Equation (2) Determined in Section 9.1 of methodology.
Measurement procedures (if any):	
Any comment:	

10.3 Monitoring of Project Implementation

Information must be provided, and recorded in the project description, to establish that:

(a) The geographic position of the project boundary is recorded for all areas of land:

a. The geographic coordinates of the project boundary (and any stratification inside the boundary) are established, recorded and archived. This can be achieved by field survey (eg, using GPS), or by using georeferenced spatial data (eg, maps, GIS datasets, orthorectified aerial photography or georeferenced remote sensing images).

(b) Commonly accepted principles of forest inventory and management are implemented:

a. Standard operating procedures (SOPs) and quality control/quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of SOPs already applied in national forest monitoring, or available from published handbooks, or from the IPCC GPG LULUCF 2003, is recommended;

b. Apply SOPs, especially, for actions likely to minimize soil disturbances in those circumstances in which site preparation or planting involves soil disturbance capable to increase soil erosion above the baseline value;

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[21] With *DBH* ≥ 5 cm.

c. The project plan, together with a record of the plan as actually implemented during the project must be available for validation or verification, as appropriate.[22]

10.4 Monitoring of project carbon stock changes and greenhouse gas emissions

10.4.1 Updating of Strata

Stratification of the project area into relatively homogeneous units can either increase the measuring precision without increasing the cost unduly, or reduce the cost without reducing measuring precision because of the lower variance within each homogeneous unit. Project proponents should present in the project description an *ex-ante* stratification of the project area or justify the lack of it. The number and boundaries of the strata defined *ex-ante* may change during the project crediting period (*ex post*).

The *ex-post* stratification must be updated because of the following reasons:

- Unexpected disturbances occurring during the project crediting period (eg, due to fire, pests or disease outbreaks), affecting differently various parts of an originally homogeneous stratum;
- Forest management activities (cleaning, planting, thinning, harvesting, coppicing, re-planting) that are implemented in a way that affects the existing stratification.

Established strata may be merged if the reasons for their establishment have disappeared.[23]

10.4.2 Sampling Framework

The sampling framework, including sample size, plot size, plot shape, and determination of plot location should be specified in the project description.[24]

To determine the sample size and allocation among strata, this methodology uses the latest version of the tool for the “Calculation of the number of sample plots for measurements within A/R CDM project activities”[25], approved by the CDM Executive Board. The targeted precision level for biomass estimation within each stratum is ± 10% of the mean at a 95% confidence level.

10.4.3 Measuring and estimating carbon stock changes and GHG emissions over time

The change in carbon stocks must be estimated by taking measurements in plots at each monitoring event. Monitoring events must take place at intervals of 5, or preferably 3 years.

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[22] This paragraph has been amended after AR-ACM0002 (ie, is not copied *verbatim*).

[23] AR ACM0002, Version 01

[24] Except for this sentence the entire Section 8.2.2 has been copied *verbatim* from AR-ACM0002.

[25] Available at: <http://cdm.unfccc.int/>

Data and parameters not monitored in the Project Scenario

Data / parameter:	BEF
Data unit:	dimensionless
Description:	Biomass expansion factor for the conversion of annual net increment (including bark) in stem biomass to total above-ground tree biomass increment for species *j*
Source of data:	The source of data must be chosen with priority from higher to lower preference as follows: a. Existing local and species-specific or group of species-specific; b. National and species-specific or group of species-specific (eg from national GHG inventory) c. Species-specific or group of species-specific from neighbouring countries with similar conditions (might be preferable to b under certain conditions) d. Climatic zone and forest type (eg IPCC literature: Table 3A.1.10 of the *GPG-LULUCF* (IPCC 2003) and Table 4.5 of the *AFOLU Guidelines* (IPCC 2006)
Measurement procedures (if any):	
Any comment:	• *BEFs* are age dependent, and use of average data may result in significant errors for both young and old stands—as *BEFs* are usually large for young stands and quite small for old stands; • *BEFs* in IPCC literature and national inventory are usually applicable to closed canopy forest. If applied to individual trees growing in open field it is recommended that the selected *BEF* be increased by a further 30%.[26]

[26] Applying a 30% increase to the BEF for solitary trees in severely logged over forest when estimating regrowth after logging in the baseline is leading to conservative estimates of carbon benefits of the project because it reduces net emissions in the baseline. In the project scenario less incidences of solitary trees will occur because the canopy will remain intact to a larger degree in comparison to the baseline.

Data / parameter:	R
Data unit:	t root d.m. t^{-1} shoot d.m.
Description:	Root:shoot ratio appropriate to species or forest type / biome
Source of data:	The source of data must be chosen with priority from higher to lower preference as follows: a. Existing local and species-specific or group of species-specific; b. National and species-specific or group of species-specific (eg from national GHG inventory) c. Species-specific or group of species-specific from neighbouring countries with similar conditions (might be preferable to b under certain conditions) d. Climatic zone and forest type (eg IPCC literature: Table 3A.1.8 of the *GPG-LULUCF* (IPCC 2003) and Table 4.4 of the *AFOLU Guidelines* (IPCC 2006)
Measurement procedures (if any):	
Any comment:	Guideline for conservative choice of default values: - If in the sources of data mentioned above, default data are available for conditions that are similar to the project (same vegetation genus; same climate zone; similar forest type), then mean values of default data may be used and considered conservative. - A root:shoot ratio for mature forest must be selected. Usually the root:shoot ratio for young trees is greater than for old trees. Applying a root:shoot ratio for mature forest is conservative, because it underestimates carbon in young trees in the project scenario (which are more abundant as a result of enrichment planting).

Data / parameter:	CF
Data unit:	t $d.m.^{-1}$

Description:	Carbon fraction of dry matter
Source of data:	IPCC default value 0.5. Used in Equation (39).
Measurement procedures (if any):	NA
Any comment:	

Data / parameter:	D_j
Data unit:	t d.m. m^{-3}
Description:	Basic wood density for species *j*
Source of data:	Values for *Dj* can be taken from tables generally used in the local or regional timber and forest industry, or from peer-reviewed literature applicable to the region. If no species-specific values for *Dj* are available, the average value across all species can be used, increased by 20% to ensure a conservative (higher) estimate of $C_{WPi,t}$. The source of data must be chosen with priority from higher to lower preference as follows: (a) National and species-specific or group of species-specific (eg, from national GHG inventory); (b) (Group of) Species-specific from neighbouring countries with similar conditions. Sometimes b) might be preferable to a); (c) Globally species-specific or group of species-specific (eg, IPCC GPG-LULUCF 2003).
Measurement procedures (if any):	NA
Any comment:	

Data / parameter:	$f_i(X, Y \ldots)$

Data unit:	t d.m. tree^{-1}
Description:	Allometric equation for species *j* linking, for example, diameter at breast height (*DBH*) and tree height (*H*) to above-ground biomass of living trees
Source of data:	Used in Equation (39). Whenever available, use allometric equations that are species-specific or group of species-specific, provided the equations have been derived using a wide range of diameters and heights, based on datasets that comprise at least 20 trees. Otherwise, default equations from IPCC literature, national inventory reports or published peer-reviewed studies may be used—such as those provided in Tables 4.A.1 to 4.A.3 of the *GPG-LULUCF* (IPCC 2003).
Measurement procedures (if any):	NA
Any comment:	If default allometric equations are available for conditions that are similar to the project (same vegetation genus; same climate zone; similar forest type), then the equation may be used and considered conservative. Otherwise, it is necessary either to use conservatively assessed values, or to verify the applicability of the equation if mean predicted values are to be used. Allometric equations can be verified by: • Selecting at least 5 trees covering the range of *DBH* existing in the project area, and felling and weighing the above-ground tree biomass to determine the total (wet) weight of the stem and branch components; • Extracting and immediately weighing sub-samples from each of the wet stem and branch components, followed by oven drying at 70ºC to determine dry biomass; • Determining the total dry weight of each tree from the wet weights and the averaged ratios of wet and dry weights of the stem and branch components. If the biomass of the harvested trees is within about ±10% of the mean values predicted by the selected default allometric equation, and is not biased—or if biased is wrong on the conservative side (ie, use of the equation results in an under- rather than over-estimate of project net anthropogenic removals by sinks)—then mean values from the default equation may be used. (IPCC Good Practice Guidance for LULUCF, 2003, Section 4.3.3.5.1, under direct approach step 3)

Data and Parameters Monitored in Project Scenario

Data / parameter:	$A_{i,t}$
Data unit:	Ha
Description:	Area of stratum *i* at year *t*
Source of data:	Monitoring of strata and stand boundaries must be done preferably using a Geographical Information System (GIS), which allows for integrating data from different sources (including GPS coordinates and Remote Sensing data). Used in Equation (35)
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$A_{sp,i}$
Data unit:	Ha
Description:	Total area of all sample plots in stratum *i*
Source of data:	Field measurements. Used in Equation (38).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	DBH
Data unit:	cm
Used in equations:	
Description:	Diameter at breast height of tree
Source of data:	Field measurement in sample plots
Measurement procedures (if any):	Typically measured 1.3 m above ground. Measure all the trees above 5 cm *DBH* in the permanent sample plots.

Any comment:	For *ex-ante* estimations, tree dimension variables (eg, diameter at breast height (*DBH*) and possibly height (*H*)) should be estimated for tree species *j* in stratum *i*, at year *t* using a growth model based on these tree dimensions.

Data / parameter:	H
Data unit:	m
Description:	Height of tree
Source of data:	Field measurement in sample plots
Measurement procedures (if any):	
Any comment:	For *ex-ante* estimations, tree dimension variables (eg, diameter at breast height (*DBH*) and possibly height (*H*)) should be estimated for tree species *j* in stratum *i*, at year *t* using a growth model based on these tree dimensions.

Data / parameter:	$Dia_{n,i,t}$
Data unit:	cm
Description:	Diameter of piece *n* of dead wood along the transect in stratum *i*, at year *t*
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	Lying dead wood can be sampled using the line intersect method (Harmon and Sexton 1996[27]). Two 50-meter lines are established bisecting each sample plot and the diameters of the lying dead wood (≥ 10 cm diameter) intersecting the lines are measured.
Any comment:	

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[27] Harmon, M.E. and J. Sexton. (1996) Guidelines for measurements of woody detritus in forest ecosystems. US LTER Publication No. 20. US LTER Network Office, University of Washington, Seattle, WA, USA.

Data / parameter:	BDia
Data unit:	cm
Description:	Basal diameter of standing dead tree
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	Measured at ground level. Measure all trees above some minimum *BDia* in the sample plots, typically $\geq$ 10 cm.
Any comment:	

Data / parameter:	H_{SDW}
Data unit:	cm
Description:	Height of standing dead tree
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	Height measured from ground level to either the top of a standing bole or to the base of crown if crown is persistent. Height is measured either directly or by using an instrument such as a clinometers, relascope or laser inventory instrument.
Any comment:	

Data / parameter:	N
Data unit:	dimensionless
Description:	Total number of wood pieces intersecting the transect
Source of data:	Field measurements
Measurement procedures (if any):	
Any comment:	

Data / parameter:	V_{extr}
Data unit:	m^3
Description:	The volume of timber extracted from within the project boundary (does not include slash left onsite), preferably reported by species and wood product class. Where no direct information on volume by wood product class is available (eg, illegal logging) it is acceptable practice to assign gross percentages of volume extracted to wood product classes on the basis of local expert knowledge of harvest activities and markets.
Source of data:	Timber harvest records and/or estimates derived from field measurements or remote assessments with aerial photography or satellite imagery.
Measurement procedures (if any):	
Any comment:	Note that this volume does not include logging slash left onsite (tracked as part of the dead wood pool). Data compilers should also make sure that extracted volumes reported are gross volumes removed (ie, reported volume does not already discount for estimated wood waste, as is often the practice in harvest records)

Data / parameter:	t_2 and t_1
Data unit:	yr
Description:	Years of the monitoring activity
Source of data:	Field measurement in sample plots
Measurement procedures (if any):	
Any comment:	$T = t_2 - t_1$

Data / parameter:	$\Delta C_{P,i,t}$
Data unit:	$t\ CO_2\text{-}e\ yr^{-1}$

Description:	Net carbon stock change due to forest regrowth and silvicultural interventions in the with-project scenario in stratum *i* at year *t*
Source of data:	Used in Equation (34).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$\Delta C_{AGB,i,t}$
Data unit:	t CO_2-e yr^{-1}
Description:	Net carbon stock change in above-ground tree biomass[28] in the with-project scenario in stratum *i*
Source of data:	Used in Equation (34) and (35).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$\Delta C_{BGB,i,t}$
Data unit:	t CO_2-e yr^{-1}
Description:	Net carbon stock change in below-ground tree biomass in the with-project scenario in stratum *i*
Source of data:	Used in Equation (34) and (40).
Measurement procedures (if any):	
Any comment:	

[28] With *DBH* ≥ 5 cm.

Data / parameter:	$\Delta C_{DW,i,t}$
Data unit:	t CO_2-e yr^{-1}
Description:	Net carbon stock change in dead wood in the with-project scenario in stratum *i* at year *t*
Source of data:	Used in Equation (34) and (41).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$\Delta C_{WP,i,t}$
Data unit:	t CO_2-e yr^{-1}
Description:	Net carbon stock change in wood products in the with-project scenario in stratum *i* at year *t*
Source of data:	Used in Equation (34) and (42).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$E_{biomassloss,i,t}$
Data unit:	t CO_2-e yr^{-1}
Description:	Emissions due to site preparation for project activities in stratum *i* at year *t*
Source of data:	Used in Equation (34).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$C_{AGB,l,j,sp,i,t}$
Data unit:	t C tree^{-1}
Description:	Carbon stock in above-ground biomass of tree *l* of species *j* in plot *sp* in stratum *i* at year *t*
Source of data:	Used in Equation (36), (37) and (39).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$V_{l,j,sp,i}$
Data unit:	m^3 tree^{-1}
Description:	Stem volume of tree *l* of species *j* in plot *sp* in stratum *i*
Source of data:	Used in Equation (36).
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$C_{AGB,,sp,i,t}$
Data unit:	t C
Description:	Carbon stock in trees in plot *sp* in stratum *i* at year *t*
Source of data:	Used in Equation (37) and (38).
Measurement procedures (if any):	
Any comment:	

Leakage

Data and parameters not monitored (default, documented value, or possibly measured one time)

Data / parameter:	LF_{ME}
Data unit:	dimensionless
Description:	Leakage factor for market-effects calculations
Source of data:	Analysis of issuance of new concessions being assigned within the national boundaries, and associated annual extracted volumes. Used in Equation (44).
Measurement procedures (if any):	
Any comment:	Documented history of extracted volumes per hectare of existing concessions can be used as evidence.

Data / parameter:	NCS
Data unit:	t CO_2-e ha^{-1}
Description:	The mean national forest carbon stock
Source of data:	National statistics from Forest Department or other reliable sources
Measurement procedures (if any):	
Any comment:	

Data and parameters monitored

Data / parameter:	C_{BSL}
Data unit:	t CO_2-e ha^{-1}
Description:	Mean carbon stock across strata in all pools in the baseline
Source of data:	Determined in Section 9.1 of methodology
Measurement procedures (if any):	
Any comment:	

11 UNCERTAINTY AND QUALITY MANAGEMENT

Quality management procedures are required for the management of data and information, including the assessment of uncertainty, relevant to the project and baseline scenarios. As far as practical, uncertainties related to the quantification of GHG emission reductions and removals by sinks should be reduced.

To help reduce uncertainties in the accounting of emissions and removals, this methodology uses whenever possible the proven methods from the GPG-LULUCF, GPG-2000, and the IPCC's Revised 2006 Guidelines. As well, tools and guidance from the CDM Executive Board on conservative estimation of emissions and removals are also used. Despite this, potential uncertainties still arise from the choice of parameters to be used. Uncertainties arising from, for example, biomass expansion factors (BEFs) or wood density, would result in uncertainties in the estimation of both baseline net GHG removals by sinks and the actual net GHG removals by sinks - especially when global default values are used.

It is recommended that project proponent identifies key parameters that would significantly influence the accuracy of estimates. Local values that are specific to the project circumstances should then be obtained for these key parameters, whenever possible. These values should be based on:

- Data from well-referenced peer-reviewed literature or other well-established published sources;[29] or,

[29] Typically, citations for sources of data used should include: the report or paper title, publisher, page numbers, publication date etc (or a detailed web address). If web-based reports are cited, hardcopies should be included as annexes in the project description if there is any likelihood such reports may not be permanently available.

- National inventory data or default data from IPCC literature that has, whenever possible and necessary, been checked for consistency against available local data specific to the project circumstances; or

- In the absence of the above sources of information, expert opinion may be used to assist with data selection. Experts will often provide a range of data, as well as a most probable value for the data. The rationale for selecting a particular data value should be briefly noted in the project description. For any data provided by experts, the project description must also record the expert's name, affiliation, and principal qualification as an expert (eg, that they are a member of a country's national forest inventory technical advisory group) as well as a 1-page summary CV for each expert consulted, included in an annex.

In choosing key parameters, or making important assumptions based on information that is not specific to the project circumstances, such as in use of default data, project proponents should select values that will lead to an accurate estimation of net GHG removals by sinks, taking into account uncertainties.

If uncertainty is significant, project proponents should choose data such that it indisputably tends to under-estimate, rather than over-estimate, net GHG removals by sinks.

APPENDIX 1: TABLE FOR REPORTING THE CALCULATION OF TOTAL VCUS THROUGH NET CARBON STOCK CHANGES AND GREENHOUSE GAS EMISSION REDUCTIONS

Project year	Calendar year	ΔC_{BSL} Carbon stock changes		GHG emissions		ΔC_{WPS} Carbon stock changes		GHG emissions		ΔC_{LK} Carbon stock changes		GHG emissions		ΔC_{IFM} Carbon stocks			
		annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
Nr	yr	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e	tCO_2e
1																	
2																	
3																	
…																	
N																	

DOCUMENT HISTORY

Version	Date	Comment
v1.0	23 Nov 2010	Initial version released
v1.1	24 Aug 2011	Updates 1) Equation (7) of the wood products section is updated to correct for the error of applying carbon stocks in an equation intended for fractions (%). This makes the equations (8) and (9) redundant and they have been removed. 2) Equation (51) for the calculation of VCU's is updated to correct for the error of applying the buffer withholding percentage to GHG emissions and removals. 3) Various typographical errors: a. Reference to section 3.4.7 instead of 3.4.6 on page 17; b. delta symbols in table 3; and, c. other corrections
v1.2	23 Jul 2013	Updates 1) Procedures to account for the decay of carbon from the dead wood and harvested wood products pools have been included. 2) Minor edits to language were made (eg, the term 'must' has been used for required procedures).

VCS Methodology

VM0006

Methodology for Carbon Accounting for Mosaic and Landscape-scale REDD Projects

Version 2.2

17 March 2017

Sectoral Scope 14

Table of Contents

1 SOURCES

This methodology uses different elements from several approved methodologies, tools and modules. More specifically, this methodology is based on elements from the following approved methodologies:

- CDM Methodology - AR ACM0001 *Afforestation and reforestation of degraded land.* (Version 01).
- CDM Methodology - AR AM0002 *Restoration of degraded lands through afforestation/reforestation.* (Version 03).
- CDM Methodology - AR AM0006 *Afforestation/Reforestation with trees supported by shrubs on degraded land.* (Version 02).
- CDM Methodology – AMS.II.G*. Energy efficiency measures in thermal applications of non-renewable biomass. (*Version 5).

This methodology also refers to the following approved tools and modules, and the latest versions of these must be used:

- CDM A/R Methodological Tool *Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities.*
- CDM A/R Methodological Tool 03 *Calculation of the number of sample plots for measurements within A/R CDM project activities.*
- CDM A/R Methodological Tool 06 *Procedure to determine when accounting of the soil organic carbon pool may be conservatively neglected.*
- CDM A/R Methodological Tool 09 *Estimation of GHG emissions related to displacement of grazing activities in A/R CDM project activity.*
- CDM Tool *Tool for testing significance of GHG emissions in A/R CDM project activities.*
- VCS Tool VT0001 *Tool for the demonstration and assessment of additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) project activities*.
- VCS Tool *Tool for calculating deforestation rates using incomplete remote sensing images*[1].

This methodology also refers to the following approved guidelines and requirements, of which the latest version shall be used:

- CDM Annex 23 *Guidelines on conservative choice and application of default data in estimation of the net anthropogenic GHG removals by sinks.*
- VCS *Jurisdictional and Nested REDD+ (JNR) Requirements*.

[1] At issuance of the this methodology, the VCS Tool, *Tool for calculating deforestation rates using incomplete remote sensing images*, is currently in development and is unavailable for use in this methodology until it is approved.

- VCS *Program Definitions*.
- VCS *Standard.*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology provides procedures for quantifying emission reductions and/or removals from activities aimed at reducing unplanned deforestation and forest degradation of the mosaic configuration. The methodology may be combined with Improved Forest Management (IFM) and Afforestation, Reforestation and Revegetation (ARR) methodologies to implement a landscape-scale Reduced Emissions from Deforestation and Forest Degradation (REDD+) project that addresses land and resource needs of communities in a holistic way. Emission reductions/removals from REDD+ activities are calculated by taking the difference between, on the one hand, *ex-post* monitored changes in carbon stocks in the project areas, and on the other hand *ex-ante* changes in baseline carbon stocks, *ex-post* monitored emissions from leakage, and *ex-post* monitored emission sources. Baseline emissions from unplanned deforestation and degradation in the project area are calculated based on historical deforestation or forest degradation rates in a reference region that is similar to the project area.

Under this methodology, new project activity instances referred to as discrete project parcels can be added after the start of the project as per VCS rules for grouped projects.

The main elements of the methodology are:

- Net emission reductions and removals (NERs) from avoided deforestation and avoided forest degradation are treated separately. When changes in forest biomass cannot be measured with sufficient accuracy, emissions reduction/removals from avoided forest degradation are excluded.
- The quantification of baseline deforestation and degradation rates is based on field-calibrated remote sensing analyses over a historical reference period. More specifically, the baseline rates of deforestation and degradation are quantified by classifying the discrete land cover classes, or forest strata, and analyzing transitions from one class or stratum to a different class or stratum over time.
- Leakage is monitored and quantified using a leakage belt approach for geographically constrained drivers, and a factor approach for geographically unconstrained drivers. Market-effect leakage is accounted for each project according to the discount factors provided in the VCS *AFOLU Requirements*.
- Increases in forest cover through natural regeneration are included in both the baseline and project scenarios. This is achieved by applying the empirically observed baseline regeneration rates in the reference region to the project and baseline scenarios. That is, the baseline scenario includes both projected degradation and deforestation, but also projected regeneration and reforestation in areas that were deforested. Similarly, the project scenario must include all forest class transitions, whether they are positive or negative.

- This methodology allows silvicultural activities and enrichment planting activities within degraded parts of the forests to accelerate the natural regeneration, promote forest regeneration, and provide opportunities for local employment. The accounting of these activities is based on a measured increase in biomass in the area in which such activities were executed.
- Projects with more accurate monitoring and verification are rewarded through a deduction mechanism based on the empirically observed accuracy. The accuracy is quantified based on (1) accuracy of remote sensing classification, and (2) the variance of biomass stock density.
- *Ex-ante,* the relative reduction in deforestation rates inside the project area is calculated by estimating the expected effect of a project activity on each driver. The simple spatial model calibrated previously is then used to divide the total deforestation and forest degradation rates in the project scenario into forest-strata specific rates. Subsequently, emission sources from project activities are calculated.
- Procedures to monitor and account for secondary emissions from increased rice production and intensification of livestock management are included in the methodology.

Note that where projects applying this methodology seek registration under a jurisdictional REDD+ program, the project must follow the requirements specified in the latest version of the VCS *Jurisdictional and Nested REDD+ (JNR) Requirements*.

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

3 DEFINITIONS AND ACRONYMS

The following definitions and acronyms apply in the methodology.

3.1 Definitions Regarding Project Boundary

Baseline Validation Period
The period during which the *ex-ante* calculation of net GHG emissions under the baseline scenario is valid. As per VCS *AFOLU Requirements*, baselines are fixed for 10 years in all projects after which a new *ex-ante* baseline needs to be calculated and validated as per VCS rules.

Discrete Project Area Parcels
A project area that is contiguous or consists of multiple smaller adjacent and non-adjacent project areas that are equivalent to project activity instances when grouping procedures are applied.

Historical Reference Period
A fixed time period during which historical deforestation and forest degradation is analyzed in the reference region to set the forward-looking baseline. At validation, the historical reference period ends at the start of the crediting period. Once the project has started, and a baseline update is calculated, the historical reference period ends at the time at which the baseline is updated.

JNR Area
The geographic area registered under the jurisdictional REDD+ program.

Leakage Area
The sum of individual leakage belts which do not have to be contiguous.

Leakage Belt
The geographical area where leakage is expected around individual discrete project area parcels. Since leakage can occur on both forest land and non-forest land, such as woodland or grassland, the leakage belt may include any of these land types.

Project Area
The geographical area where the project participants will implement activities to reduce deforestation and forest degradation.

Reference Region
The region from which historical and current deforestation and forest degradation quantities and trends are obtained to predict future deforestation and degradation quantities in the absence of project activities (i.e., baseline scenario).

3.2 Definitions Regarding Classification, Stratification and Transition of Land Use and Land Cover

Forest Regeneration
The persistent increase of canopy cover and/or carbon stocks in an existing forest due to natural succession or human intervention, and falls under the IPCC GPG-LULCF 2003 land category of forest remaining forest.

Forest Strata
A division of forest land use and land cover (LULC) class determined by carbon stock density, native forest type, past and future management, landscape position, biophysical properties, and the degree of past disturbance.

Forest Stratification
The sub-division of the LULC class into narrower forest strata.[2]

[2] The minimum mapping unit established for LULC class is also applied to forest strata.

Increased Forest Cover

The transition of non-forest land into forest land, and encompasses both reforestation and natural succession.

Land Transition

A change from one LULC class or forest stratum into another within one geographical area. This methodology considers six main categories of transitions defined as deforestation, forest degradation, forest regeneration, increased forest cover, natural succession and reforestation.

Land Use and Land Cover (**LULC**) **Classes**

A land classification system that is hierarchical in nature. Specific definitions for cropland, grassland, settlement, wetland, and other land are provided in the IPCC Change's Good Practice Guidance for Land Use, Land-Use Change and Forestry 2003 report (IPCC GPG-LULCF 2003).

Minimum Mapping Unit

The minimum unit used for remote sensing and classification procedures. In this methodology, a minimum mapping unit of 1 hectare (ha) applies.

Natural Succession

The natural increase in forest covers without any human intervention.

3.3 Other Definitions

Agents of Deforestation or Forest Degradation (**Agent**, **Agent of Deforestation**, or **Agent of Degradation**)

The social group, community or other entity involved in deforestation or forest degradation.

Assisted Natural Regeneration (ANR).

Human-induced forest regeneration through silvicultural activities that induce or accelerate increase in forest biomass, as compared to natural regeneration. ANR silvicultural activities include thinning to stimulate tree growth, removal of invasive species, coppicing, and enrichment planting.

Commercial Timber Harvesting.

The extraction of timber wood for further sale on regional or global timber markets outside of the project area.

Cook Stove and Fuel Efficiency (CFE) Activities.

Activities that result in efficiency improvements in the thermal application of non-renewable biomass. Example of such activities include the introduction of high efficiency biomass fired cook-stoves, ovens, dryers and/or improvement of energy efficiency of existing biomass fired cookstoves, ovens, or dryers.

Driver of Deforestation and Forest Degradation (Driver, Driver of Deforestation, Driver of Forest Degradation)

The immediate activity executed by agents of deforestation or degradation that leads to deforestation/ degradation.

Subsistence Farming
A system of farming where all or almost all of the produce is used to meet the consumption needs of the farm family without any significant surplus for commercial sale.

3.4 Acronyms

AFOLU	Agriculture, Forestry, and Other Land Use
ARR	Afforestation, Reforestation, and Revegetation
CDM	Clean Development Mechanism
CP	Conference of the Parties
CV	Coefficient of Variation
DBH	Diameter at Breast Height (1.3 m)
DF	Deforestation
DG	Forest Degradation
DM	Dry Matter
DNA	Designated National Authority
EF	Emission Factor
GHG	Greenhouse Gas
GIS	Geographic Information System
GPG-LULUCF	Good Practice Guide for Land Use, Land Use Change and Forestry
GPS	Global Positioning System
GWP	Global Warming Potential
ha	Hectare
IPCC	Intergovernmental Panel on Climate Change
LCL	Lower Confidence Limit
Mg	Mega gram = 1 metric tons
MMU	Minimum Mapping Unit
tCO2e	Metric Tons of Carbon Dioxide Equivalents
NER	Net Greenhouse Gas Emission Reduction
PD	Project Document
QA/QC	Quality Assurance / Quality Control
RED	Reduced Emissions from Deforestation
REDD	Reduced Emissions from Deforestation and Forest Degradation
SOC	Soil Organic Carbon
VCS	Verified Carbon Standard
VCU	Verified Carbon Unit

4 APPLICABILITY CONDITIONS

4.1 General Applicability Conditions

The following applicability conditions apply. Note that in case the project area consists of multiple discrete project area parcels, each discrete project area parcel must also meet all applicability conditions below.

4.1.1 Conditions Related to Eligible Land Conditions

This methodology is applicable to areas where land prior to project implementation meets the following conditions:

- Land in the project area consists of either one contiguous area or multiple discrete project area parcels, and must meet an internationally accepted definition of forest, such as those based on UNFCCC host-country thresholds or FAO definitions, and must qualify as forest for a minimum of 10 years before the project start date.
- The project area must be deforested or degraded in absence of the REDD project activity and the deforestation and degradation must be mosaic in nature as described in the VCS *AFOLU Requirements.*
- Drivers of deforestation and forest degradation must fall into one or more of the following categories):
  - Conversion of forest land to cropland for subsistence farming.
  - Conversion of forest land to settlements.
  - Conversion of forest land to infrastructure, including new roads.
  - Logging of timber for commercial sale (eg, wood planks or poles for commercial sale).
  - Logging of timber for local enterprises and domestic uses.
  - Wood collection for commercial sale of fuelwood and charcoal.
  - Fuelwood collection for domestic and local industrial energy needs (eg, cooking, home heating, tobacco curing, brick making).
  - Cattle grazing in forests.
  - Extraction of understory vegetation (eg, thatch grass collection for roof and livestock bedding materials, shrubs and small trees for straw fences).
  - Forest fires to the extent that they are not part of natural ecosystem dynamics (eg, forest fires related to hunting, honey collection, intentional land clearing on land with a high fuel-load).

None of the drivers listed above must be planned in nature. If deforestation from a specific driver is occurring as a result of planned forest conversion activities, then such a driver must be excluded from analysis.

- This methodology is not applicable to organic soils or peatland.

4.1.2 Conditions Related to Eligible Project Activities

This methodology is applicable to projects that implement one or more of the following activities:

- Strengthening of land-tenure status and forest governance.
- Supporting the development and implementation of sustainable forest and land use management plans.
- Demarcating forest, tenure and ownership boundaries; promoting forest protection through patrolling of forests and forest boundaries; promoting social inclusion and stewardship in local communities; facilitating social fencing through capacity building; and creating mechanisms to alert law enforcement authorities of forest trespassing.
- Fire prevention and suppression activities including the construction of fire breaks, reduction of fuel loads, prescribed burning, education to minimize intentionally started fires, support for fire brigades, water cisterns, fire lookouts, and communication systems.
- Reducing fuelwood consumption and/or increasing energy efficiency by introducing fuel-efficient woodstoves or brick kilns and curing equipment.
- Creation of alternative sources of fuelwood through agroforestry, farm woodlots management and introduction/intensification of other renewable and non-fossil fuel based energy sources (such as solar).
- Sustainable intensification of agriculture on existing agricultural land.
- Development of local enterprises based on sustainably harvested non-timber forest products (NTFPs) such as honey, medicinal plants, etc.

4.2 Applicability Conditions for Optional Activities

4.2.1 Conditions Related to Optional Assisted Natural Regeneration Activities

Implementing Assisted Natural Regeneration Activities (ANR) activities as described in Section 8.2.5 is optional, but is only eligible under this methodology if all of the following applicability conditions are met:

- ANR activities must take place on degraded land on which no prior ANR activities have taken place. However, areas that were forest at the start of the project, but became deforested during the project crediting period are eligible as per the provisions under Section 9.3.7.
- ANR activities consist of thinning, removal of invasive species, enrichment planting, and coppicing.
- If harvesting takes place or is planned on areas on which ANR activities take place, this area must be considered area under harvest as specified in Section 8.2.7.

- The area on which emission reductions/removals from ANR activities are generated must never exceed the total area that would have been deforested under the baseline scenario . For example, if the baseline scenario includes 500 ha of deforestation per year of which 100 ha becomes forest again due to natural reforestation every year, ANR activities may only be planned for 400 ha in the first year, 800 ha, in the second and1200 ha in the third..

Note that the total size of the areas on which ANR activities are planned must be specified either in the project description (PD) or the monitoring report depending on when the ANR activities are implemented. For example, if ANR is implemented in a given area between the first and second verification, the total size of the area where ANR is to be implemented must be reported in the second monitoring report and the exact location of the ANR activities must be identified at verification.

4.2.2 Conditions Related to Optional Cookstove and Fuel Efficiency Activities

Implementing cookstove and fuel efficiency (CFE) activities as described in Section 8.2.6 are optional, but are only eligible under this methodology if all of the following applicability conditions are met:

- CFE activities must be implemented by the project proponent managing the project area that is being degraded or deforested, and must be targeted towards households and/or local institutions in the immediate vicinity of the project area,
- Fuelwood use such as collection of fuelwood, and charcoal production must be identified as one of the drivers of deforestation and degradation in the project according to the procedure under this methodology.
- The project forests and leakage belts must be the source for non-renewable biomass in the baseline scenario.
- In the baseline scenario, at least 50% of the households in the reference region must be using traditional cookstoves which can be demonstrated through appropriate local or regional statistics on fuelwood use.

4.2.3 Conditions Related to Optional Harvest Activities in the Project Area

Implementing harvesting in the project area as described in Section 8.2.7 is optional but is only is eligible under this methodology only if the following applicability conditions are met:

- The harvest plan and harvest activities must follow Best Management Practice (BMP) guidance of the country or jurisdiction, if such BMP guidance exists.
- The harvest plan must describe procedures to protect soil, water and residual trees in the harvest area and provide documentation on the presence/absence of any threatened or endangered species on the site, potential impacts on species and mitigation measures that will be employed.

- The harvest plan must describe the biophysical sustainability of the harvesting practices. At minimum, the biophysical sustainability must be demonstrated by ensuring that the net removal of biomass from harvesting is less than the net increment of the biomass in the forest. Where possible, the project proponent should use criteria and indicators such as from International Tropical Timber Organization (ITTO) to assess the sustainability of harvesting practices. In addition, it is recommended to obtain sustainability certification from third parties, such as the Forest Stewardship Council or the Sustainable Forestry Initiative.

4.2.4 Conditions Related to Optional Intensification of Annual Crop Production Systems as a Leakage Prevention Activity

Intensification of annual crop production systems as a leakage prevention activity (see Section 8.3.4.1) is optional, but is only eligible under this methodology if all of the following applicability conditions are met:

- The agricultural intensification measures must be implemented only on land that is located within the leakage belt.
- The agricultural intensification measures must be implemented on land on already under annual crop production systems at the time of validation.
- The agricultural intensification measures must not be implemented on organic soils.

4.2.5 Conditions Related to an Optional Increase in Flooded Rice Production Systems as a Leakage Prevention Activity

The introduction of flooded rice production systems as a leakage prevention activity (see 8.3.4.2) is optional, but is only eligible under this methodology only if all of the following applicability conditions are met:

- Flooded rice production systems must be implemented on land that is located within the leakage belt.
- Flooded rice production systems must be implemented on land that is already under annual crop production systems at the time of validation.
- The flooded rice production systems cannot be implemented on organic soils.
- The N_2O emissions from flooded rice production systems must be insignificant.

4.2.6 Conditions Related to an Optional Increase in Livestock Stocking Rates as a Leakage Prevention Activity

Increasing livestock stocking rates as a leakage prevention activity (see 8.3.4.3) is optional, but is only eligible under this methodology if all of the following applicability conditions are met:

- Increased stocking must only occur within the leakage belts of the project area, not within the project boundary.

- If the proposed activity produces forage to feed livestock, all forage must have a similar nutritional value and digestibility, and support only a single livestock group with a single manure management system.
- If the stocking rate is increased for animals that are already in a zero-grazing system or are moved to a zero-grazing system then the grazing activity that is monitored must be the production of fodder.
- Increased stocking rates must only occur on identified forest land, identified cropland, identified grassland, and unidentified land).
- Increased stocking rates must not occur on settlements, wetlands, or other lands as defined by the GPG LULUCF (i.e., bare soil, rock, ice, and all unmanaged land areas that do not fall into category of forest land, cropland, grassland, settlements or wetlands).

5 PROJECT BOUNDARY

5.1 Gases

This methodology requires accounting of all potential emissions of CO_2, N_2O and CH_4 from sources not related to changes in carbon pools, henceforward referred to as emission sources (Table 1). Insignificant emission sources may be excluded according to the VCS rules if insignificance can be demonstrated after using the latest version of CDM *Tool for testing significance of GHG emissions* in EB31 Appendix 16.

Table 1: GHG emissions from sources not related to changes in carbon pools (emission sources) to be included in the GHG assessment.

<table>
<tr><th colspan="2">Source</th><th>Gas</th><th>Include?</th><th>Justification/Explanation</th></tr>
<tr><td rowspan="3">Baseline</td><td rowspan="3">Baseline Deforestation and Forest Degradation</td><td>CO2</td><td>Optional</td><td>Emissions are related to changes in carbon pools. Include only when the degradation has not been included in the estimation of changes in carbon pools and if CFE activities are implemented.</td></tr>
<tr><td>CH_4</td><td>Optional</td><td>Conservatively omitted except when CFE activities are implemented.</td></tr>
<tr><td>N_2O</td><td>Optional</td><td>N_2O emissions from burning woody biomass are assumed negligible and conservatively excluded except when CFE activities are implemented.</td></tr>
<tr><td rowspan="2">Project</td><td rowspan="2">Cookstove and Fuel Efficiency (CFE) activities</td><td>CO_2</td><td>Optional</td><td>Emissions are already included in the changes of carbon pools. Include only when the degradation has not been included in the estimation of changes in carbon pools.</td></tr>
<tr><td>CH_4</td><td>Yes</td><td>CH_4 emissions of burning woody biomass in CFE activities are significant.</td></tr>
</table>

		N_2O	Yes	N_2O emissions of burning woody biomass in CFE activities are significant.
	Biomass burning from unplanned large and small scale fires	CO_2	No	Emissions are already included in the changes of carbon pools
		CH_4	No	CH_4 emissions of burning woody biomass from unplanned fires are insignificant. If the fires are catastrophic, CH_4 emissions must be estimated and demonstrated negligible or otherwise accounted for.
		N_2O	No	N_2O emissions of burning woody biomass from unplanned fires are insignificant, unless fires are catastrophic, N_2O emissions must be estimated and demonstrated negligible, or otherwise accounted for.
	Fossil fuel used during harvesting	CO_2	No	Emissions from fossil fuel combustion is considered de-minimis for REDD.
		CH_4	No	Insignificant
		N_2O	No	Insignificant
	Removal of woody biomass for fire prevention and suppression activities	CO_2	Yes	Emissions related to changes in carbon pools are taken into account
		CH_4	Yes	CH_4 emissions from removal of woody biomass are significant when prescribed burning is used to clear the land.
		N_2O	No	N_2O emissions from burning woody biomass are assumed negligible and conservatively excluded.
	Removal of woody biomass during assisted natural regeneration (ANR) activities	CO_2	Yes	Emissions related to changes in carbon pools are taken into account
		CH_4	Yes	CH_4 emissions from removal of woody biomass are significant when fire is used in preparing the land for ANR activities
		N_2O	No	N_2O emissions from burning woody biomass during ANR activities are assumed negligible and conservatively excluded.
	Fertilizer used during enrichment planting for assisting natural regeneration	CO_2	No	Assumed negligible
		CH_4	No	Assumed negligible
		N_2O	No	Assumed negligible per VCS guidance
	Increased area of	CO_2	No	Assumed negligible

	rice production systems	CH_4	Yes	CH_4 emissions from rice cropping systems are significant
		N_2O	No	Assumed negligible per VCS guidance
	Increased fertilizer use	CO_2	No	Not applicable
		CH_4	No	Not applicable
		N_2O	No	N_2O emissions related to increased fertilizer use are de minimis
	Increased livestock stocking rates	CO_2	No	Not applicable
		CH_4	Yes	CH_4 emissions related to increases in livestock stocking rates are significant
		N_2O	Yes	N_2O emissions related to increases in livestock stocking rates are significant

5.2 Carbon Pools

Table 2 summarizes the carbon pools that must be included in projects following this methodology.

Table 2: Selected Carbon Pools

Carbon Pool	Included?	Justification/ Explanation of Choice
Aboveground tree biomass	Yes	Major carbon pool affected by project activities
Aboveground non-tree biomass	Yes / Optional	Expected to increase from project activities. Must be included when the land cover under the baseline scenario is perennial tree crop. May be excluded when baseline land cover is annual crop or pasture grass.
Belowground biomass	Optional	Major carbon pool affected by project activities. May be conservatively excluded.
Dead wood	Optional	Major carbon pool affected by project activities. May be conservatively excluded. If included either or both of standing or lying deadwood may be included.
Litter	No	Excluded as per VCS *AFOLU Requirements*.
Soil organic carbon	Optional	Conservative to exclude since this pool is expected to decrease under the baseline scenario. However, may be only included per VCS *AFOLU Requirements* on the condition that the land cover under the baseline scenario is comprised of annual cropping systems.
Wood products	Yes	Major carbon pool affected by project activities

5.3 Spatial Boundaries

The spatial boundaries of (1) the project area, (2) the leakage area and (3) the reference region or the JNR Area if a project is nested within a jurisdictional REDD+ program. The spatial boundary must be unambiguously defined in the PD. Project proponent must provide digital (vector-based) files of the discrete project area parcels in Keyhole Markup Language (KML) file format or any other format required by *VCS Standard*. The project area may be contiguous or consist of multiple adjacent or non-adjacent parcels i.e., discrete project area parcel. A leakage belt for each discrete project area parcel must be defined, if applicable. The leakage area is the sum of the individual leakage belts. The reference region excludes the project and leakage areas. Therefore, as new project and leakage areas are defined over the course of the project crediting period as new project activity instances (i.e., discrete project area parcels) are added, project and leakage areas must be excluded from the reference region polygon.

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

Under this methodology, the most plausible baseline scenario for a project is the existing or historical changes in carbon stocks in the carbon pools within the project boundary. This baseline scenario is consistent with scenario identified in the CDM Modalities and Procedures for afforestation and reforestation, project activities (Decision 5/CMP.1), paragraph 22, option (a):

Existing or historical, as applicable, changes in carbon stocks in the carbon pools within the project boundary.

This option was selected because under the mosaic typology of deforestation, the historical changes in land-use are representative for the most likely future changes in land-use. The most appropriate future scenario is that historical rates, change in rate, and dynamics of deforestation and forest degradation will continue in the future.

The net GHG sources and sinks under the baseline scenario must be estimated *ex-ante* for each year of the crediting period. Once validated, the baseline is to be used for the calculation of actual NERs. Baseline calculations remain valid only for a limited period of time and must be updated in accordance with the VCS rules on renewal of baselines. The procedure for updating the baseline is specified in Section 9.3.9.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

Projects must apply the latest version of the VCS *Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities* to demonstrate additionality.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions for Projects

8.1.1 Select Spatial Boundaries

This step includes the demarcation of the project area and the reference region. Note that the demarcation of the leakage area is included in Section 8.3.2.2.

8.1.1.1 Describe Spatial Boundaries of the Discrete Project Area Parcels

The project proponent must provide digital (vector-based) files of the discrete project area parcels in Keyhole Markup Language (KML) file format as required by *VCS Standard*. A clear description must accompany each file, and the metadata must contain all necessary projection reference data. In addition, the PD must include a table containing the name of each discrete project area parcel, the centroid coordinate (latitude and longitude using a WGS1984 datum), the total land area in hectares (ha), details of tenure/ownership and the relevant administrative unit it belongs to (county, province, municipality, prefecture, etc.). New discrete project area parcels (referred to as new project instances) may be integrated into an existing project after the project starts and must be verified for crediting.

8.1.1.2 Select a Valid Reference Region

A reference region must be representative of the future trajectory of the project area in absence of the project activities. For a reference region to be fully representative, and selected without any bias, the following necessary conditions must be met:

- The minimum size of the reference region excluding the project area and leakage area must be 250,000 ha or the size of the project area at the start of the crediting period, whichever is greater. If the entire country or autonomous territory is less than this size, then the reference region must be equal to the entire country or that territory. When a project area is located on an island which is smaller than the required reference region, then it is sufficient to have the entire island as the reference region.
- The boundaries of the reference region must be unbiased and coincide with a combination of natural, geopolitical, satellite footprint, and/or watershed boundaries, or boundaries that were created by applying a distance buffer around the discrete project parcels. A natural boundary is a boundary of a naturally occurring phenomenon such as a river, mountain range, lake, ocean, or watershed. Where possible, natural boundaries that coincide with administrative or jurisdictional boundaries so that land-use and land cover related policies are consistent across the reference area must be selected.
- The project proponent must demonstrate that the reference region does not contain areas where agents of deforestation have restricted acces**s**. Include maps where the reference region and the project area have been overlaid with maps of protected areas, including:
    - National parks that are effectively protected.

- Military bases or installations.
- Areas under conservation that are effectively protected.
- Areas under a logging or economic land concession where access is effectively being restricted.
- Large plantations that are effectively protected.

- The reference region must exclude areas where planned deforestation activities took place. It must be demonstrated that planned deforestation areas have been excluded from the reference region or proof of non-existence of such areas within the reference region must be provided.
- The reference region must exclude deforested areas caused by natural (non-anthropogenic) large-scale, extraordinary events (e.g. geological and weather impacts which are infrequent but significant in their impact on the landscape). Such areas are excluded from the reference region since these are not likely to occur within the project area during the crediting period.
- The project proponent must demonstrate that the reference region contains, at minimum, 15% forest cover at the beginning of the crediting period**,** unless the reference region encompasses a whole country or island[3]. This condition must be explicitly checked using the classification that is developed under Section 8.1.2 of this methodology.
- The project proponent must compare a number of key variables between the reference region and project area according to the procedures outlined in Table 3 below. Areas in the potential reference region where one or more of these variables differ from the project area are not eligible and must be excluded from the reference region.

These conditions are designed as safeguards against biases caused by arbitrary boundary demarcation. However, it is impossible to provide a sufficient set of rules to avoid bias under all project circumstances. Therefore, at validation, the validation/verification body must determine that the selection of the reference region is truly unbiased.

The reference region may include project area and leakage belts initially, but the project area and leakage belts are excluded from the reference region after the start of the crediting period. Additionally, whenever new instances of project areas and leakage areas that were previously included in the reference region are added into the existing project area, the new added instances must be removed from the reference region.

[3] Given historical deforestation, the reference region is likely to have a significantly higher percentage of forest cover at the beginning of the historical reference period.

Table 3: Comparison variables to demonstrate similarity between project area and reference region.

Category	Variable	Comparison procedure	Explanation
Drivers of deforestation	Drivers of deforestation	All drivers that were identified in the project area must also be present in the reference region. A comparison of the existence of every driver between the project area and the reference region must be carried out. The similarity between the project area and the reference region drivers must be documented and justified with relevant evidence.	Since the reference region will be used to determine baseline deforestation and degradation rates in the project area, the drivers of deforestation must be similar in the reference area and the project area.
Landscape configuration	Distribution of native forest types	The proportion of each forest type within the reference region (see Section 8.1.2.2) at the beginning of the historical reference period must be within 10% of forest type proportions within the project area. Percentages must be calculated relative to the total area of forests, not the total land area.	Deforestation and land-use change dynamics are highly dependent on geographical conditions. For example, if the project is to protect montane forest at the top of a watershed then lowland and valley forests should not be used as a reference region.
	Elevation	The proportion of area contained within 500-m elevation classes of the reference region must be within 10% of these elevation class proportions in the project area.	
	Slope	The proportion of area contained within 5% slope classes of the reference region must be within 10% of these slope class proportions in the project area.	
Socio-economic and	Land-tenure status	The land-tenure system prevalent in the reference	The specific land tenure system impacts the rate of

cultural conditions		region must be demonstrated to be similar to the land-tenure system in the project area with reference to peer-reviewed literature, reports, or expert opinion. Any differences in land tenure systems between the project area and reference region must not affect the drivers of deforestation and degradation or the operation of the agents of deforestation and degradation	land use changes, and must therefore be similar between the project area and reference region, especially in terms of how the land tenure system may impact access and mobility of the agents or influence the drivers of deforestation and degradation.
	Policies and regulations	The reference region must be governed by an administrative unit that has comparable enforced policies, regulations and capacities as the administrative unit of the project area.	Different governing bodies may have a different legislative framework or capacity for enforcement. It has to be demonstrated that the forest is similar in the reference region and project area.
	Degree of urbanization	Proportion of urbanized and agriculture-based population within the reference region must be within 10% of this proportion in the project area.	People living in urban areas have a significantly different relation to forest land compared to people that are agriculture-based.

8.1.2 Analyze Historical Deforestation and Forest Degradation in the Reference Region

8.1.2.1 Describe Data Sources

The quantification of deforestation and forest degradation rates under this methodology is based in part on remote sensing and other spatial data. The selection of data sources must follow Chapter 3A.2.4 of the IPCC 2006 GL AFOLU. Table 4 below lists the data that are required. This table also outlines the information about these data that must be documented in the PD. At least three images of forest cover are required during the historical reference period, (1) at minimum one image from 0-3 year before project start date, (2) at minimum one image from 4-9 years before project start date, and (3) at minimum one image from 10-15 years before project start date. No images older than 15 years may be used for the historical reference period.

Table 4: Information to be reported with respect to remote sensing and other spatial data employed for assessing deforestation and forest degradation.

Data Source	Main Use for Data	Information Needed about the Data Collected
High to medium resolution (≤ 30 m) remote sensing data are required for at least three time points: (1) at least one image from 0-3 years before project start date, (2) at least one image from 4-9 years before project start date, and (3) at least one image from 10-15 years before project start date. No images older than 15 years may be used for the historical reference period.	Historical analysis of deforestation and forest degradation	Source Type Resolution (spatial and spectral) Acquisition date Coordinate system and pre-processing If different sources of remote sensing data are used, a formal comparison of the sensors should be added to the monitoring report to ensure consistency.
Readily available LULC maps which are already processed are complementary	Training of classification procedures Independent verification of the analysis of historical images	Minimum Mapping Unit (ha) Description of method used to produce these data Descriptions of the LULC classes and/or LULC-change categories Information on how these classes may match with IPCC classes and categories
Recent (< 5 yr) high resolution (< 5 m) remote sensing data is required for at least part of the reference region at a time point coinciding with one of the	Training of classification procedures. Ground-truthing and check of accuracy	Source Type Resolution (spatial, spectral) Acquisition date Coordinate system and pre-

medium-resolution remote sensing images.		processing
Direct field observations or visually interpreted locations from remote sensing images are required for calibration of the classification and stratification procedures and validation of the calibration and classification accuracy.	Training of classification procedures. Ground-truthing and check of accuracy	Acquisition date Type of data coordinate system Location of coordinates

8.1.2.2 Define LULC Classes and Forest Strata

The ultimate goal of a classification and stratification system is to partition an analysis area, into LULC classes or forest strata that are homogeneous in carbon stock density, in a cost-effective and practically-feasible way. The exact number and type of LULC classes and forest strata used is project-specific and dependent on local conditions. A number of iterations between the remote sensing image analysis and LULC class and forest strata definitions may be necessary before an optimal classification is attained. The same LULC classification and forest stratification must be developed for and applied to all analysis areas (i.e. reference region, project area and leakage area) and crediting periods in order to avoid any spatial or temporal bias in carbon accounting.

The result of forest stratification reflects the current condition or state, and not the process of change or future evolution of a specific forest stratum. A degraded forest stratum will regenerate if drivers of deforestation are restricted. In contrast, a low-density, open forest may stay in a low-carbon state due to persistent biophysical conditions and constraints. Although their future evolution will be different, these two forest systems may share similar carbon stock densities for a time.

A sound definition of LULC classes and forest strata is crucial for accurate and conservative carbon accounting. The project proponent must demonstrate that the LULC classes and forest strata identified will not lead to systematic overestimation of carbon losses in the baseline and therefore overall emission reductions/removals attributed to the project. This assessment must be done after biomass density values are available for each LULC class or forest stratum, as described in Section 8.1.4.4.

LULC classification and forest stratification must be conducted for the whole analysis area, which is the union of the reference region, leakage area and project area, as follows:

- Include, at minimum, the six IPCC LULC classes (Forest Land, Crop Land, Grassland, Wetlands, Settlements, and Other Land) in the LULC class definitions. The definition of these classes must be consistent with Chapter 2 of the IPCC GPG-LULUCF 2003. In cases where the country has defined more specific LULC classes than the IPCC classes, these definitions must be used if they are accurate enough for project-specific classification.
- The minimum mapping unit for LULC classes must be less than 1 ha.

- To achieve the goal of defining classes that are homogeneous in carbon stock density, the forest LULC class must be sub-divided into forest strata. Forest land is usually heterogeneous in terms of local climate, soil condition, forest canopy cover, and forest type. Forest stratification can help define homogeneous units with reduced variance in terms of carbon stock density, and thereby increase the measurement precision without increasing cost, or reduce the measurement cost without reducing precision.
- If emissions from avoided degradation are included, appropriate forest strata representing regeneration stages must be included as well. Because emission reductions are discounted based on the uncertainty of the biomass inventory, stratifying forest may lead to increased emission reductions.
- It is recommended that forest stratification be based on an assessment of the key factors that influence carbon stocks in the included carbon pools such as soil features, local climate, landform (e.g., elevation, slope, and aspect), forest type, dominant tree species, soil erosion intensity, forest management, regeneration stage and human degradation intensity using a GIS analysis augmented with forest surveys.
- Managed forests must be divided into different forest strata according to the forest management regimes, unless the differences in management among regimes do not lead to significant differences in carbon density during the baseline validation period.
- The accuracy of stratification maps must be determined using the procedures described in Section 8.1.2.7
- All areas that will be subject to ANR activities within the project area[4] must be further divided into forest strata according to the specific silvicultural management activities that will be employed on these areas. The project proponent must present maps of the stratified project areas in the PD.
- All areas that will be subject to harvest activities within the project area must be further divided into forest strata according to the harvest plan. The project proponent must present maps of the stratified project areas in the PD.

8.1.2.3 Define Land Transitions between LULC Classes/Forest Strata

A list of the expected land transitions must be included in the PD in the form of a LULC and forest strata transition matrix.

Land that only temporarily transitions from forest to non-forest and transitions back to forest after a short while is considered temporarily unstocked forest and may not be counted towards the total deforestation and increased forest cover rates. For every deforestation transition, select the maximal period that the “from” forest stratum can be out of forest cover and is temporarily unstocked. Use a default value of two years, unless project-specific

[4] ANR activities are carried out only in areas that would otherwise be deforested in the baseline scenario which is different from Afforestation and Reforestation activities.

conditions demand a different period.

By definition, degradation is a process that must have persisted for at least 3 years. In other words, forest land that transitions from a stratum with a larger carbon density stock to a stratum with smaller carbon density stock can only be considered degradation if it has persisted for 3 years.

8.1.2.4 Analyze Historical LULC Class and Forest Strata Transitions

The historical rates of all LULC classes and forest strata transitions must be calculated on the union of the reference region, leakage area, and project area, based on a remote sensing analysis executed by the project proponent. However, existing classification or stratification maps can be used if (1) the classes or strata in these maps can be matched to the LULC class and forest strata definitions developed according to this methodology and (2) the accuracy of these maps is quantified using the procedures in Section 8.1.2.7.

A wide range of remote sensing products exist for LULC classification and forest stratification based on optical, multispectral, RADAR or LiDAR sources, and acquired from airborne or satellite platforms. The most appropriate data product is dependent on project conditions and requirements. The analysis of land cover change must be performed by processing and analyzing remote sensing data in three steps described in the following sections:

- Pre-processing of remote sensing data.
- LULC classification and forest stratification.
- Accuracy assessment and discounting factor determination.

8.1.2.5 Pre-processing of Remote Sensing Data

Pre-processing includes geometric correction and handling image data loss due to cloud cover.

- Geometric correction ensures that images in a time series overlay properly to each other and to other GIS maps used in the analysis (i.e. for post-classification stratification). The average location error between two images (RMSE) must be less than or equal to one pixel.
- Clouds or cloud shadows must be masked out and excluded from the calculation of deforestation rates. The maximum allowable cloud cover is ≤ 20% for a single image or ≤ 20% on average across image pairs used in the transition rate analysis.
- A forest benchmark map must be generated to show forest cover status in the project and leakage areas. The final LULC map in the historic series can be used as the forest benchmark map, however missing values within the project and leakage areas due to cloud and cloud shadow must be filled with RS data acquired within three years before the start of the crediting period to be eligible. Geographic areas for which no cloud-free or cloud-shadow-free imagery is available within three years of the project start must be excluded from the project area. These may only be added back to the project area at verification following the rules of

"Additions of New Project Area" set out in Section 9.3.

- Calculation of GHG benefits in the project and leakage areas after the project start must include only cloud-free imagery. When clouds and cloud shadows are present, calculation of the GHG benefits from these areas must be postponed until cloud-free remote sensing data is available in a subsequent monitoring period. These temporarily halted NERs may be added to the NERs generated in the subsequent monitoring period. This is only allowed on areas for which the forest status was unambiguously demonstrated at the beginning of the crediting period (see previous point).

Consult experts and literature for further advice on pre-processing techniques. Duly record all pre-processing steps for later reporting.

8.1.2.6 LULC Classification and Forest Stratification

LULC classification and forest stratification may be (sub-) pixel based or segment-based. Attribution of classes to pixels or segments must be done using widely accepted methods such as maximum likelihood, decision trees, or support vector machines. Ancillary data may be included to improve classification accuracy. Typical ancillary data includes climate, soil, elevation, slope, proximity to certain built or natural features (e.g. roads, settlements, or water bodies), and land tenure status (e.g. protected forest, logging concession, indigenous reserve, etc.). The minimum mapping unit for LULC classification and forest stratification must be set according to the forest definition employed for the project, but must be less than 1 ha (see Section 3.2).

If emission reductions from avoided degradation are included, a forest stratification model must be unambiguously defined at validation. The forest stratification model may use input data that includes a combination of optical remote sensing, radar and LiDAR measurements, as well as ancillary data such as topography or LULC classes. The model itself may be rule-based, regression-based, or machine-learning based. However, the parameters of the model may not be changed after validation (ie, the forest stratification model itself is fixed until the next baseline update). In addition, if biomass plot or biomass carbon stock density is used during the development of a forest stratification model, either to develop a regression model or to verify the stratification model, these data may not be used for calculating the biomass stock densities and emission factors of the strata.

8.1.2.7 Map Accuracy Assessment and Discounting Factor Determination

Different procedures to determine discounting factors for the broad classification into forest types or forest/non-forest land and the stratification of forest land into different carbon density classes are imposed.

Discounting factor for LULC classification, $u_{classification}$: The accuracy by which broad LULC classes can be discerned is used to discount emission reductions and/or removals from avoiding deforestation. The discounting factors for LULC classification are fixed until the next baseline update.

The accuracy assessment of LULC classification must be conducted for all LULC maps across the whole analysis area, i.e., the union of the project and leakage areas and the reference region. The accuracy must be assessed by comparing predicted LULC classes for a number of reference locations with independently determined LULC classes. Reference locations must be located throughout the reference region, leakage area, and project area. The LULC classes for these reference locations must be identified using field observations, in-situ maps, remote sensing data, and/or other ground-truthing data. At minimum 50 reference locations per LULC class must be used. If the area of the class exceeds 500 km^2 or the number of classes is more than 12, then, at minimum,75-reference locations per class must be used.[5] The reference locations within each LULC class must be systematically distributed to represent varying topography, parcels and other geographic features.

The accuracy of historic images may be assessed using historic medium to high-resolution images, aerial photographs or local topographic maps existing at the time when the historic image was acquired. At validation, the historic period is relative to the start of the crediting period. However, when a baseline update occurs, the historic period is relative to the current project year, and more historical data may become available to conduct an accuracy assessment at that time. See monitoring Section 9.3.2 for procedures to apply after the project start.

The discounting factor for the LULC classification is determined in three steps:

- **Step 1**: Determine the accuracy of LULC classification for each map by creating a confusion matrix. Report the overall accuracy, and the commission and omission errors (see Congalton 1991 and Pontius 2002 for an in-depth explanation of these concepts).
- **Step 2**: Multiply the accuracy of LULC classification from step 1 with a factor based on the smallest accuracy of all maps (see Table 5 below). If the accuracy of broad LULC classification is less than 70%, the project is not eligible under this methodology.

Table 5. Uncertainty deduction factors for LULC classification as a function of accuracy attained.

Accuracy attained	STEP 2 factor
≥85%	1.00
≥80 to <85%	0.80
≥75 to <80%	0.75
≥70 to <75%	0.70
<70%	Project is not eligible

[5] The specification of the number of reference locations is based on recommendations by Congalton (1991), Hay (1979) and Fenstermaker (1991).

- **Step 3**: Multiply the factor from Step 2 with a factor based on the number of images in the historical reference period to get $u_{classification}$, the total discounting factor for avoiding deforestation as indicated in Table 6, An absolute minimum of three images is required to quantify the historical deforestation rate.[6]

Table 6. Uncertainty deduction factors for LULC classification as a function of number of images in historical reference period.

Number of images in historical reference period	STEP 3 factor
1-2	Project is not eligible
3	0.90
>3	1.00

The classification accuracy of every map used for verification must be greater than the smallest accuracy obtained during the historical reference period. The $u_{classification}$ factor must be fixed at validation until the next baseline update, even when the classification accuracy improves after the start of the project.

Discounting factor for forest stratification, $u_{stratification}$: As forest strata are determined by their carbon content, the full uncertainty of stratification can be assessed in an unbiased way through the discounting factor for the carbon stock density of the stratum, as explained in Section 8.1.4.4. However, there are two important conditions for this statement to be true:

- The plots used in calculating the uncertainty of the carbon stock density were not used to develop the forest stratification model; and
- The plots used in calculating the uncertainty are randomly selected and represent all time points that are covered.

While the first is covered by the requirement that different plots must be used for creating the forest stratification model and determining the carbon stock density and its uncertainty, the second can only be fulfilled if biomass plot densities measured and assessed at multiple times are used in the calculation of the carbon stock density and the associated uncertainty following Section 8.1.4.4. Since it is unlikely that a project will have historical biomass inventories available, the methodology allows using biomass inventories collected at different time points after the project start date to estimate $u_{stratification}$, the discounting factor for forest stratification. Further, to incentivize a sound monitoring effort by the project proponent, the discounting factor for forest stratification is dependent on the number of time points available in biomass inventories. Note that there must be at least one year in between time points for biomass inventories. Finally, it is allowed to only use biomass inventories that are located within the project area on conditions that these plots do not cause any bias and that these plots are representative of the stratum and/or LULC of the reference region.

[6] Note that when baselines are updated during the crediting period, a similar procedure must be used to update baseline deforestation rates. The historical reference period always ends at the time of the baseline update. Therefore, gradually more data points will become available during the crediting period, and eventually eliminate this discounting.

Table 7. The discounting factor for forest stratification as a function of the number of time points available in biomass inventories.

Number of time points available in biomass inventories	$u_{stratification}$
1	0.75 for ex-ante; not eligible for ex-post
2	0.75
3	0.90
>3	1.00

For example, if validation is done separate from verification, only 1 set of biomass inventories is available at validation, therefore $u_{stratification}$ must be set to 0.75 for ex-ante calculations. At first verification, the project proponent is required to measure an additional set of biomass plots so that at least 2 time points of biomass inventories are available. Section 8.1.4.4 explains how to update the average carbon stock density values and the uncertainty associated with them when plot measurements from multiple times are available. Therefore, at first verification, $u_{stratification}$ remains 0.75 according to the table above. At second verification, the project proponent has a choice to either not measure additional plots and keep $u_{stratification}$ at 0.75, or measure a third set of biomass inventories and use 0.9 as $u_{stratification}$.

In contrast to $u_{classification}$, $u_{stratification}$ is not fixed at validation and may be updated at verification

8.1.2.8 Summarize all Historical Land Transitions

For every pair of subsequent images in the historical reference period, calculate the area of each land transition and report in a LULC and forest strata transition matrix. Note that for deforestation, lands should have been without forest cover for longer than the period defined as temporarily un-stocked. Likewise, for degradation, lands must have been in the smaller carbon stock density stratum for at least 3 years. Apply an appropriate temporal filter to ensure that only land that meets the three-year condition is designated as degradation. In addition, the PD must contain a table which contains the overall areas (ha) of deforestation, increased forest cover, forest degradation, and regeneration for each sub-period. These data will be used to project future land use change (Section 8.1.5.1).

8.1.3 Analyze the Agents and Drivers of Deforestation and Degradation

Deforestation can be the result of a short-term process (e.g., forest clear-cutting) or a gradual progressive process referred to as forest degradation (see definitions). Therefore, it is often challenging to distinguish agents/drivers of deforestation from agents/drivers of forest degradation. As a consequence, throughout this document, the term agents/drivers of deforestation is used for agents/drivers of deforestation and forest degradation. The drivers of deforestation and/or forest degradation must be those set out under the applicability conditions.

The PD must contain an analysis of the agents of deforestation and drivers similar to the analysis in Angelsen and Kaimowitz (1999) and Chomitz et al. (2006) by performing four steps, as described below.

8.1.3.1 Identify Agents and Drivers of Deforestation and Forest Degradation

For each of the ten included categories of drivers covered by this methodology that are present in the reference region, the main agents must be identified. Agents of deforestation may include small-scale farmers, encroachers, hunters, ranchers and loggers. In some cases, one or more of the listed categories of drivers need to be sub-divided into separate individual drivers based on main agents acting on particular drivers. A qualitative analysis of the broader underlying forces determining the agents' motivations for deforestation and forest degradation must be included. Where relevant to a driver, the following aspects must be considered in this analysis:

- Population pressure.
- Poverty.
- War and other types of conflicts and their effects.
- Changes in policies related to subsidies or payments for environmental services
- Property and land tenure regime.
- Market forces influencing land and commodity prices.

8.1.3.2 Assess the Relative Importance of the Drivers of deforestation

The relative contribution of each of the drivers of deforestation to the total historical deforestation and forest degradation is estimated in two steps: (1) estimating the absolute annual carbon loss per driver, and (2) estimate the relative contribution of each driver to the total carbon loss from deforestation and degradation.
Sub-Step 1: Estimating the absolute annual carbon loss per driver using the formulas in Table 8, which are based on GPG-LULUCF.

Table 8. Formulas to calculate the absolute annual carbon loss per deforestation or forest degradation driver category

No.	Driver category	Annual carbon loss
1	Conversion of forest land to cropland for subsistence farming	$$L(1) = CF \cdot \sum_{i=1}^{nrStrata} \left(\Delta area_{cropland,baseline}(i) \cdot \left(OM(i) - OM(cropland)\right)\right)$$ [EQ1] (Equation 3.3.8 from GPG LULUCF)
2	Conversion of forest land to settlements	$$L(2) = CF \cdot \sum_{i=1}^{nrStrata} \left(\Delta area_{settlement,baseline}(i) \cdot \left(OM(i) - OM(settlement)\right)\right)$$ [EQ2] (Equation 3.3.8 from GPG LULUCF)
3	Conversion of forest land to infrastructure such as roads, cell phone tower, power lines	$$L(3) = CF \cdot \sum_{i=1}^{nrStrata} \left(\Delta area_{infrastructure,baseline}(i) \cdot \left(OM(i) - OM(infrastructure)\right)\right)$$ [EQ3] (Analogous to Equation [EQ2])
4	Logging of timber for commercial sale	$$L(4) = CT_{baseline} \cdot \rho_{wood} \cdot BEF_2 \cdot CF$$ [EQ4] (Equation 3.2.7 from GPG-LULUCF)
5	Logging of timber for local enterprises, and domestic uses	$$L(5) = DT_{baseline} \cdot \rho_{wood} \cdot BEF_2 \cdot CF$$ [EQ5] (Equation 3.2.7 from GPG-LULUCF)
6	Wood collection for commercial on-sale of fuelwood and charcoal	$$L(6) = CFW_{baseline} \cdot \rho_{wood} \cdot BEF_2 \cdot CF$$ [EQ6] (Equation 3.2.8 from GPG-LULUCF)
7	Fuelwood collection for domestic and local industrial energy needs	$$L(7) = DFW_{baseline} \cdot \rho_{wood} \cdot BEF_2 \cdot CF$$ [EQ7] (Equation 3.2.8 from GPG-LULUCF)
8	Grazing	$$L(8) = CF.GR_{baseline}$$ [EQ8] (Adaption of Equation 1 of CDM A/R Methodological Tool *Estimation of GHG emissions related to displacement of grazing activities in A/R CDM project activity*)
9	Understory vegetation collection	$$L(9) = CF \cdot VG_{baseline}$$ [EQ9]

		(Analogous to Equation [EQ9])
10	Forest fires	$L(10) = CF.\sum_{i=1}^{nrStrata} \Delta area_{fire,baseline}(i) \cdot E \cdot P \cdot OM(i)$ [EQ10] (Equation 3.2.9 from GPG-LULUCF)

where:

$L(d)$	Annual carbon loss associated with driver d. [Mg C yr^{-1}]
ρ_{wood}	Basic wood density, estimated using Table GPG-LULUCF 3A.1.9. [Mg DM m^{-3}]
BEF_2	Biomass expansion factor for converting volumes of extracted round wood to total aboveground biomass (including bark), estimated using GPG-LULUCF Table 3A.1.10. [-]
CF	Carbon fraction of dry matter (default = 0.5). [Mg C (Mg DM)$^{-1}$]
$nrStrata$	Number of deforestation and forest degradation strata. [-]
$\Delta area_{fire,baseline}(i)$	Annual forest areas in the project area affected by disturbances from forest fires. [ha yr^{-1}]
E	Average combustion efficiency of the aboveground tree biomass. [-]
P	Average proportion of mass burnt from the aboveground tree biomass; estimate from GPG-LULUCF Table 3A.1.13 relative to C_{class1} . [-]
$OM(i)$	Average organic matter for forest stratum i. [Mg DM ha^{-1}]
$\Delta area_{cropland,baseline}(i)$	Forest area converted from forest stratum i to cropland at the beginning of the crediting period. [ha yr^{-1}]
$OM(cropland)$ $OM(settlement)$ and $OM(infrastructure)$	Average organic matter of cropland, settlement, developed infrastructure respectively; [Mg DM ha^{-1}]
$\Delta area_{settlement,baseline}(i)$	Average forest area converted from forest stratum i to settlement land. [ha yr^{-1}]
$\Delta area_{infrastructure,baseline}(i)$ =	Average forest area converted from forest stratum i to developed infrastructures such as, but not limited to, roads, power transmission lines, phone lines, towers etc. [ha yr^{-1}]
$CT_{baseline}$	Annually extracted volume of harvested timber, round wood for commercial on-sale. [m^3 yr^{-1}]
$DT_{baseline}$	Annually extracted volume of timber for domestic and local use, round wood. [m^3 yr^{-1}]
$CFW_{baseline}$	Annual volume of fuelwood gathered for commercial sale and charcoal production in the baseline scenario. [m^3 yr^{-1}]
$DFW_{baseline}$	Annual volume of fuelwood gathered for domestic as well as local energy needs in the baseline scenario. [m^3 yr^{-1}]

$GR_{baseline}$	Total dry matter intake by grazing animals under the baseline scenario. Calculate by multiplying the number of animals taking into account different types of grazing animals [Mg DM yr^{-1}]
$VG_{baseline}$	Biomass (dry matter) of understory vegetation extraction by project participants under the baseline scenario. Calculate by multiplying the number of households involved in extraction of vegetation with the average annual extraction rate by household for different vegetation types [Mg DM yr^{-1}]

Sub-Step 2: Estimating the relative contribution of each driver to the total carbon loss from degradation and deforestation. Carbon losses must be separated into losses from deforestation and losses from degradation. In case of conversion of forestland to cropland and settlements, all of the carbon loss is related to deforestation. However, drivers that have a more gradual carbon decrease (fuelwood collection, wildfires, and logging) will first lead to forest degradation, and eventually deforestation when biomass density becomes smaller than the arbitrary threshold implied under the forest definition. For example, a loss of 25 Mg biomass per hectare on a well-stocked forest of 200 Mg biomass per hectare may, according to the forest definition, be categorized as forest degradation, while the same loss on a poorly-stocked forest of 50 Mg standing biomass per hectare could be deforestation, because the final tree cover has become smaller than the forest cover threshold in the forest definition. The default proportion of the carbon loss from fuelwood collection, wildfires, and logging that leads to deforestation versus forest degradation is estimated depending on specific conditions outlined in Table 9. The default proportion can be modified when justification for such changes can be provided. Such justifications must be based on locally observed scientific publications.

Table 9. Proportion of carbon loss leading to deforestation vs. forest degradation for different drivers.

Driver	$proportion_{DF}(i)$	$proportion_{DG}(i)$
1. Conversion of forest land to cropland	100%	0%
2. Conversion of forest land to settlements	100%	0%
3. Conversion of forest land to infrastructure	100%	0%
4a. Logging for commercial sale by clear cutting[7].	100%	0%
4b. Logging for commercial sale by selection cutting (i.e. by employing either individual tree selection method and/or group selection).	0%	100%
5a. Logging for domestic use as clear cutting.	100%	0%
5b. Logging for domestic use by selection cutting (i.e. by employing either individual tree selection method and/or group selection).	0%	100%
6. Wood collection for commercial on-sale of fuelwood and charcoal.	5%	95%
7. Fuelwood collection for domestic and local industrial energy needs	5%	95%
8. Cattle grazing (i.e., in-forest grazing)	5 %	95%
9. Understory vegetation extraction (i.e., thatch grass collection for roof and livestock bedding materials, shrubs and small trees for straw fences)	50%	50%
10a. Small forest fires to the extent that they are not part of natural ecosystem dynamics	0%	100%
10b. Large crown fires to the extent that they are not part of natural ecosystem dynamics.	100%	0%

The total carbon loss due to deforestation versus forest degradation can be calculated as following:

$$\Delta C_{DF} = \sum_{d=1}^{nrDrivers} proportion_{DF}(d) \cdot L(d)$$

[7] Clear-cutting is defined as removing more than 75% of the trees on an area that is considered as forest in the forest definition used.

$$\Delta C_{DG} = \sum_{d=1}^{nrDrivers} proportion_{DG}(d) \cdot L(d)$$

where:

ΔC_{DF}	=	Total carbon loss due to deforestation. [Mg C yr^{-1}]
ΔC_{DF}	=	Total carbon loss due to degradation. [Mg C yr^{-1}]
$nrDrivers$	=	Number of drivers of deforestation or forest degradation. [-]
$proportion_{DF}(d)$ and $proportion_{DG}(d)$	=	Proportion of the gradual carbon loss that leads to deforestation or forest degradation, respectively, due to driver d. Estimate using the procedure detailed in Table 9.
$L(d)$	=	Annual carbon loss associated with driver d. [Mg C yr^{-1}]

The relative importance of the deforestation and forest degradation drivers can be calculated by combining the absolute carbon losses from Table 8 with the contributions from Table 9 using the following formula (as an example for the first driver):

$$contribution_{DF}(i) = \frac{proportion_{DF}(d) \cdot L(d)}{\Delta C_{DF}}$$

$$contribution_{DG}(i) = \frac{proportion_{DG}(i) \cdot L(d)}{\Delta C_{DG}}$$

where:

$contribution_{DF}(d)$	=	Relative contribution of driver i to the total deforestation. [-]
$contribution_{DG}(d)$	=	Relative contribution of driver i to the total forest degradation. [-]
$proportion_{DF}(d)$	=	Proportion of the gradual carbon loss that leads to deforestation. [-]
$proportion_{DG}(d)$	=	Proportion of the gradual carbon loss that leads to degradation. [-]
ΔC_{DF}	=	Total carbon loss due to deforestation. [Mg C yr^{-1}]
ΔC_{DG}	=	Total carbon loss due to degradation. [Mg C yr^{-1}]
$L(d)$	=	Annual carbon loss associated with driver d. [Mg C yr^{-1}]

8.1.3.3 Analyze of the Mobility of Each Deforestation and Forest Degradation Driver

The geographical extent of leakage is, in part, dependent on the mobility of each agent of deforestation. It must be determined how far each agent of deforestation is willing to go to acquire the forest resource or clear the land for cropland, grassland or settlement.

- For every driver of deforestation, report the main mode of transportation used by the main agent of deforestation of that driver: on foot, bike, scooter, motorcycle, car, or truck. Substantiate the choice with data from (lower-ranked options may only be used if higher-ranked options are not available) (1) social appraisals, (2) recent (preferably less than 10 years old) peer-reviewed scientific literature conducted among groups similar to the agents of deforestation of the project, (3) consultations with local socio-cultural and anthropological experts.
- Present a table of the average speed by which each identified mode of transportation can cross each of the LULC classes and forest strata and road categories, such as tracks, seasonally accessible small roads, and year-round accessible two-lane roads. Note the average speed on land with restricted access, such as national parks, as 0. Substantiate the choice with data from (lower-ranked options may only be used if higher-ranked options are not available) (1) social appraisals, (2) recent (preferably less than 10-year old) peer-reviewed scientific literature conducted among groups similar to the agents of deforestation of the project, (3) consultations with local socio-cultural and anthropological experts.
- Drivers that are less geographically constrained will still be confined to a “sphere of influence”. For example, illegal timber logging activities may shift outside of project boundary, possibly to outside of provincial boundary, upon inception of REDD project activity. In this case, the sphere of influence of the driver is national. However, for the purpose of this methodology, planned timber concessions, must not be considered within “sphere of influence”.

8.1.3.4 Identify the Quantitative Driving Variables of Deforestation and Forest Degradation

For each identified driver, provide potential spatial driving variables that explain the location of land cover change are also called “predisposing factors” (De Jong, 2007) (to be used in Section 8.1.5.2). The project proponent must select one or more of the following variables that potentially explain the location of deforestation and forest degradation.

- Access to forests (such as vicinity to existing roads, railroads, navigable rivers and coastal lines).
- Slope.
- Aspect.
- Proximity to markets.
- Proximity to industrial facilities (e.g., sawmills, agricultural products processing facilities, etc.).
- Proximity to forest edges.
- Proximity to settlements.

- Soil fertility and rainfall.
- Management category of the land (e.g., national park, logging concession.indigenous reserve, etc.).

Once the agents and drivers of deforestation have been identified, the project proponent must re-assess the similarity between the project area and the reference region, according to the procedure in Section 8.1.1.2. If necessary, adjust the area and location of the reference region to ensure that the same drivers of deforestation are present in both the reference region and the project area.

8.1.4 Determine Emission Factors for All Included Transitions

The project proponent must develop the emission factors following the requirements below.

For each LULC class or forest stratum that could be subject to a transition as identified in Section 8.1.2.3, it is necessary to determine the average carbon stock density, based on sampling plots. Plots may be either permanent or temporary, but the location of the plots must be known and available at the time of verification. Alternatively, on non-forest land, conservative defaults gathered from scientific literature may be used to quantify the carbon stock density. The applicability of these default values must be confirmed by the validator. The number of plots and their location must be determined in a stratified sampling design. The following steps are to be followed:

- Identify the LULC classes and forest strata for which carbon stocks are to be quantified.
- Review existing biomass stock density and biomass increment data for comparison with field measurements.
- Determine the sample size per LULC class or forest stratum.
- Measure carbon density stocks of each LULC class or forest stratum.
- Calculate emission factors for each land transition category.

8.1.4.1 Identify the LULC Classes and Forest Strata for which Carbon Stocks are to be Quantified.

Present a table of the LULC classes and forest strata that are likely to be subject to transitions within the project area or anticipated leakage area based on the land transition matrix.

8.1.4.2 Review Existing Data of Biomass Stock Densities and Biomass Net Annual Increments

Review existing data on biomass stock densities: For the purpose of sampling design and quality assurance of the measured values, all existing data on biomass stock densities must be reviewed. Sources that must be consulted include (lower-ranked options may only be used if higher-ranked options are not available): (1) peer-reviewed scientific literature conducted within the reference region, (2) peer-reviewed scientific literature from an area ecologically similar to the reference region, (3) non peer-reviewed reports or studies from the reference region or similar areas. Sources that contain a measure of the variation of the values (range, standard deviations, standard errors, or coefficients of variation) are specifically useful, since these can be used for preliminary determination of the number of sampling plots required during field sampling. For every data source used, note the following items:

- Methodology (field inventory, extrapolation from satellite imagery, ecosystem model, or GIS analysis).
- Number of measurement plots used.
- Whether all species are included in the sampling.
- The minimum DBH of measured trees in the biomass inventory or any other relevant threshold.
- Region in which the samples were taken.

The carbon stock density on non-forest land may be quantified using conservative defaults gathered from scientific literature. The applicability of these default values must be confirmed by the validator.

For project areas registered within a JNR area and where biomass stock data has been registered under the jurisdictional REDD+ program for the same LULC class and forest strata as in the project area, the most accurate estimates will be used, subject to any requirements specified within the jurisdictional REDD+ program.

Review existing data on net annual increments of biomass: Whereas the GHG benefits from avoided deforestation and avoided forest degradation are based on observed transitions between LULC classes and forest strata, the GHG benefits from ANR activities are based directly on the empirically observed increases in biomass stock densities. Therefore, for accurate ex-ante estimates, all existing data on net annual increments of biomass carbon stocks must be reviewed. Sources that must be consulted include (lower-ranked options may only be used if higher-ranked options are not available): (1) values measured by the project proponent in the project area using the methods used for forest inventories discussed in this methodology, (2) national or local growth curves and tables that are usually used in national or local forest inventories, (3) values from peer-reviewed literature, and (4) values from IPCC GPG-LULUCF (2003) Table 3A.1.5.

8.1.4.3 Determine the Sampling Design, i.e., Number, Location, and Layout of Plots

The determination of the sample size (number of sampling plots) required per LULC class and forest strata that are identified in 8.1.4.1 is dependent on (1) the required precision of at least 15% at a confidence level of 95% and (2) the anticipated variance in the specific LULC class and forest strata. Extra measurement plots must be installed within the ANR and harvest areas to reliably estimate the increase in carbon density. The CDM tool AR-AM Tool 03 *Calculation of the number of sample plots for measurements within A/R CDM project activities* may be used to determine the number of biomass sample plots required.

Further explanation on how to select the layout of sampling plots (form, nesting, etc.) can be found in textbooks such as Hoover (2008). For measuring and monitoring carbon density in the forest strata, a network of permanent or temporary forest sampling plots must be established. Due to the significant anthropogenic influence on non-forest land, it is not deemed feasible to install permanent sampling plots. Therefore, the average carbon stock density on non-forest LULC classes must be assessed using non-permanent sampling plots. Alternatively, conservative defaults gathered from scientific literature may be used to quantify the carbon stock density on non-forest land. The applicability of these default values must be confirmed by the validator.

Within a LULC class or forest stratum, the location of sample plots should be selected as random as practically feasible. However, in cases where access to the forest land is challenging, biomass plots located along a forest transects may be used instead of a stratified random sampling design on the condition that all forest classes and strata are represented in an unbiased way along the transect.. The randomization must be done *ex-ante* by a computer program. This is required to avoid subjective choice of plot locations. For each sample plot, record the observed LULC class, forest type, and estimated forest canopy closure. Note that stratification is usually an iterative process in which the stratification model – as defined in Section 8.1.2.6 - is adjusted based on biomass inventories and the stratum of a biomass inventory is guided by the stratification model. To avoid bias in the calculation of the uncertainty of stratification, the plots used to develop the forest stratification model must not be used to calculate the uncertainty of the carbon stock density of a specific stratum, as stipulated in Section 8.1.2.7.

This methodology allows implementing ANR and harvesting activities under certain conditions (see Section 8.2.5). The sample plots used to calculate the plant emission factors must not be located within areas in which ANR or harvest activities are planned. This requirement is necessary to prevent bias in the calculation of increases in forest biomass from natural regeneration and decreases in forest biomass due to harvesting.

Summarize the sampling framework following the guidance of Section 4.3.3.4 of GPG LULUCF in the PD and provide a map and the coordinates of all sampling locations.

8.1.4.4 Measure and Calculate Carbon Stock Density

Plot-based measurements must be aggregated within the LULC class or forest stratum they belong to.

- If degradation is not included, the LULC class of a specific biomass plot must be determined based on the LULC map that is closest in time to the time of measurement of the biomass plot. In case multiple measurements are available for one permanent biomass inventory plot, only the most recent value of the carbon stock density must be used.
- If degradation is included, the aggregations of non-forest LULC classes follow the procedures outlined above “if degradation is not included”. However, biomass inventory plots located in forest area must be assigned the appropriate forest stratum using the forest stratification model developed in Section 8.1.2.6. In case multiple measurements are available for one permanent biomass inventory plot, all values in time of the carbon stock density must be used in the aggregation and used to calculate the average and uncertainty metrics.

The carbon stock density from sampling plots must be kept separate for aboveground live biomass, aboveground dead biomass, belowground biomass, and soil organic carbon. The above ground dead plant carbon stock density can be calculated by summing the biomass carbon stock density in the lying deadwood and standing deadwood components. Likewise, the aboveground live plant carbon stock density can be calculated by summing the biomass carbon stock density in the aboveground tree and aboveground non-tree components.

$$OM_{AGD,plot\text{-}wise}(i,p) = OM_{LDW,plot\text{-}wise}(i,p) + OM_{SDW,plot\text{-}wise}(i,p) \quad \text{[EQ15]}$$

$$OM_{AGL,plot\text{-}wise}(i,p) = OM_{AGT,plot\text{-}wise}(i,p) + OM_{AGNT,plot\text{-}wise}(i,p) \quad \text{[EQ16]}$$

where:

$OM_{LDW,plot\text{-}wise}(i,p)$	=	Lying deadwood organic matter of plot p within LULC class or forest stratum i. [Mg DM ha^{-1}]
$OM_{SDW,plot\text{-}wise}(i,p)$	=	Standing deadwood organic matter of plot p within LULC class or forest stratum i. [Mg DM ha^{-1}]
$OM_{AGD,plot\text{-}wise}(i,p)$	=	Aboveground dead tree organic matter of plot p within LULC class or forest stratum i. [Mg DM ha^{-1}]
$OM_{AGL,plot\text{-}wise}(i,p)$	=	Aboveground live organic matter of plot p within LULC class or forest stratum i. [Mg DM ha^{-1}]
$OM_{AGT,plot\text{-}wise}(i,p)$	=	Aboveground live tree organic matter of plot p within LULC class or forest stratum i. [Mg DM ha^{-1}]
$OM_{AGNT,plot\text{-}wise}(i,p)$	=	Aboveground live non-tree organic matter of plot p within LULC class or forest stratum i. [Mg DM ha^{-1}]

In addition, the following symbols are used in subsequent equations, calculations as well as monitoring tables:

$OM_{BG,plot\text{-}wise}(i,p)$	=	Belowground tree organic matter of plot p within LULC class or forest stratum i. [Mg DM ha^{-1}]
$OM_{SOM,plot\text{-}wise}(i,p)$	=	Soil organic matter of plot p within LULC class or forest stratum i. [Mg DM ha^{-1}]

For the aboveground live (AGL), aboveground dead (AGD), belowground (BG), and soil organic matter (SOM) pools, the average stock densities of stratum $\boldsymbol{i}$ and associated statistics are calculated using the equations below. The “o” subscript indicates a pool out of the possible pools (AGL, AGD, BG, or SOM carbon).

$$OM_o(i) = average\left(OM_{o,plot\text{-}wise}(i,p)\right) \quad \text{[EQ17]}$$

$$stdev\big(OM_o(i)\big) = stdev\left(OM_{o,plot\text{-}wise}(i,p)\right) \quad \text{[EQ18]}$$

$$stderr\big(OM_o(i)\big) = \frac{stdev\big(OM_o(i)\big)}{\sqrt{n_i}} \quad \text{[EQ19]}$$

$$HCWI\big(OM_o(i)\big) = t_{0.95,n-1} \cdot stderr\big(OM_o(i)\big) \quad \text{[EQ20]}$$

$$CE_{inventory}(i) = \frac{\sqrt{\sum_o HWCI\big(OM_o(i)\big)^2}}{\sum_o OM_o(i)} \quad \text{[EQ21]}$$

$$u_{inventory}(i) = \begin{cases} 1 & \text{if } CE(i) \leq 0.15, \\ 1 - CE(i) & \text{if } 0.15 \ < CE_{inventory}(i) < 1, \\ 0 & \text{if } CE(i) \geq 1 \end{cases} \quad \text{[EQ22]}$$

where:

$OM_o(i)$	=	Average plant organic matter density of LULC class or forest stratum i in pool o. [Mg DM ha^{-1}]
$OM_{o,plot\text{-}wise}(i,p)$	=	Total biomass stock density of plot p within LULC class or forest stratum i in pool o. [Mg DM ha^{-1}]
$stdev\big(OM_o(i)\big)$	=	Standard deviation of the total plant-derived organic matter density of LULC class or forest stratum i in pool o. [Mg DM ha^{-1}]
$stderr\big(OM_o(i)\big)$	=	Standard error of the average of the total plant-derived organic matter density of LULC class or forest stratum i in pool o. [Mg DM ha^{-1}]
n_i	=	Number of sampling plots of LULC class or forest stratum i in pool o. [-]
$HCWI\big(OM_o(i)\big)$	=	Half-width of the confidence interval around the average of the total plant-derived organic matter density of LULC class or forest stratum i in pool o. [Mg DM ha^{-1}]
$t_{0.95,n-1}$	=	Value of t-statistics (i.e., from *t*-table) at 95% confidence interval and n-1 degree of freedom [-]
o	=	Carbon pool, either aboveground live (AGL), aboveground dead (AGD), belowground (BG) or soil organic matter (SOM).
$CE_{inventory}(i)$	=	Combined error in estimate of average biomass stock density of LULC class or forest stratum i. [−]
$u_{inventory}(i)$	=	Uncertainty of biomass stock density in stratum i. [−]

[EQ21] and [EQ22] are used in estimating the combined error, $CE_{inventory}(i)$, and the uncertainty, of the biomass stock density, $u_{inventory}(i)$, respectively. Note that procedures to calculate the uncertainty of the *difference* of two biomass stock densities due to a land transition are explained in the Section8.1.4.5. Estimation of combined error of the inventory, $CE_{inventory}(i)$ is prerequisite to estimation of uncertainty, $u_{inventory}(i)$. These two equations must be treated as generic and can be applied in estimating uncertainty for some specific project area when needed. For example, when uncertainty in estimated carbon stock density in harvest areas are needed, then inventory data from areas under harvest alone must be used in these two equations to estimate inventory uncertainty in harvest areas i.e., $u_{inventory,harvest}(i)$.

Stratum specific average organic matter can be estimated by summing organic matter in different carbon pools. Subsequently, the average total carbon stock is calculated by multiplication with the carbon fraction:

$$OM(i) = \sum_{o} OM_o(i) \quad \text{[EQ23]}$$

$$C_o(i) = CF \cdot OM_o(i) \quad \text{[EQ24]}$$

$$C(i) = \sum_{o} C_o(i) \quad \text{[EQ25]}$$

where:

$OM(i)$	=	Average plant-derived organic matter of LULC class or forest stratum i. [MG DM ha^{-1}]
$OM_o(i)$	=	Plant-derived organic matter of LULC class or forest stratum i in pool o. [Mg DM ha^{-1}]
$C_o(i)$	=	Average carbon stock density of LULC class or forest stratum i in pool o. [MT C ha^{-1}]
CF	=	Carbon fraction of dry matter in wood (default = 0.5). [Mg C (Mg DM)$^{-1}$]
$C(i)$	=	Average carbon stock density of LULC class or forest stratum i. [MT C ha^{-1}]

The exact measurement of aboveground and below tree carbon must follow international standards and follow IPCC GPG LULUCF 2003. These measurements are explained in detail in CDM approved methodology AR-AM0002 *Restoration of degraded lands through afforestation/reforestation*. A step-by-step Standard Operations Procedure for field measurements should be prepared ex-ante and contain a detailed, step-by-step explanation of all of the required field-work for both ex-ante and ex-post measurements. This document will ensure consistency during the crediting period by standardizing sampling procedures from year to year.

Aboveground organic matter, $OM_{AGT}(i,p)$. The aboveground organic matter must be determined by measuring the appropriate tree metric (e.g. DBH) of all trees using the appropriate cutoff DBH specified in the allometric equation (e.g., DBH ≥ 5 cm) within the sampling plot. The applicability of the allometric equation $f_{allometric}$ used must be specifically verified using the procedures Section. The allometric equation(s) must remain fixed during a baseline validation period. During a baseline update, the project proponent may replace previously used allometric equations, and BEF values by more accurate ones, if these would become available.

Aboveground non tree organic matter, $OM_{AGNT}(i,p)$. The above ground non-tree vegetation must be measured by destructive harvesting techniques. Alternatively, the aboveground organic matter can also be estimated using default values IPCC default values by following appropriate tool as the latest version of CDM Tool *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in AR CDM project activities*.

Belowground organic matter, $OM_{BG}(i,p)$. The below organic matter pool is estimated from the aboveground organic matter using a relationship $f_{belowground}$ between aboveground and belowground organic matter, such as a root-to-shoot ratio. Similar to the constants used for the aboveground organic matter, $f_{belowground}$ must be fixed during a baseline validation period. During baseline validation, the project proponent may replace a previously used $f_{belowground}$ by a more accurate one, if this would become available.

Lying deadwood organic matter, $OM_{LDW}(i,p)$. Lying deadwood must be sampled with the line intersect method (Harmon and Sexton, 1996) using the equation by Warren and Olsen (1964) as modified by Van Wagener (1968). Each piece of dead wood is assigned to one of three decay classes as (a) Sound, (b) Intermediate, or (c) Rotten, on the basis of a machete test . The estimated biomass for each dead wood piece is subject to density reduction factor. While the project proponent may use most applicable density reduction factor, the default density reduction factors are 1, 0.80, and 0.45 respectively for decay classes- sound, intermediate and rotten.

Standing deadwood organic matter, $OM_{SDW}(i,p)$. Standing dead trees must be measured using the same procedures used for measuring live trees with the addition of a decomposition class and the addition of an appropriate biomass reduction factor. Specifically, all the standing dead trees must be assigned with one of the two conditions (a) Dead trees which have lost only leaves and twigs, and (b) Dead trees which have lost leaves, twigs, and small branches (diameter < 10cm) and use an appropriate biomass reduction factor for each of the two conditions. The project proponent may use biomass reduction factors based on local or national data/study or use a default factor of 0.975 for trees in condition (a) and 0.80 for trees in condition (b). If the tree has lost all the branches, such a tree must be considered a Dead Tree Stump.

Dead tree stump organic matter, $OM_{DTS}(i,p)$*.* If the stump height is greater than the mid-point diameter of a stump or dead tree without branches, then the biomass must be estimated using the method found in Ormerod (1973). First, the volume of the dead tree stump must be estimated using Huber’s formula in which the cross-sectional area is estimated using the mid-point diameter of tree or tree stump multiplied with height of the stump. The estimated volume is subsequently multiplied by wood density. A density reduction factor is assigned to each of the decay classes, which is to be multiplied by the basic wood density of the species of the stump to obtain its estimated wood density. The following default values of the density reduction factors for the three decay classes must be used, unless project specific data is available for the decay class: (i) 1.0 for sound organic matter, (ii) 0.8 for organic matter in an intermediate decay class and (iii) 0.45 for rotten organic matter.

Soil organic matter, $OM_{SOM}(i,p)$. Soil organic carbon pool must be estimated using soil samples taken at different soil horizons. The depth to which the soil samples are taken and analyzed must be at least 30 cm as per the recommendation of the IPCC GPG-LULUCF (2003). In these samples, depth, bulk density and concentration of organic dry matter must be recorded.

Stratum-specific average organic matter density, $\boldsymbol{OM}(\boldsymbol{i})$ and its associated uncertainty, $\boldsymbol{u_{inventory}}(\boldsymbol{i})$ may also be (partially) estimated using other sampling approaches such as double sampling, regression estimators e.g. LiDAR on the condition that (1) it can be demonstrated that the use of such approach is conservative, and (2) valid and unbiased uncertainty estimators are provided for the biomass stock density that are equivalent to the uncertainty estimators used for plot-based measurements described in this methodology.

8.1.4.5 Calculate Emission Factors

Emission factors only include the carbon pool-related sources due to changes in carbon stock densities between the LULC classes and forest strata. Since N_2O and CH_4 emissions from forest fires increase emissions, they can be conservatively omitted for baseline calculations[8]. Once the carbon stock densities are calculated, biomass carbon emission factors and their uncertainties for each LULC class or forest stratum transition are calculated. A positive emission factor (i.e. EF_o) indicates a net sequestration of carbon, or an increase in the carbon stock, while a negative emission factor sign indications emission. The emission factor for aboveground live biomass is calculated as:

$$EF_{AGL}(CS1 \rightarrow CS2) = \frac{44}{12} \cdot \left(C_{AGL}(CS2) - C_{AGL}(CS1)\right) \quad \text{[EQ26]}$$

where:

$EF_{AGL}(CS1 \rightarrow CS2)$	=	Emission factor for change in aboveground live plant organic matter from an LULC Class or forest Stratum (CS) 1 to 2. [tCO_2e ha^{-1}]
$CS1 \rightarrow CS2$	=	Land transition from LULC class or forest stratum 1 to 2.
$C_{AGL}(i)$	=	Carbon density of aboveground plant organic matter of classes or forest stratum i. [MT C ha^{-1}]

The emission factor for aboveground deadwood must be gradually spread over time. The project proponent may propose their own temporal component (e.g., an exponential equation) if the conservative nature of the temporal component can be demonstrated using peer-reviewed literature or field measurements. If no temporal component is proposed by the project proponent, the default temporal component from the VCS must be used using the following formula:

For $t \leq 10$:

$$EF_{AGD}(CS1 \rightarrow CS2, t) = \frac{44}{12} \cdot \frac{\left(C_{AGD}(CS2) - C_{AGD}(CS1)\right)}{10} \quad \text{[EQ27]}$$

For $t > 10$:

$$EF_{AGD}(CS1 \rightarrow CS2, t) = 0 \quad \text{[EQ28]}$$

[8] Note that under the project scenario, N_2O emissions from prescribed burning must be included in the carbon accounting.

where:

$EF_{AGD}(CS1 \rightarrow CS2, t)$	=	Emission factor from change in above ground dead wood from an LULC Class or forest Stratum (CS) 1 to 2 at t years after transition. [tCO_2e ha^{-1}]
$CS1 \rightarrow CS2$	=	Land transition from LULC class or forest stratum 1 to 2.
$C_{AGD}(i)$	=	Carbon density of aboveground dead plant organic matter of classes or forest stratum i. [MT C ha^{-1}]

The total belowground biomass emission factor must also be must be gradually spread over time. The project proponent may propose their own temporal component (e.g., an exponential equation) if the conservative nature of the temporal component can be demonstrated using peer-reviewed literature or measurements conducted by the project proponent. If no temporal component is proposed by the project proponent, the default temporal component from the VCS must be used using the following formula:

For $t \leq 10$:

$$EF_{BG}(CS1 \rightarrow CS2, t) = \frac{44}{12} \cdot \frac{\left(C_{BG}(CS2) - C_{BG}(CS1)\right)}{10} \quad \text{[EQ29]}$$

For $t > 10$:

$$EF_{BG}(CS1 \rightarrow CS2, t) = 0 \quad \text{[EQ30]}$$

where:

$EF_{BG}(CS1 \rightarrow CS2, t)$	=	Emission factor for change in belowground plant organic matter from an LULC Class or forest Stratum (CS) 1 to 2 at t years after transition. [tCO_2e ha^{-1}]
$CS1 \rightarrow CS2$	=	Land transition from LULC class or forest stratum 1 to 2.
$C_{BG}(i)$	=	Carbon density of belowground plant organic matter of classes or forest stratum i. [MT C ha^{-1}]

The total soil emission factor must be gradually spread over time. The project proponent may propose their own temporal component (e.g., an exponential equation) if the conservative nature of the temporal component can be demonstrated using peer-reviewed literature or measurements conducted by the project proponent. If no temporal component is proposed by the project proponent, the temporal component from the IPCC GPG-LULUCF 2003 and used in following formula for the soil emission factor must be used:

For $t \leq 20$:

$$EF_{SOM}(CS1 \rightarrow CS2, t) = \frac{44}{12} \cdot \frac{\left(C_{SOM}(CS2) - C_{SOM}(CS1)\right)}{20} \quad \text{[EQ31]}$$

For $t > 20$:

$$EF_{BG}(CS1 \rightarrow CS2, t) = 0 \quad \text{[EQ32]}$$

where:

$EF_{SOM}(CS1 \rightarrow CS2, t)$	=	Emission factor for change in soil organic matter from LULC Class or forest Stratum (CS) 1 to 2 at t years after transition. [$tCO_2e\ ha^{-1}$]
$cs1 \rightarrow cs2$	=	Land transition from LULC class or forest stratum 1 to 2.
$C_{SOM}(i)$	=	Carbon density of soil organic matter plant of LULC class or forest stratum i. [MT C ha^{-1}]

For aboveground live, aboveground dead, belowground, or soil organic matter emission factor, the combined error in estimated biomass stock densities for a transition from one stratum to another is measured as:

$$CE_{transition}(CS1 \rightarrow CS2) = \frac{\sqrt{\sum_o \left(HWCI\left(OM_o(CS1)\right)^2 + HWCI\left(OM_o(CS2)\right)^2\right)}}{\left|\sum_o OM_o(CS2) - \sum_o OM_o(CS1)\right|}$$

The uncertainty discounting for estimated emissions factors for a transition from one stratum to another is estimated using

$$u_{transition}(CS1 \rightarrow CS2) = \begin{cases} 1 & \text{if } CE_{transition}(CS1 \rightarrow CS2) \leq 0.15, \\ 1 - CE_{transition}(CS1 \rightarrow CS2) & \text{if } 0.15 < CE_{transition}(CS1 \rightarrow CS2) < 1, \\ 0 & \text{if } CE_{transition}(CS1 \rightarrow CS2) \geq 1 \end{cases} \quad \text{[EQ34]}$$

where:

$u_{transition}(CS1 \rightarrow CS2)$	=	Discounting factor for the emission factor for the transition from LULC class or forest stratum 1 to class 2 according to the uncertainty of the biomass inventory. [-]
$HWCI\left(OM_o(i)\right)$	=	Half-width of the 95% confidence interval around the mean plant organic matter density of LULC class or forest stratum i in pool o. [$tCO_2e\ ha^{-1}$]
$CE_{transition}(CS1 \rightarrow CS2)$	=	Combined error in estimated biomass stock density change for a transition from one stratum to another. [-]

List the estimated emission factors, the associated uncertainties, and the lower confidence limit per LULC class and forest strata category in a table in the PD. The inventory must be iteratively expanded until for every transition, $u_{transition}(CS1 \rightarrow CS2)$ is greater than 0.75. This threshold serves to ensure a minimal accuracy of biomass inventories. Finally, it must be checked that all forest stratum transitions are compatible with the definition of degradation. More specifically, it must be checked that the carbon stock densities in two different strata differ at least by 10% of the carbon stock of strata with lower level of carbon stock. For example, if stratum "A" has 50 Mg C ha-1, then stratum "B" must have at least 55.1 Mg C ha-1.

8.1.5 Estimate Ex-ante Land Transition Rates under the Baseline Scenario

The goal of this step is to calculate all land transitions, including deforestation and increased forest cover, and forest degradation and regeneration under the baseline scenario. The procedure below calculates first the total deforestation and forest degradation rates, and also the relative regeneration and increased forest cover change rates per forest stratum and LULC class. Subsequently, the total rates of deforestation and forest degradation are split into LULC class and forest stratum specific rates using a geographical modeling approach, similar to the GEOMOD model[9]. Note that the exact location of future deforestation predicted by the model is not used as such for carbon accounting. Location-specific data on deforestation, forest degradation, and other LULC transitions are aggregated again into a land-use change transition matrix, which is the activity data on which the carbon accounting is based.

8.1.5.1 Calculate Total Rates of Deforestation and Forest Degradation in the Project Area

The total future deforestation and degradation rates are interpolated from past trends. However, scarcity of land may decrease rates to values below the maximal rates interpolated on past trends. This is accounted for in Section 8.1.5.4.

Create a graph of the historical deforestation rates in the reference region (hectares per year) versus time (years) for each consecutive pair of images in the historical reference period. Create a similar graph of the historical degradation rates versus time. From these graphs, calculate the future deforestation and degradation rates using two beta regression[10] equations, one for deforestation and one for forest degradation:

$$D_{referemceRegion,baselineScenario,DF}(t) = BetaReg_{DF}(t) \quad \text{[EQ35]}$$

$$D_{referenceRegion,baselineScenario,DG}(t) = BetaReg_{DG}(t) \quad \text{[EQ36]}$$

where:

[9] This approach is conservative since upon exhaustion of one forest stratum, the deforestation will be displaced to the stratum with the greatest likelihood of being deforested. In case stratum-specific deforestation rates were calculated up front, the displacement of deforestation to other forest strata would have been more challenging.

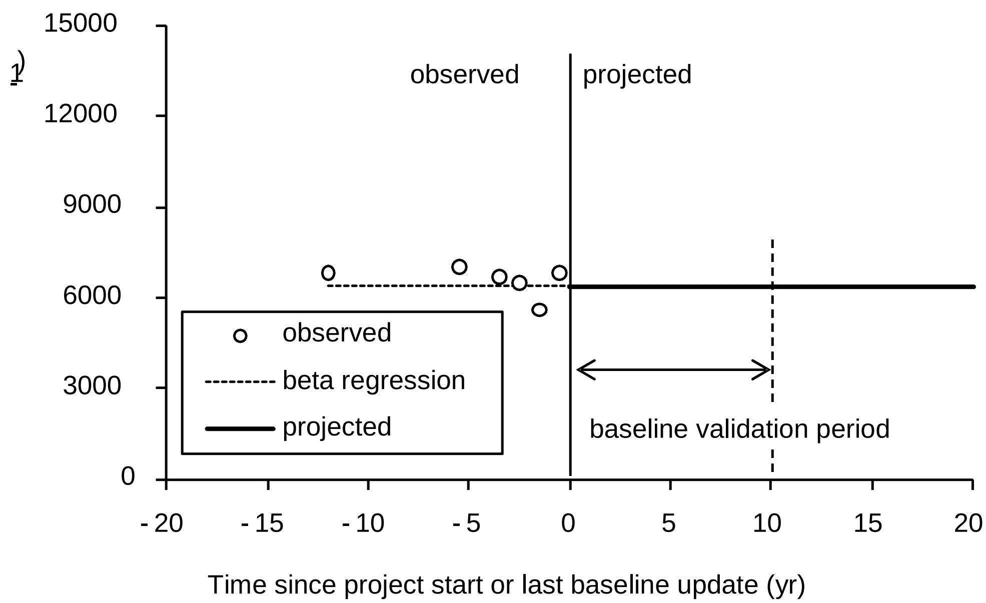
[10] Beta regression is commonly used to model variables that assume values in the standard unit interval (0; 1). Beta regression assumes that the dependent variable is beta-distributed and that its mean is related to a set of regressors through a linear predictor with unknown coefficients and a link function. Parameter estimation is performed by maximum likelihood.

$D_{referenceRegion,baselineScenario,DF}(t)$, $D_{referenceRegion,baselineScenario,DG}(t)$	=	Rate of deforestation/degradation within the reference region for during year t. [ha yr^{-1}]
$BetaReg_{DF}(t)$ and $BetaReg_{DG}(t)$	=	Beta regression model describing the relationship between time and deforestation/degradation rate in the reference region during the historical reference period. [ha yr^{-1}]
t	=	Time since project start (negative before project start). [yr]

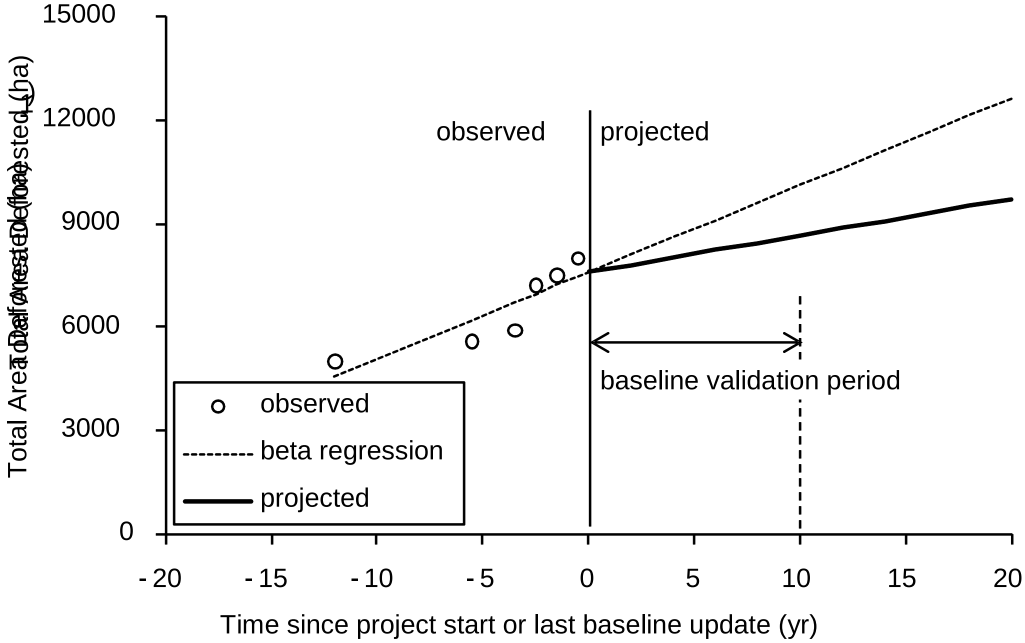
However, if only three images were included in the historical analysis, and, therefore, only two deforestation/degradation rates are available, the average of the two rates must be used instead of the extrapolation using the Beta regression.

The future deforestation and forest degradation must be calculated as follows:

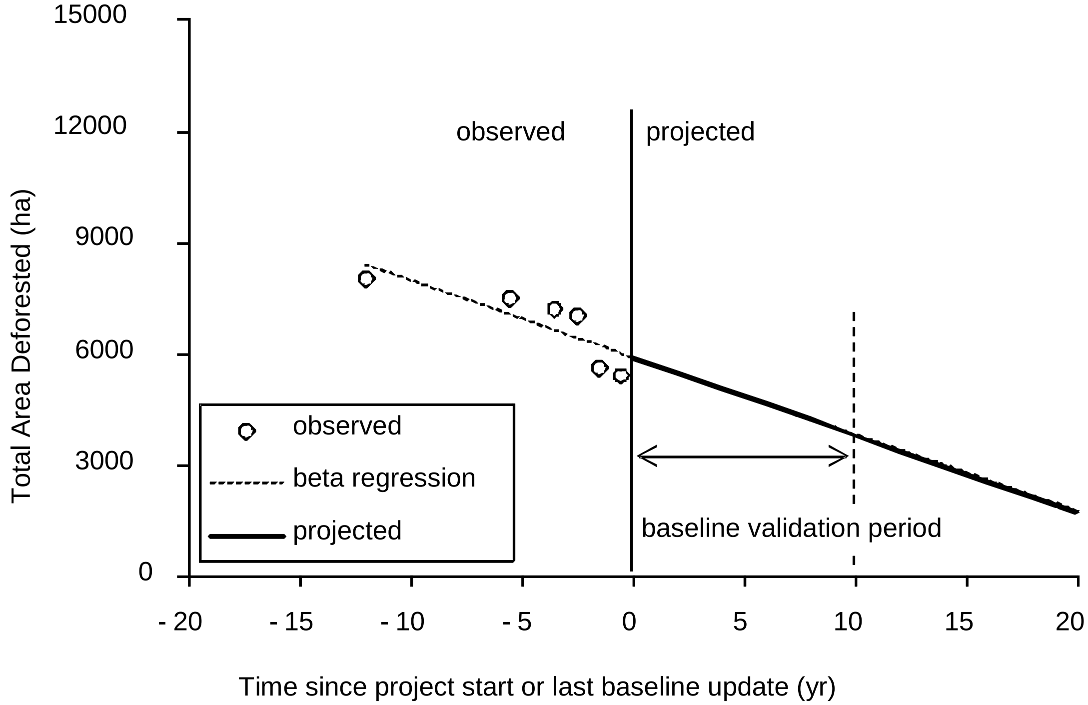
If the area of deforestation/degradation is constant (i.e. if the slope of the relation between deforestation/degradation quantities and time is not significantly different from 0 at the 95% confidence level), a constant future deforestation/degradation quantity is set as the mean of the observed deforestation/degradation amounts in the reference region.



If the deforestation/degradation quantity increases (i.e. if the slope of the relation between deforestation/degradation quantities and time is significantly larger than 0 at the 95% confidence level), the lower 95% confidence interval of the beta regression model must be used.

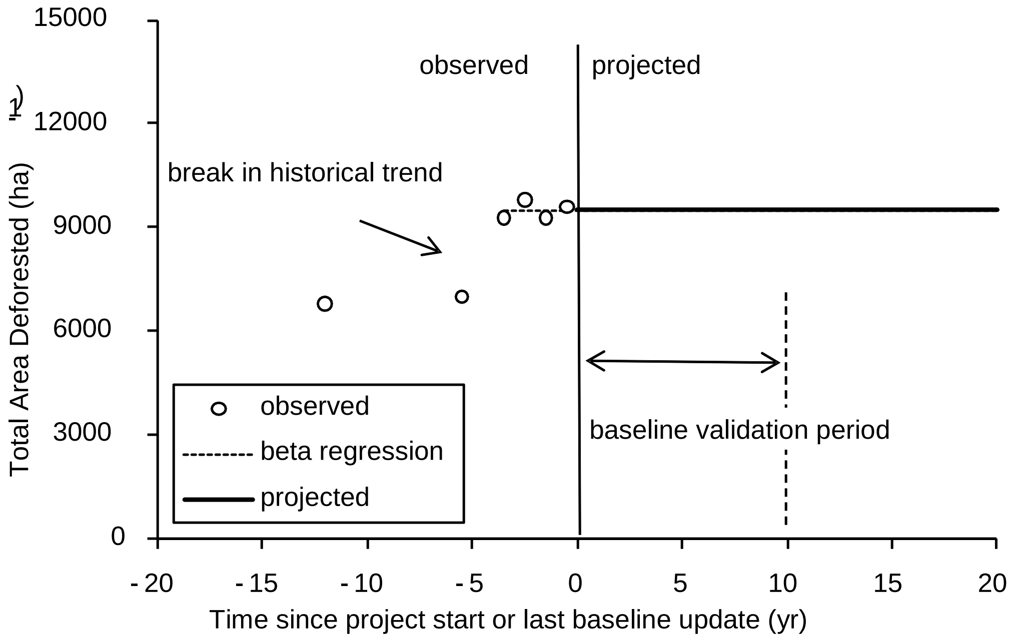


If the deforestation/degradation quantity decreases (i.e. if the slope of the relation between deforestation/degradation quantities and time is significantly smaller from 0 at the 95% confidence level), the original beta regression model must be used.

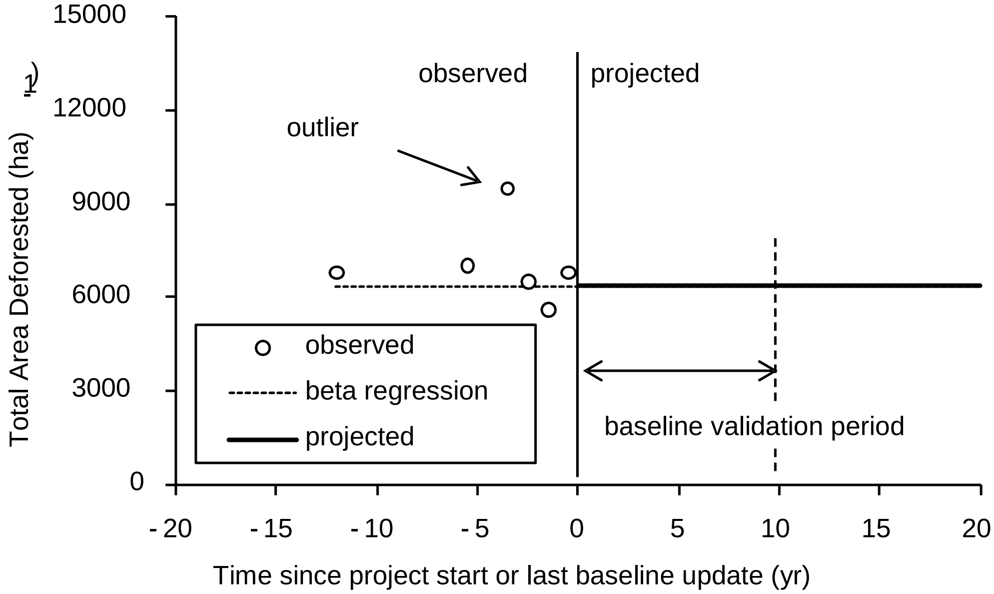


When there is a clear break in the historical trend, it is required to examine when the anomaly occurred, why it occurred, and whether the change is likely to be stable to determine whether to adjust the data points used in the beta regression. A break in the historical trend must only be considered when at least six points in time are available[11]. A break in the historical trend usually indicates a technological breakthrough, a policy reform, or change in land use practice. If it is demonstrated that the reasons for a break in the trend continued into the future, omit the observations occurring before the break to project the future deforestation quantity. The projected deforestation rate must be determined from the period that goes back no farther than the appearance of the breakpoint (Sataye and Andrasko, 2007). Use one of the approaches above depending on the trend observed after the break.

[11] Even though, often, only 3 or 4 data points will be available upon validation, increasingly more data points will become available during the crediting period. Therefore, when the baseline is updated, sufficient points may be available to detect a break.



Single outliers are most likely due to once-only anomalies (e.g., loss of forest land due to fire, hurricane or other natural disturbance). It is required that the cause of this single outlier be examined to determine if it may be removed. They may only be removed from the other points in the historical reference period if it is demonstrated that the occurrence of the outlier is due to specific conditions that are not present anymore (as would be the case for a natural disturbance). Use one of the approaches above depending on the trend observed after removing the outlier.



Once the coefficients from the beta regressions are determined, calculate the baseline total deforestation and degradation rates in the project area as:

$$D_{projectArea,baselineScenario,DF}(t) = BetaReg_{DF}(t) \cdot \frac{size_{projectArea}}{size_{referenceForest}} \quad \text{[EQ37]}$$

$$D_{projectArea,baselineScenario,DG}(t) = BetaReg_{DG}(t) \cdot \frac{size_{projectArea}}{size_{referenceForest}} \quad \text{[EQ38]}$$

where:

$D_{projectArea,baselineScenario,DF}(t)$, and $D_{projectArea,baselineScenario,DG}(t)$	=	Baseline rate of deforestation/degradation within the project area during year t. [ha yr^{-1}]
$BetaReg_{DF}(t)$ and $BetaReg_{DG}(t)$	=	Beta regression model describing the relationship between time and deforestation/degradation rate in the reference region during the historical reference period. [ha yr^{-1}]
t	=	Time since project start (negative before project start). [yr]
$size_{projectArea}$	=	Total size of the project area. [ha]
$size_{referenceForest}$	=	Total size of the forest area in the reference region. [ha]

The deforestation rate or degradation rate calculated from this procedure represents the gross deforestation rate, but not net deforestation or degradation rate. Therefore, all non-forest to forest transitions need to be explicitly included in the baseline to achieve a correct representation of the forest cover dynamics.

8.1.5.2 Calculate LULC Class or Forest Stratum-Specific Relative forest cover increase and Regeneration Rates

Although reforestation is not allowed as a project activity, the baseline scenario must include potential increases in forest cover or forest biomass that would have happened without project activities. There must be a full symmetry in carbon accounting: degradation in the baseline scenario may only be included if regeneration under the baseline is included as well. Likewise, both transitions from forest to non-forest and non-forest to forest (and that were forest at the start of the crediting period, per applicability condition 1) must be included in the baseline. Note that the quantification of transitions of non-forest to forest areas must not be based on areas on which large-scale reforestation has occurred as such areas should have been excluded from the reference region.

The extent of increase in forest cover or forest regeneration that would have happened under the baseline scenario is quantified based on historical observations in the reference region during the historical reference scenario. For every land class or forest stratum that transitions into a different class with higher biomass, calculate the relative regeneration or forest cover increase rate by dividing the area of the transition by the area of the "from" class:

for every transition for which $C(CS_2) > C(CS_1)$:

[EQ39]

$$RFRGrate(CS_1 \rightarrow CS_2) = \frac{\Delta area_{historical}(CS_1 \rightarrow CS_2, t_1 \rightarrow t_2)}{area_{historical}(CS_1, t_1) \cdot (t_2 - t_1)}$$

where:

CS_1 and CS_2	=	Class or Stratum 1 and 2, respectively
$C(CS_1)$ and $C(CS_2)$	=	Average carbon stock density of LULC class or forest stratum 1 and 2, respectively. [Mg C ha^{-1}]
$RFRGrate(CS_1 \rightarrow CS_2)$	=	Relative annual forest cover increase and regeneration factor for the transition from class or stratum 1 to 2. [yr^{-1}]. Multiply with 100 to obtain a forest cover increase and regeneration rate in percentage per year.
$\Delta area_{historical}(CS_1 \rightarrow CS_2, t_1 \rightarrow t_2)$	=	Area of transition from class or stratum 1 to 2 from time 1 to 2 during the historical reference period. [ha]
$area_{historical}(CS_1, t_1)$	=	Total area of class or stratum 1 at time 1. [ha]
t_1 and t_2	=	Time 1 and time 2, respectively. [years]

Calculate the LULC class or forest stratum-specific regeneration or forest cover increase rates for every pair of subsequent images in the historical reference period, and report the averages in a table in the PD.

8.1.5.3 Calibrate and Validate a Spatial Model to Predict the Suitability for Deforestation and Degradation

Deforestation and degradation do not occur randomly within the forest area, but occur preferentially at specific locations where predisposing factors are present (De Jong 2007). These factors are referred to as *spatial driver variables* and were identified in Section 8.1.3.4. By examining the impact of spatial driver variables on historical land use change, the likelihood of land-use change can be quantified; this likelihood relation can be extrapolated into the future to predict the location of future land use change. This Section focuses on examining the relation between spatial drivers and historical land use change, while Section 8.1.5.4 focuses on extrapolating this relation into the future. Spatial driver variables may be constant, meaning that they will never change during model execution, such as slope or elevation, or dynamic, meaning that they may change during project runs, such as distance to the nearest road, or forest density. In addition, they may be continuous, such as distance to the closest market, or categorical, such as soil type. Logistic regression models are one class of models that have been used successfully to quantify the suitability of deforestation and degradation (Lambin 1997, Verburg et al. 2004 and Boer et al. 2006). However, this methodology does not prescribe an exact form of a statistical model. The following steps are to be followed once to calibrate the deforestation model and once to calibrate the degradation model. For brevity, the steps below assume a deforestation model.

For each pair of two subsequent LULC classification maps developed as per Section**,** randomly select a large number (>10,000) of forested grid-cells/pixels from the first image. Use the second image of the pair to determine whether these grid-cells/pixels were deforested, degraded, or showed no change during the period in between the two images. Since grid-cells are selected randomly from the baseline LULC maps, pixels will be selected from degrading, deforested, and no-change areas in an unbiased way.

Calculate the value of each spatial driver variable based on the first LULC map of the image pair for each of the points selected in the previous step. Create a list containing the location, land transition category, and all values of each of the spatial driver variable identified in Section 8.1.3.4. In case of dynamic spatial driver variables, use a spatial driver at the time the first image was recorded. Deforestation and degradation usually occur in a clustered fashion. Therefore, include the distance to the forest edge, or forest fragmentation as spatial driver variables (Lambin et al., 1997).

Split this list randomly into a calibration dataset and a (statistical) validation dataset. The calibration data will be used to fit the deforestation and degradation statistical models and the validation data will be used to independently assess the quality of the model. 2/3 of the points should be used for calibration and 1/3 for validation.

Calibrate a statistical model for deforestation based on the values of spatial driver variables at the calibration point dataset. The statistical model must predict the suitability for deforestation for every location in the project area, and must therefore be bound by the interval [0,1]. A logistic regression model is an example of an appropriate statistical model. If necessary, apply mathematical transformations to make the effect of the spatial driver variables linear. For instance, the influence of a road on deforestation will decrease exponentially with distance to the road, and a log-transformation should be applied.

Calibrate a statistical model for degradation based on the values of spatial driver variables at the calibration point dataset.

Calibrate a statistical model to predict the LULC class of the new land use on cells selected for deforestation**.** In case that there are more than two potential new LULC classes, use multinomial logit model, which predicts a multilevel categorical variable bases on the spatial driver variables. Quality assurance: significance and goodness-of-fit. As a quality assurance step, report the significance of the statistical model. In case of a regression, report the results of a likelihood ratio test, and the significance of individual drivers of deforestation (t-tests). Both the full model and all individual drivers must be significant at the 95% confidence level. In addition, perform a goodness-of-fit test by predicting the new LULC classes and forest strata for the independent statistical validation data, and comparing the results with the measured data. Present a table of the empirically observed land-use change rates vs. the land-use change rate predicted using the statistical model. The difference in aggregated deforestation and forest degradation rates as well as forest stratum and LULC-class transition rates averaged over all the time periods (in between images of the reference period) between empirically observed and modeled rates may not be more than 15%. The capability of the model to adequately estimate likelihoods of deforestation and forest degradation must be confirmed by the validation/verification body.

8.1.5.4 Calculate All Class or Stratum-Specific Transition Rates.

Once the statistical models for deforestation and forest degradation, and the carbon density map are prepared, a simple cellular automata type model can be used to predict the future land use and land cover in each grid-cell and for each year of the crediting period. Even though the spatial model produces maps of the exact location of future deforestation, these maps are not used outside of the modeling step. The main output of the modeling step is a land-use change transition matrix. This matrix is calculated by aggregating the LULC class and forest stratum maps that are produced by the spatial model. In addition to the principles of neighborhood constraint and land suitability, as explained in Pontius (2002), the land-use change model incorporates the forest scarcity principle, the notion that deforestation rates decrease upon the gradual depletion of the native forest resources. Without forest scarcity, it is assumed that deforestation occurs linearly until all forest is gone, which will be incorrect in most circumstances and lead to an overestimate of net emission reductions. It is well documented that deforestation rates decrease when forest areas are gradually disappearing. The “forest transition” theory (Mather and Needle, 1998) explains how areas with vast forest areas which are initially characterized by rapid deforestation rates, stabilize their forest area after some time. To incorporate a decrease in deforestation rate upon a gradual depletion of forest resources, initial deforestation rates are multiplied with a “forest scarcity” factor, which is initially 1, but gradually decreases as the proportion of remaining forest decreases (Figure 1). This “scarcity factor” must be calibrated using scientific literature in an area close to the project area that has followed a more advanced deforestation route. Examples are neighboring countries, states or provinces that have undergone a more rapid deforestation course than the area where the project is located. Typically, deforestation rates start to decrease when around 50% of the original forest cover has disappeared. In addition, deforestation usually halts when around 80% of the forest area has disappeared. This pattern has been observed by Meyfroidt and Lambin (2008) in Vietnam. Deforestation rates started decreasing when 50% of forest cover remained, and halted in 1991-1993 at around 25% forest cover. However, the specific values of the forest cover when deforestation will decrease are dependent on project conditions and should be analyzed and substantiated within the project document at validation.

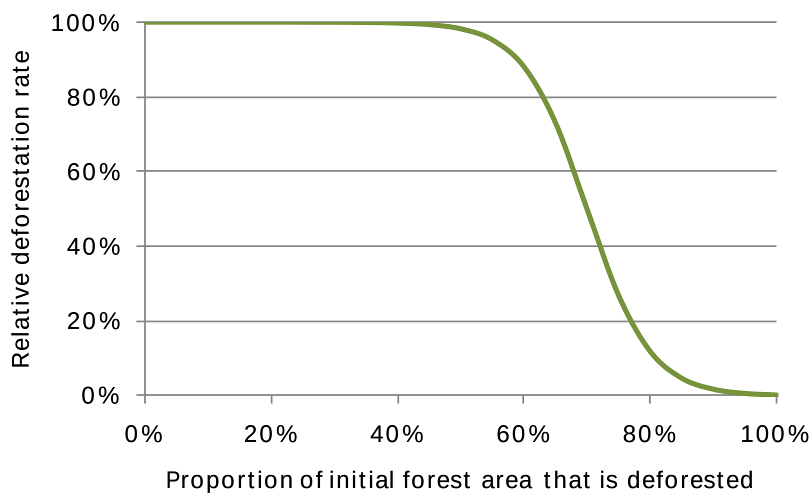


Figure 1. Example of “forest scarcity factor”: the relative Deforestation Rate as a Function of Proportion of Initial Forest Area that is Deforested.

The following equation must be used to model the scarcity factor:

$$f_{scarcity}(t) = \frac{1}{1 + e^{sc_1\left(sc_2 - \frac{area(t,nonForest)}{size_{projectArea}}\right)}} \qquad \text{[EQ40]}$$

Where:

$f_{scarcity}(t)$	=	Forest scarcity factor used to reduce the historical deforestation rate at time t. [-]
sc_1	=	First shape factor for the forest scarcity equation; steepness of the decrease in deforestation rate (greater is steeper). [-]
sc_2	=	Second shape factor for the forest scarcity equation; relative deforested area at which the deforestation rate will be 50% of the initial deforestation rate. [-]

$area(t, nonForest)$	=	Total area that is not forest within the project area at time t after project start. [ha]
$size_{projectArea}$	=	Total size of the project area. [ha]

The two shape factors sc_1 and sc_2 within this equation must be fitted using historical information in areas similar to the project area or data from peer-reviewed literature. Data sources that must be used are remotely sensed forest cover data in heavily deforested areas close to the project area such as neighboring provinces, states or countries. Values of sc_1 and sc_2 should be selected so that the carbon accounting is conservative. Lower values of sc_1 and higher values of sc_2 will result in lower deforestation, and are therefore more conservative. The project proponent must demonstrate that the source data used to fit this equation is appropriate. The following steps must be followed:

- Calculate the deforestation suitability for all forest cells using the logistic regression model.
- Sort the forest cells according to their deforestation suitability from highest suitability to lowest suitability.
- During a given year, the area that is effectively deforested is dependent on (1) the total rate of deforestation $D_{projectArea,baselineScenario,DF}(t)$, and (2) the remaining total forest cover. More specifically, the area that is effectively deforested equals the total rate of deforestation $D_{projectArea,baselineScenario,DF}(t)$ multiplied with the forest scarcity factor, which is a function of the remaining forest cover. Since deforestation is dependent on the remaining forest cover and the remaining forest cover changes as deforestation occurs, an iterative loop is necessary in which the remaining forest cover is updated as more and more forest is deforested. To begin the iterative loop, set $D_{projectArea,baselineScenario,DF,remaining}(t)$ to $D_{projectArea,baselineScenario,DF}(t)$ multiplied with the forest scarcity factor based on the remaining forest cover at the end of the previous year. Start deforesting cells (in order of highest to lowest deforestation probability). Every time a cell is deforested, update the remaining forest cover and the scarcity factor and re-calculate $D_{projectArea,baselineScenario,DF,remaining}(t)$ as $D_{projectArea,baselineScenario,DF}(t)$ minus the total amount of deforested cells and multiplied with the updated forest scarcity factor as a function of the remaining forest cover. Continue the loop until $D_{projectArea,baselineScenario,DF,remaining}(t)$ = 0.
- Calculate the suitability for a new non-forest LULC class on the cells that were selected for deforestation. Assign the LULC class with the highest suitability, according to the calibrated models in previous step.
- Repeat steps 1-4 for forest degradation on the forest cells that were not assigned for deforestation, and that are not in the forest strata or LULC class with the lowest carbon density. Degrade the cells selected for degradation by assigning them to the next-lower forest strata. The scarcity factor calculated based on remaining forest cover must be used for forest degradation. Note that degradation must be applied on the result of the deforestation, so that cells that were deforested that year cannot be subject to forest degradation as well.
- Using the maps developed in the previous steps, sum the areas for each transition

separately for (1) the project area excluding ANR and harvest ($\Delta area_{projectAreaEAH,baselineScenario}(t,i)$), (2) the areas with ANR ($\Delta area_{projectAreaWithANR,baselineScenario}(t,i)$) and (3) the areas with harvesting ($\Delta area_{projectAreaWithHarvest,baselineScenario}(t,i)$). This step will yield three transition matrices.

- For each of the three areas and three transition matrixes, calculate the regeneration transitions from one class or stratum ("CS1" in the equation below) to another class or stratum ("CS2" in the equation below) by multiplying the total area of the first class or stratum with the relative regeneration rate for transitions from one class or stratum to another, in the following formula noted as class or stratum 1 to 2. As explained in the summary, the baseline scenario includes not only projected degradation and deforestation, but also projected regeneration and reforestation in areas that were deforested. The equation below describes the carbon accounting for projected regeneration and reforestation under the baseline scenario.

$$\Delta area(t, CS1 \rightarrow CS2) = RFRGrate(CS1 \rightarrow CS2) \cdot area(t, CS1) \quad \text{[EQ41]}$$

where:

$\Delta area(t, CS1 \rightarrow CS2)$	=	Area of transition from class or stratum 1 to 2 from time t to $t+1$. [ha]
$RFRGrate(CS1 \rightarrow CS2)$	=	Relative annual regeneration rate for the transition from a class or stratum 1 to another, 2, from time t to $t+1$. [yr^{-1}]
$area(t, CS1)$	=	Total area of class or stratum 1 for time t of the crediting period. [ha]

Apply the regeneration area $\Delta area(t, CS1 \rightarrow CS2)$ to the appropriate LULC classes and forest strata obtained after step 5 (degradation) so that the areas of all LULC classes are updated. The resulting areas of LULC classes and forest strata represent all land use dynamics for year t for one of the three areas considered. Report the final areas of all LULC classes and forest strata for year t separately for each of the three areas introduced in step 7.

8.2 Project Emissions

One or more of the drivers of deforestation described in Section 8.1.3 must be mitigated through specific project activities. Some activities may focus on increasing the livelihood options of local communities or preventing leakage through, for example, increasing the land use intensity of already deforested land. Success of the implementation and on-going maintenance of these activities is critically dependent on the active involvement of all stakeholders in the planning and execution of these project activities. In particular, the local communities must be actively involved. Therefore, project management, advisory, oversight, and consultative structures must be developed to ensure the active involvement of all stakeholders.

A holistic approach should be taken to meet the various resource needs of local communities. For example, rather than excluding local communities from using any forest resources at all (and therefore necessarily forcing them to acquire these resources outside of the project area or purchase these in local or provincial markets, leading to leakage), a sustainable land management plan including key components of agriculture and forestry practices should be put in place to meet local wood and agricultural needs.

The *ex-ante* estimation of the deforestation and forest degradation rates is based on a breakdown of the effectiveness of every project activity (a) in decreasing any driver of deforestation (d) relative to that driver's contribution to deforestation and forest degradation, i.e. $effectiveness(a, d)$. For example, assume that the collection of fuelwood leads to a degradation of 200 Mg C per year, and the introduction of fuel-efficient woodstoves decreases emissions equivalent to 50 Mg C per year. Furthermore, assume that the development of biogas plants reduce emissions equivalent to 100 Mg C per year. The effectiveness of fuel-efficient woodstoves to decrease degradation from fuelwood collection, i.e. $effectiveness\left(fuel\text{-}efficient\ stoves, fuel\text{-}wood\ collection\right)$, is 25%, whereas the effectiveness of biogas plants to decrease degradation from fuelwood collection, i.e. $effectiveness\left(fuel\text{-}efficient\ stoves, fuel\text{-}wood\ collection\right)$, is 50%. Values of effectiveness factors must be estimated for every combination of project activity and driver of deforestation and forest degradation. Note that effectiveness values are only meant for *ex-ante* estimates of emission reductions/removals. E*x-post* emission reduction/removals are not quantified based on these values. The effectiveness values are often challenging to quantify, and depend on local conditions and the experience of the project proponent. However, estimation of the volume of emission reductions/removals that a project will generate depends on the ability of the project proponent to estimate the effectiveness values and refine these estimations throughout project monitoring.

The $effectiveness(a, d)$ factor represents the maximal effectiveness during the crediting period. This maximal effectiveness is adjusted over time using a rate factor, i.e., $rate(a, t)$, to reflect changes in the effectiveness due to gained experience, changes in funding levels, or on-going capacity building.

8.2.1 Identify Project Activities and Estimate the Effectiveness in Reducing Deforestation and Degradation Rates under the Project Scenario

A description of the REDD project activities that are included in this methodology, together with procedures to quantify the effectiveness for each project activity and each targeted driver follows.

8.2.1.1 Strengthening of Land-Tenure Status and Forest Governance

Legal agreements between the participating communities, landowners, project developers, and relevant government administrative levels are a necessary first step to secure land tenure and carbon rights. These agreements are particularly important when participating communities do not legally own the forest land, and the land-tenure status is unclear or obscured by a complex administrative hierarchy. The project proponent can assist local communities in securing their land tenure status. This can include developing legally binding community forestry agreements, purchasing or securing long-term conservation easements, or the revision of spatial plans and zoning laws. The expenses related to the establishment of these agreements can be covered by the revenue from REDD credit sales.

Strengthening the land-tenure status is essential for protecting land from encroachment by people other than participating communities and provide clarity on the allowed land use by the participating communities. However, legal tenure is insufficient for an effective protection of the forest resources. It must be complemented with on-the-ground protection measures such as social fencing or a patrolling system.

Table 10. Procedures to quantify the maximal effectiveness of strengthening land-tenure for target drivers.

Target driver	Maximal effectiveness quantification
Logging of timber for commercial on-sale	$effectiveness < 5\%$ [EQ42] Legal recognition of the land-tenure status will eliminate overlapping authority from different administrations and reduce the potential that logging concessions are granted without explicit permission of participating communities. In addition, it is a necessary (but insufficient) step to reduce illegal logging of timber for commercial on-sale. Note that strengthening land-tenure alone usually does not directly lead to a reduction in deforestation.
Conversion of forest land to cropland (by people other than participating communities)	$effectiveness < 5\%$ [EQ43] Legal recognition of the land tenure status will reduce the potential of conversion of forest land to cropland within the project area because it will provide clarity on the legal land uses. However, on-the-ground patrolling is necessary to effectively avoid conversion to cropland.
Conversion of forest land to settlements (by people other than participating communities)	$effectiveness < 5\%$ [EQ44] See previous driver
Conversion of forest land to infrastructure	$effectiveness < 5\%$ [EQ45] See previous driver

8.2.1.2 Support with the Development and Implementation of Sustainable Forest and Land Use Management Plans

Forest and land use management plans should be established in a participatory and democratic way. These plans can include the volumes of timber, fuelwood or NTFP each community can sustainably harvest, the areas for livestock grazing, or the area of forest land that can be converted into settlements or cropland and where the conversion must take place. The management plans must be based on the current and future need for forest products and land. Such plans will increase the efficiency of the current land use and avoid unplanned conversion of forest patches that can accelerate forest degradation. Plans must be integrated and compatible with the land tenure and usage rights and be long-term or permanent (where possible) in nature.

The management plan is only binding for participating communities and will not affect the drivers of deforestation for which the agents are not participating in the project. The following table outlines the procedure to quantify the maximal effectiveness for this driver.

Table 11. Procedure to quantify the maximal effectiveness of forest and land use plans for target drivers.

Target driver	Maximal effectiveness quantification
Conversion of forest land to cropland by participating communities	$$effectiveness = \left(1 - \frac{\Delta area_{cropland,allowed}}{\Delta area_{cropland,baseline}}\right)\%$$ [EQ46] Forest and land-use plans usually explicitly indicate how much land can be converted from forest to cropland. The baseline conversion rates must be estimated based on remote sensing analysis or social assessments when no remote sensing analysis is feasible.
Conversion of forest land to settlements by participating communities	$$effectiveness = \left(1 - \frac{\Delta area_{settlement,allowed}}{\Delta area_{settlement,baseline}}\right)\%$$ [EQ47] See previous driver
Logging of timber for commercial on-sale (commercial timber = CT)	$$effectiveness = \left(1 - \frac{CT_{allowed}}{CT_{baseline}}\right)\%$$ [EQ48] The baseline harvesting rate comes from (1) recent reports and studies within the project area, (2) peer-reviewed literature in regions similar to the reference region, (3) expert opinion.
Logging of timber for local and domestic use by participating communities (domestic timber = DT)	$$effectiveness = \left(1 - \frac{DT_{allowed}}{DT_{baseline}}\right)\%$$ [EQ49] See previous driver
Fuelwood collection for domestic and local energy needs (domestic fuelwood = DFW)	$$effectiveness = \left(1 - \frac{DFW_{allowed}}{DFW_{baseline}}\right)\%$$ [EQ50] See previous driver
Cattle grazing in forests (grazing = GR)	$$effectiveness = \left(1 - \frac{GR_{allowed}}{GR_{baseline}}\right)\%$$ [EQ51] See previous driver

Extraction of understory vegetation (vegetation = VG)	$$effectiveness = \left(1 - \frac{VG_{allowed}}{VG_{baseline}}\right)\%$$ [EQ52] See previous driver

Any variable with the subscript "allowed" represents the allowed quantity or amount under the project scenario within the project boundary. Analogously, variables with the subscript "baseline" refer to the quantity in the baseline scenario. At the start of the project, information on parameters for the baseline must come from the project area itself. During a baseline update, these values must come from the reference region and/or leakage belts.

8.2.1.3 Demarcating Forest, Tenure and Ownership Boundaries, and Areas of Forest Protection

The installation of fences, gates, boundary poles, and signage provides local communities a transparent, recognizable and fixed boundary of the project area. Because legal protection alone (project action 1, "Strengthening the land-tenure status") may be insufficient to prevent deforestation, often a physical boundary or signage is required to avoid deforestation and to support social fencing and patrolling. Once the boundaries are demarcated, they must be protected and patrolled. Often, the capacity of the law enforcing authorities is too limited to do this task, so communities commit to defend their own land-tenure and land use rights by engaging in regular patrolling of the forest area. It must be clarified with the local administration which types of actions can be undertaken in the case of illegal trespassing (e.g., confiscating chainsaws, alerting local law enforcers, etc.). This often results in improved synergies amongst local communities, law enforcement and other relevant agencies to support boundary protection. Other project actions can include the creation of logistical plans to protect boundaries, social fencing, and the acquisition of equipment (e.g., small motorized vehicles) for patrolling and enforcement. The following table outlines the procedure to quantify the maximal effectiveness for this driver.

Table 12. Procedures to quantify the maximal effectiveness of demarcating boundaries for target drivers.

Target driver	Maximal effectiveness quantification
Logging of timber for commercial on-sale	$$50\% < effectiveness < 100\%$$ [EQ53] Since legally sanctioned logging is already regulated under forest management plans, the main driver affected here is illegal logging for commercial on-sale. With a sound forest patrolling plan in place, it is assumed that illegal logging for commercial on-sale can be at least halved.
Conversion of forest land to cropland by people other than participating communities	$$effectiveness = 100\%$$ [EQ54] Boundary demarcation and forest protection can eliminate conversion of forest land to crop land in most instances.
Conversion of forest land to settlements by people other than	$$effectiveness = 100\%$$ [EQ55] See previous driver

participating communities	

8.2.1.4 Fire Prevention

If forest fires threaten the project's forest resources, specific fire prevention measures could be taken. These include (1) installation of fire breaks, (2) clearing the forest of dead wood that can act as fuel for fires, especially around regenerating and young secondary forests, (3) discouraging or eliminating (if possible) fire-based hunting techniques, and (4) social inclusion activities to ward off revenge related fires. Saplings and small trees are particularly vulnerable to forest fires. If fire prevention activities require cutting down trees, or removing dead wood, this loss of carbon should be accounted for. The following table outlines the procedure to quantify the maximal effectiveness for this driver.

Table 13. Procedures to quantify the maximal effectiveness of fire prevention for target drivers.

Target driver	Maximal effectiveness quantification
Forest fires	$40\% < effectiveness < 60\%$ [EQ56] Fire prevention measures such as fire breaks, together with education, can effectively reduce fire-related deforestation and forest degradation by 50%. Set the value of effectiveness between the thresholds above based on (1) pilot experiments in the project area, (2) peer-reviewed studies in an area similar to the project area or (3) advice from experts.

8.2.1.5 Reduce the Fuelwood Consumption by Increasing Energy Efficiency

The collection of fuelwood only leads to forest degradation if it is collected from live trees. A low-intensity collection of fuelwood from downed dead wood may, in fact, have a positive effect on forest regeneration by decreasing the potential for forest fires. In cases where the collection of fuelwood leads to forest degradation, the introduction of fuel-efficient woodstoves will decrease the need for local consumption of fuelwood (Top et al. 2004). Adoption rates of these alternatives need to be monitored, together with the potential on-sale of fuelwood on local markets, which can potentially annul the GHG benefits generated by the alternative stoves. Only fuelwood gathering for domestic use is allowed in project areas. No fuelwood gathering is allowed for commercial purposes. The carbon accounting related to a decrease in consumption of fuelwood is done by monitoring the changes in carbon stocks; the following table outlines the procedure to quantify the maximal effectiveness for this driver.

Table 14. Procedures to quantify the maximal effectiveness of energy efficiency for the target driver.

Target driver	Maximal effectiveness quantification
Fuelwood collection for domestic and local industrial energy needs	$$effectiveness = \sum (maximal\ adoption\ rate) \cdot (increase\ in\ efficiency\ of\ action)$$ [EQ57] Estimate the maximal adoption rate based on the willingness of project participants to change their practices as quantified (1) in social assessments, or (2) by expert opinion. Estimate the relative increase in efficiency of stoves from (1) field studies, (2) peer-reviewed literature, or (3) local experts.

8.2.1.6 Creation of Alternative Sources of Fuelwood

While the previous project action focuses on the *demand side* of energy, the set of project actions discussed in this section affects the *supply side* of energy. Activities can focus on creating alternative sources of fuelwood through agroforestry interventions, such as interplanting agricultural fields with trees that benefit agricultural yields, (as does Winterthorn, *Faidherbia albida*), but also provide some fuelwood to local farmers. Other examples include the creation of farm or village woodlots and woodlands on degraded land. Obviously, no forest may be cut to establish a woodlot or woodland. However, emissions related to the removal of biomass as part of a set of silvicultural interventions to maximize biomass growth, such as clearing of shrubs and weeds, are considered de minimis. Finally, renewable and non-fossil fuel based energy sources, such as solar or micro-hydro, can reduce the need for fuelwood by providing an alternative source of energy for cooking, heating or light.

Table 15. Procedures to quantify the maximal effectiveness of alternative fuelwood sources for target drivers.

Target driver	Maximal effectiveness quantification
Fuelwood collection for domestic and local industrial energy needs	$$effectiveness = \frac{DFW_{baseline} - DFW_{alternative}}{DFW_{baseline}}$$ [EQ58] Estimate the production of alternative fuelwood sources that would go to domestic uses. Calculate the fuelwood equivalent of solar and micro-hydro technologies, if applicable.
Wood collection for commercial on-sale	$$effectiveness = \frac{CFW_{baseline} - CFW_{alternative}}{CFW_{baseline}}$$ [EQ59] Estimate the production of alternative wood sources that would go to further on-sale. Calculate the fuelwood equivalent of solar and micro-hydro technologies, if applicable.

8.2.1.7 Sustainable Intensification of Agriculture on Existing Agricultural Land

Forest land is often deforested to make a place for subsistence farming or extensive grazing. Project activities that will increase productivity and agricultural yields on existing cropland and increase animal stocking rates on grazing lands minimize the need for further forest clearing. Such activities include increases in mechanization, installation of irrigation systems, the introduction of high-yielding crop varieties, increases in livestock stocking rates, conservation agriculture and agroforestry activities, and farm-wood lot management. Intensification of agriculture also provides alternative forest-based biomass resources. Only sustainable farming techniques should be promoted and any increases in GHG emissions due to these activities must be monitored, reported and accounted for. Agriculture can be intensified through (1) sponsoring pilot and demonstration studies on sustainable agriculture and agroforestry, (2) strengthening the relations with local agricultural extension services, colleges and universities and (3) establishing a system of small grants or micro-financing for local farmers to invest into agricultural equipment, infrastructure, seeds, or fertilizer.

Intensification measures must be done on land that was already under agricultural production, or on land that is sanctioned to become agricultural land given the land-use plans. The following table outlines the procedure to quantify the maximal effectiveness for this driver.

Table 16. Procedures to quantify the maximal effectiveness of agricultural intensification for target drivers.

Target driver	Maximal effectiveness quantification
Conversion of forest land to cropland by the project proponent	$effectiveness = (maximal\ adoption\ rate) \cdot (increase\ in\ yield\ per\ hectare)$ [EQ60] Estimate the maximal adoption rate based on the willingness of project participants to change their practices based on (1) quantified in social assessments, or (2) expert opinion. Estimate the relative increase in yield from (1) field studies, (2) peer-reviewed literature or (3) local agricultural extension experts. Latter options may only be used if former options are not available.
Cattle grazing	$0\% \leq effectiveness \leq 100\ \%$ [EQ61] See previous driver
Understory vegetation extraction	$0\% \leq effectiveness \leq 100\ \%$ [EQ62] See previous driver

8.2.1.8 Providing Alternative Livelihoods to the Agents of Deforestation

If agents of deforestation can engage in alternative livelihoods that are not based on deforestation, they can secure income without the need to further clear forests.

- As much as possible, planned project activities should be carried out by the local communities**.** Engaging communities in forest patrolling, biomass inventory, fire prevention activities, installation of fences and boundary poles, and assisted natural regeneration activities will provide employment and a greater financial return to the communities. In addition, the active involvement of the local communities will strengthen the project goals and decrease the risks of project failure.
- Part of the forest can be made accessible for sustainable eco-tourism, which will create jobs and increase revenue.
- The sustainable extraction of non-timber forest products can be further developed and commercialized. This includes the harvesting of honey, medicinal plants, fungi, and the extraction of resins. Clear harvesting plans need to be developed to ensure the sustainable extraction of these commodities.

It is assumed that people will shift automatically towards a livelihood alternative that has a sufficiently greater return than their current livelihood. Therefore, the total effectiveness is calculated by dividing the income from alternative livelihoods by the total value of forest products that are harvested from the forest and sold on local markets. It is further assumed that alternative livelihood options must be 25% more economically attractive before people will switch to these alternative livelihoods. The total effectiveness thus becomes $0.75 \cdot \frac{\sum income\ through\ alternative\ livelihood}{\sum total\ value\ of\ forest\ products}$. This total effectiveness is then divided into individual values for the effectiveness for each target driver by multiplying the respective relative financial contribution of the target driver with the total value of forest products. The following table outlines the procedure to quantify the maximal effectiveness for this driver.

Table 17. Procedures to quantify the maximal effectiveness of alternative livelihoods for target drivers.

Target driver	Maximal effectiveness quantification
• Conversion of forest land to cropland • Logging of timber for commercial on-sale • Logging of timber for local enterprises and domestic use • Collection of fuelwood and charcoal production for sale on markets • Cattle grazing	$effectiveness = 0.75 \cdot \frac{\sum income\ through\ alternative\ livelihood}{\sum total\ value\ of\ forest\ products}$ [EQ63]

8.2.2 Calculate Effectiveness of Project Activities in Reducing GHG Emissions

The effectiveness of project actions may change during the crediting period, due to the increased experience of project implementers or an increased allocation of funds during the crediting period. This time-dependent project activity rate is accounted for by integrating a factor $rate(a,t)$ for project activity a during year t. As was mentioned before, $effectiveness(a,d)$ represents the maximally attainable effectiveness given project conditions and capacity are optimal. As a consequence, $rate(a,t)$ must be 100% at least once during the crediting period. The relative reduction in deforestation can be estimated *ex-ante* by integrating the relative proportion of each driver of deforestation with the effectiveness coefficients and the estimated adoption rates for each project activity.

$$RelativeDriverImpact_{DF}(t,d) = \sum_{a=1}^{nrActivities} \left(rate(a,t) \cdot effectiveness(a,d) \cdot contribution_{DF}(d) \right) \quad \text{[EQ64]}$$

$$RelativeDriverImpact_{DG}(t,d) = \sum_{a=1}^{nrActivities} \left(rate(a,t) \cdot effectiveness(a,d) \cdot contribution_{DG}(d) \right) \quad \text{[EQ65]}$$

$$RelativeProjectImpact_{DF}(t) = \sum_{d=1}^{nrDrivers} RelativeDriverImpact_{DF}(t,d) \quad \text{[EQ66]}$$

$$RelativeProjectImpact_{DG}(t) = \sum_{d=1}^{nrDrivers} RelativeDriverImpact_{DF}(t,d) \quad \text{[EQ67]}$$

where:

$RelativeDriverImpact_{DF}(t,d)$ and $RelativeDriverImpact_{DG}(t,d)$	=	Relative impact of a driver d on deforestation and forest degradation, respectively for year t of the crediting period.[-]
$RelativeProjectImpact_{DF}(t)$ and $RelativeProjectImpact_{DG}(t)$	=	Impact of all project activities on deforestation and forest degradation respectively, relative to the baseline deforestation and forest degradation rates during year t. [-]
$nrActivities$	=	Total number of project activities. [-]
$nrDrivers$	=	Total number of drivers of deforestation. [-]

$rate(a,t)$	=	Adoption rate or relative degree of activity for activity a during year t. A value of 100% indicates that the activity cannot be more efficient in reducing deforestation or forest degradation. [-]
$effectiveness(a,d)$	=	The effectiveness of project action a to reduce driver of deforestation d. [-]
$contribution_{DF}(d)$ and $contribution_{DG}(d)$	=	The relative importance of driver d in deforestation and degradation to the total deforestation and degradation, respectively. [-]

The absolute rate of deforestation in hectares per year in the project region under the project scenario can be calculated by multiplying the relative project impact with the total deforestation and forest degradation rates in the project region under the baseline scenario.

$$D_{projectArea,projectScenario,DF}(t) = RelativeProjectImpact_{DF}(t) \cdot D_{projectArea,baselineScenario,DF}(t) \quad \text{[EQ68]}$$

$$D_{projectArea,projectScenario,DG}(t) = RelativeProjectImpact_{DG}(t) \cdot D_{projectArea,baselineScenario,DG}(t) \quad \text{[EQ69]}$$

Where:

$D_{projectArea,projectScenario,DF}(t)$ and $D_{projectArea,projectScenario,DG}(t)$	=	Rate of deforestation/degradation within the project area during year *t* under the project scenario. [ha yr^{-1}]
$RelativeProjectImpact_{DF}(t)$ and $RelativeProjectImpact_{DG}(t)$	=	Relative impact of all project activities on deforestation and forest degradation respectively during year t. [-]
$D_{projectArea,baselineScenario,DF}(t)$ and $D_{projectArea,baselineScenario,DG}(t)$	=	Baseline rate of deforestation/degradation within the project area during year *t.* [ha yr^{-1}]

8.2.3 Calculate Forest Strata-Specific Deforestation and Degradation Rates

Use the LULC model calibrated and validated in Section in 8.1.5 to divide the total *ex-ante* deforestation and forest degradation rates under the project scenario into individual rates for every forest stratum transition. The same statistical models may be used for calculating the stratum-specific rates under the project scenario. For every year of the crediting period, present a land transition table for the project areas under the project scenario.

8.2.4 Estimate GHG Emissions Sources from Firebreaks

The only project activity that may lead to an increase in emissions in the project is the clearing of trees to establish fire breaks or other fire prevention measures.[12] Increases in emissions from this activity must be duly accounted for and subtracted from the GHG emission reductions generated by the project activities. In case prescribed burning is used to remove woody biomass, all CH_4 emissions related to the burning must be included. The GHG emissions from fire breaks can be calculated by:

$$GHG_{fireBreaks} = \frac{44}{12} \cdot \sum_{i=1}^{nrFireClasses} area_{biomassLoss}(i) \cdot \left(C_{AGL}(i) + C_{AGD}(i) + C_{BG}(i)\right) + \sum_{i=1}^{nrStrata} area_{fireBiomassLoss}(i) \cdot \left(C_{AGL}(i) + C_{AGD}(i) + C_{BG}(i)\right) \cdot \frac{16}{12} \cdot GWP_{CH4} \cdot ER_{CH4} \quad \text{[EQ70]}$$

where:

$E_{fireBreaks}$	=	Annual GHG emissions from implementation of fire-preventing actions as REDD project activities. [$tCO_2e\ yr^{-1}$]
$nrFireClasses$	=	Number of forest strata in which fire breaks were installed. [-]
$area_{biomassLoss}(i)$	=	Total annual area of forest stratum i that was cleared for creating fire breaks. [$ha\ yr^{-1}$]
$C_{AGL}(i), C_{AGD}(i), C_{BG}(i)$	=	Carbon content in the aboveground live, aboveground dead, and belowground pools in forest stratum i. It is conservatively assumed that all biomass is removed. [$Mg\ C\ ha^{-1}\ yr^{-1}$].
$area_{fireBiomassLoss}(i)$	=	Annual area of forest stratum i that was cleared by prescribed burning. [$ha\ yr^{-1}$]
GWP_{CH4}	=	Global Warming Potential for CH_4 [-]
ER_{CH4}	=	Emission ratio for CH_4 (IPCC default value = 0.012). See Table 3A.1.15 in IPCC GPG-LULUCF (2003). [-]
$nrStrata$	=	Number of forest strata. [-]

12 Emissions from clearing herbaceous vegetation are insignificant.

Add annual values of $E_{fireBreaks}$ to the summary table of all GHG emissions due to project activities.

8.2.5 Estimate the Net GHG Sequestration from Assisted Natural Regeneration (ANR) Activities

8.2.5.1 Scope and Applicability

This methodology includes procedures to quantify the GHG removals generated from silvicultural activities aimed at restoring degraded forest. These ANR activities serve a triple goal: (1) increase the project area's overall GHG sink strength, (2) reduce activity-shifting, and (3) provide alternative livelihoods to local communities by employing local communities for executing the work.

See Section 4.2.1 for a list of applicability conditions related to ANR activities .Further specific requirements related to ANR activities are provided below.

Assisted natural regeneration must only be done by implementing one or more of the following measures:

- Removal of invasive understory species such as ferns or herbs to promote the growth of tree seedlings.
- Thinning of over-stocked and stagnated forest stands to promote radial growth.
- Removal of exotic and/or invasive tree species to promote the growth of native species.
- Stem removal on trees with multiple shoots to promote the growth of a single stem.
- Enrichment planting with trees of biodiversity or social value.

A detailed ANR management plan with a detailed description of all activities including their location must be included in the PD. An update to the management plan may be submitted at verification.

8.2.5.2 General Quantification

Since the general approach to quantify increases in biomass under the project scenario using remote sensing is not very sensitive to gradual changes in forest biomass, regeneration in the areas with ANR are better accounted for using forest biomass inventories only. As a consequence, the changes in carbon stocks in the ANR areas in the project scenario must be accounted for by directly measuring increases in forest biomass using forest biomass inventories. These forest biomass inventory plots must be established, which are re-measured periodically. The calculation of the GHG removals by sinks due to assisted natural regeneration activities follows the latest version of CDM methodology AR-ACM0001 by combining and annualizing equations (11) and (12) (equation numbers from AR-ACM0001). The activity-shifting leakage from ANR activities is already included in the total project's leakage, as explained in Section 8.3. The following equation must be used to calculate sequestration from ANR activities.

$$C_{ANR}(t) = \Delta C_{ANR}(t) - \Delta C_{ANR,BSL}(t) \quad \text{[EQ71]}$$

where:

$C_{ANR}(t)$	=	Net anthropogenic greenhouse gas removals due to biomass increase in assisted natural regeneration during year t. [tCO_2e]
$\Delta C_{ANR}(t)$	=	Annual change in carbon stocks in all selected carbon pools due to ANR during year t. [tCO_2e]
$\Delta C_{ANR,BSL}(t)$	=	Baseline GHG gas emissions or sources during year t. [tCO_2e]

The procedure for calculating $\Delta C_{ANR}(t)$ is explained in Section 8.2.5.3. The procedure for calculating $\Delta C_{ANR,BSL}(t)$ is explained in Section 8.2.5.4. Section 8.2.5.5 explains how to calculate $GHG_{sources,ANR}(t)$, the increase in CO_2 emissions from loss of existing woody biomass due to site-preparation (including burning), and/or to competition from forest (or other vegetation) planted as part of the ANR activities during year t.

8.2.5.3 Estimate Carbon Stock Increase

The procedure to calculate the carbon uptake by biomass in the areas where assisted natural regeneration activities are implemented follows the procedure described in the latest version of CDM-approved methodology AR-ACM0001.

$$\Delta C_{ANR}(t) = \frac{44}{12} \cdot \sum_{i=1}^{nrStrata} \Delta C(t,i) \cdot u_{inventory,ANR}(i) \quad \text{[EQ72]}$$

$$\Delta C(t,i) = area_{projectAreaWithANR,projectScenario}(t,i) \cdot \frac{C(t_2,i) - C(t_1,i)}{t_2 - t_1} \quad \text{[EQ73]}$$

where:

$\Delta C_{ANR}(t)$	=	Annual change in carbon stocks in all selected carbon pools due to ANR during year t of the crediting period. Corresponds to Equation (12) of AR-ACM0001excluding GHG_E, but converted to CO_2 equivalents. [tCO_2e]
$nrStrata$	=	Number of forest strata. [-]
$\Delta C(t,i)$	=	Carbon stock change for ANR stratum i during year t of the crediting period. [Mg C yr^{-1}]
$area_{projectAreaWithANR,projectScenario}(t,i)$	=	Amount of land on which ANR activities are planned under the project scenario during year t and in stratum i. [ha]

$C(t_2, i)$ and $C(t_1, i)$	=	Carbon stock density at time t_2 and t_1 respectively and in stratum i. [Mg C ha^{-1}]
$t_2 - t_1$	=	Duration between times 1 and 2. [year]

The larger of the two combined errors of the carbon stock density at time t_1 and t_2 must be used for uncertainty assessment in ANR areas using [EQ74].

$$CE_{inventory,ANR}(i) = max\left(CE_{inventory,ANR}(t_2, i), CE_{inventory,ANR}(t_1, i)\right) \quad \text{[EQ74]}$$

The discounting factor for uncertainty around biomass stock densities in the ANR area is estimated as :

$$u_{inventory,ANR}(i) = \begin{cases} 1 & \text{if } CE_{inventory,ANR}(i) \leq 0.15, \\ 1 - CE_{inventory,ANR}(t, i) & \text{if } 0.15 < CE_{inventory,ANR}(i) < 1, \\ 0 & \text{if } CE_{inventory,ANR}(i) \geq 1 \end{cases} \quad \text{[EQ75]}$$

Where:

$CE_{inventory,ANR}(t, i)$	=	Combined error in estimated biomass stock density at time period t (i.e., time t_1 or time t_2) within stratum i using equation EQ21. [-]
$CE_{inventory,ANR}(i)$	=	Combined error in estimated biomass stock density within stratum i. [-]
$HWCI(C(t_1, i))$ and $HWCI(C(t_2, i))$	=	Half-width of the 95% confidence interval around the mean carbon stock density of LULC classes of forest stratum i respectively at time t_1 and t_2. [tCO_2e ha^{-1}]
$u_{inventory,ANR}(i)$	=	Uncertainty discounting factor around biomass stock densities in transition stratum i within ANR areas during time t. [−]
$max\left(CE_{inventory,ANR}(t_2, i), CE_{inventory,ANR}(t_1, i)\right)$	=	Maximum of combined error in inventories that were carried out at time t_2 and t_1 in LULC class or forest stratum i.[-]

To ensure that any loss of biomass that occurs as part of ANR activities such as from site preparation is duly accounted for, in the first verification $C(t_1, i)$ are the carbon stocks at the starting date of the crediting period or the starting date of the crediting period of added instance and $C(t_2, i)$ are the carbon stocks at the time of verification in stratum i. In the successive verifications, $C(t_1, i)$ are the carbon stocks at the preceding verificaiton and $C(t_2, i)$ are the carbon stocks at the time of verification in stratum i.

Ex-ante, values for biomass densities in ANR areas must be based on pilot projects or data on biomass increases in regenerating forests from the literature. *Ex-post*, this quantity must be monitored for actual biomass according to a network of sampling plots according to the procedures within this document. Select a sampling design with a confidence level of 95%.

8.2.5.4 Calculate Baseline Emissions or Sinks on Land on which Assisted Natural Regeneration Activities are Planned

The baseline emissions or sinks on land with ANR are calculated similarly as to the land without ANR using [EQ76].

$$\Delta C_{ANR,BSL}(t) = -\sum_{i=1}^{nrFNFtransitions} \sum_{tt=1}^{t} \begin{pmatrix} u_{classification} \cdot u_{transition}(i) \\ \cdot \Delta area_{projectAreaWithANR,baselineScenario}(t,i) \\ \cdot \left(EF_{AGL}(i) + EF_{AGD}(i,t-tt) + EF_{BG}(i,t-tt) + EF_{SOM}(i,t-tt)\right) \end{pmatrix} - \sum_{i=1}^{nrStrataTransitions} \sum_{tt=1}^{t} \begin{pmatrix} u_{stratification} \cdot u_{transition}(i) \\ \cdot \Delta area_{projectAreaWithANR,baselineScenario}(t,i) \\ \cdot \left(EF_{AGL}(i) + EF_{AGD}(i,t-tt) + EF_{BG}(i,t-tt) + EF_{SOM}(i,t-tt)\right) \end{pmatrix} \quad \text{[EQ76]}$$

where:

$\Delta C_{ANR,BSL}(t)$	=	Baseline GHG gas emissions or sources during year t. [tCO_2e]
$u_{classification}$	=	Discounting factor for NERs from avoided deforestation, based on the accuracy of classification, i.e. dividing land into broad land use types. Section 8.1.2.7.
$u_{transition}(i)$	=	Discounting factor for all emission reductions, based on the uncertainty of biomass inventory related to transition i.
$\Delta area_{projectAreaWithANR,baselineScenario}(t,i)$	=	Hectares undergoing transition i within the ANR area under the baseline scenario during year t. [$ha\ yr^{-1}$]. Section 8.2.5.3
$EF_{AGL}(i), EF_{AGD}(i,t-tt), EF_{BG}(i,t-tt), EF_{SOM}(i,t-tt)$	=	Aboveground live, aboveground dead, belowground, and soil emission factor for transition i, and time after transition

		$t - tt$. Section 8.1.4.5
$u_{stratification}$	=	Discounting factor for NERs from avoided degradation, based on the accuracy of stratification, i.e. dividing forest into individual forest biomass classes. Section 8.1.2.7
$nrFNFtransitions$	=	Number of forest/non-forest transitions among land classes or forest strata, meaning transitions in which either the “from” or the “to” class are non-forests. Section 8.1.2.3
$nrStrataTransitions$	=	Number of transitions among forest strata. Section 8.1.2.38.1.2.3

8.2.5.5 Calculate Emission Sources from Assisted Natural Regeneration

The increase in GHG emissions as a result of the prescribed burning during the implementation of the proposed ANR activity, $GHG_{sources,ANR}(t)$ consists of CH_4 emissions from prescribed burning of woody biomass and is calculated as following:

$$GHG_{sources,ANR}(t) = \sum_{i=1}^{nrANRStrata} area_{fireBiomassLoss,ANR}(t,i) \cdot \left(C_{AGL}(i) + C_{AGD}(i) + C_{BG}(i)\right) \cdot \frac{16}{12} \cdot GWP_{CH4} \cdot ER_{CH4} \quad \text{[EQ77]}$$

where:

$GHG_{sources,ANR}(t)$	=	Increase in GHG emissions as a result ANR activity within the project boundary during year t. [tCO_2e]
$nrANRStrata$	=	Number of strata within the project area on which ANR activities are proposed. [-]
$area_{fireBiomassLoss,ANR}(t,i)$	=	Area of biomass removed within ANR stratum i using prescribed burning during year t. [ha]
$C_{AGL}(i), C_{AGD}(i), C_{BG}(i)$	=	Carbon content in aboveground live, aboveground dead and belowground pool in ANR stratum i. [Mg C ha^{-1}]
GWP_{CH4}	=	Global Warming Potential for CH_4 [-]
ER_{CH4}	=	Emission ratio for CH_4 (IPCC default value = 0.012). See Table 3A.1.15 in IPCC GPG-LULUCF (2003). [-]

8.2.6 Estimate the Net GHG Emissions Reductions from Cookstove and Fuel Efficiency Activities

8.2.6.1 Scope and Applicability

Cookstove and Fuel Efficiency (CFE) activities comprise improvements in the thermal application of non-renewable biomass. Examples of such activities include the introduction of high efficiency biomass-fired cookstoves, ovens and dryers, and improvement of energy efficiency of existing biomass-fired cookstoves, ovens and dryers. This methodology anticipates assisting the project proponent in reducing GHG emissions from degradation that can occur due to collection of fuelwood even if forest degradation is not included in the general quantification of GHG emissions reductions benefits. This methodology can be used to quantify GHG emissions reduction generated from reducing consumption of non-renewable biomass based on the procedures below.

See Section 4.2.2 for a list of applicability conditions related to CFE activities. Further specific requirements related to CFE activities are provided below.

8.2.6.2 General Quantification

The quantification approach assumes that, under the baseline scenario, the communities are collecting and consuming biomass fuel from the project area, directly causing deforestation and forest degradation. With the use of appliances with higher efficiency, the consumption of biomass is expected to decrease under the project scenario. The introduction of CFE activities reduces non-CO_2 from burning of fuelwood as well as CO_2 emissions from the loss of carbon stocks in the forest. When the degradation is included in the general quantification of GHG emissions reductions, emissions reductions from CFE activities arising from reducing CO_2 related emissions may have potential to be counted twice. In order to avoid double counting of emissions reductions generated from CFE activities are limited to those arising from non- CO_2 emissions reductions if degradation is included in the REDD project. On the other hand, when the degradation is excluded, GHG emissions emission reductions/removals from CFE activities include the non- CO_2 emissions and CO_2 related emissions. The CO_2 related emissions, however, exclude those related to deforestation activities.

Leakage related to the non-renewable biomass saved by the project activity must be assessed from surveys. Following method AMS.II.G. a leakage discount factor ($\mathrm{DF_{LeakageCFE}}$) of 0.95 can be applied to estimated emissions reduction benefits from CFE, in which are surveys are not required.

If the degradation is excluded:

$$ER_{CFE}(t) = DF_{LeakageCFE} \sum_{i=1}^{nrCFE} HH_{non-CFE}(i,t) \cdot U_{CFE}(t) \cdot Fuel(t) \cdot \left(1 - \frac{\eta_{old}}{\eta_{new}}\right) \cdot NCVfuel \cdot (EF_{non-CO2,fuel} + proportion_{DG,fuel} \cdot EF_{CO2,fuel}) \quad \text{[EQ78]}$$

If the degradation is included:

$$ER_{CFE}(t) = DF_{LeakageCFE} \sum_{i=1}^{nrCFE} HH_{non-CFE}(i,t) \cdot U_{CFE}(t) \cdot Fuel(t) \cdot \left(1 - \frac{\eta_{old}}{\eta_{new}}\right) \cdot NCVfuel \cdot EF_{non-CO2,fuel}$$

where:

$ER_{CFE}(t)$	=	Emission reduction from CFE activities during year t from cookstoves in the project area. [t CO2e]
$DF_{LeakageCFE}(t)$	=	Leakage discount factor [-]. A default factor from AMS.II.G of 0.95 can be used.
$U_{CFE}(t)$	=	Fraction of cumulative usage rate for technologies in project scenario in year t based on cumulative adoption rate and drop off rate revealed by usage surveys [-].
$Fuel(t)$	=	Average annual volume of biomass fuel consumed by households in the absence of the project activity at time t for cooking purpose. [Mg DM yr^{-1} HH^{-1}]
$HH_{non-CFE}(t,i)$	=	Total number of households in the project area that collect biomass fuel from the project area and use i number of efficient or alternative appliances under the project scenario and do not use CFE under the baseline at time t. [-]
i	=	Number of improved cookstoves and/or fuel efficient appliances from 1 to $nrCFE$ [-]
$nrCFE$	=	Total number of number of improved cookstoves and/or fuel efficient appliances [-]
η_{old}	=	Efficiency of the baseline cookstoves or appliances being replaced. [-]
η_{new}	=	Efficiency of the project CFE appliances deployed. [-]
$proportion_{DG}(fuelwood)$	=	The default proportion of degradation related carbon loss from fuelwood collection activities [-], (See Table 7)
NCV_{fuel}	=	Net calorific value of non-renewable biomass that is substituted. [TJ $(Mg\ DM)^{-1}$]
$EF_{non-CO2,fuel}$	=	Non--- CO_2 emission factor of the fuel that is reduced. [MgCO2 TJ^{-1}]
$EF_{CO2,fuel}$	=	Emission factor for the substitution of non-renewable biomass by similar consumers. [$MgCO_2$ TJ^{-1}]

8.2.7 Estimate GHG Emissions from Harvesting

This methodology allows (limited) harvesting of timber from the project area. Allowing harvesting activities (1) increases the attractiveness of a REDD project to participating communities by providing employment and/or controlled access to forest resources, (2) reduces activity-shifting and market leakage, and (3) ensures that harvesting occurs legally, controlled and in a sustainable fashion. An integrated forest management plan or a harvest plan must be developed and all harvesting activities must be carried out according to this plan. The plan must include boundary of areas within a REDD project where harvest activities take place, as well as details of the forest inventory, projected forest growth, projected removal and harvest schedules, harvest methods, and location of harvest activities. In addition, forest management as well as silvicultural activities that aim at enhancing the growth and vigor of the forests inside the harvested areas must be described in the plan. The integrated forest management plan must be submitted at validation or during a verification event and may be updated at a verification event. If a specific area on which ANR activities are done or were done in the past but on which harvesting activities are planned at any point in the future, this area must be considered under this section and not in the section on ANR so to avoid overlap in areas. The quantification of the carbon stock density in harvest areas ($C_{harvest}(t,i)$) must be made from sample plots established in the harvest areas.

See Section 4.2.3 for a list of applicability conditions regarding harvesting. Further specific requirements related to harvesting are provided below.

The harvest plan description in PD must include the following information:

- Description of harvest areas in terms of location, size, forest inventory and topography.
- A description of all silvicultural activities that will be applied in the areas where harvesting will be carried out. This description must include number of trees removed and number of trees retained, in case of individual tree selection cut methods. For clear-cut methods or group selection cut methods, maximum opening size must also be described.
- The harvesting methods, i.e. mechanized vs. manual, as well as all processes such as felling, bunching, skidding/ forwarding, loading, and unloading. All machinery and equipment must be described.
- The harvest frequency (years between harvests) and volume of harvest at each time period.
- Regeneration assumptions and description of site indexes for dominant species in the strata. The harvest plan must include the expected tree density that will be maintained in the project area. Additionally, growth estimates for harvest areas in terms of total biomass as well as biomass stock density per unit area must be described and all assumptions and validity of any growth estimates must be justified. If any software based models have been used, proper justification of the suitability of such models used must also be described in the harvest plan.
- Activities that are practiced to protect soil, water, site and residual trees in the

harvest area.

- Documentation on presence/absence of any threatened or endangered species and/or habitat on site, potential impacts on species and mitigation measures, presence/absence of natural heritage areas, and potential impacts on natural heritage areas and mitigation measures.
- A map of the harvest site including the following:
    - Plot locations.
    - Harvest area boundary within the project area boundary.
    - Slope classes.
    - Streams/rivers/roads (if present).
    - Wetlands (if present).
    - Stream side management zones or river buffer (if applicable).
    - Planned skid trails (if applicable).
    - Landing sites/areas (if applicable).

8.2.7.1 Determining Long-term Average Carbon Stock

The long-term average carbon stock represents the maximum carbon stock that can be attained in harvest areas. GHG benefits must be calculated using a carbon stock that never exceeds the long-term average carbon stock in the areas where harvest activities take place. The long-term average must be quantified based on an appropriate minimal time period which must include at least one full harvest/cutting cycle. The minimal time period must be established as following:

- If the harvest plan concentrates harvest activities in smaller blocks and continuously moves harvesting activities from one block to the next throughout the forest until all the areas are harvested within one harvesting cycle (as practiced in clear-cut or group-selection cut methods), the minimal time period must end at the first year after the end of the crediting period during which all forest blocks have undergone a similar number of harvesting cycles. For example, if the crediting period is 30 years and the duration for all blocks to be harvested once is 12 years, the minimal time period must be 36 years even though project crediting period is only 30 years.
- If the harvest plan intends to target individual trees for harvest throughout the crediting period and the harvest can take place anywhere in a specified are within the forest (as practiced in individual tree selection cut methods), then the established time period over which the long-term average is calculated must be the length of the project crediting period. For example, if the crediting period is 30 years and harvesting of individual trees are carried out throughout the forest during the project crediting period, then the long-term average must be estimated based on the project crediting period.

- After determining the time period for estimating the long-term average, the long-term average carbon stock density must be calculated using [EQ79].

$$LTAC_{harvest} = \frac{\sum_{t=0}^{T}\sum_{i=1}^{nrStrata} C_{harvest}(t,i) \cdot u_{inventory,harvest}(i)}{T} \quad \text{[EQ79]}$$

where:

$LTAC_{harvest}$	=	Long-term average Carbon stock density contained in harvested areas. [tCO_{2e} ha-1]
$nrStrata$	=	Number of forest strata. [-]
$C_{harvest}(t,i)$	=	Biomass carbon stock density at time t in stratum i in harvested areas. [tCO_2 ha^{-1}]
$u_{inventory,harvest}(i)$	=	Discounting factor for the uncertainty in biomass estimation in harvested areas in stratum i in harvest areas. The most recent $u_{inventory,harvest}(t,i)$ value must for used for discounting the estimate for future years. [-]
T	=	Minimal time period for estimating long term average. [yr].

The ex-ante estimation of the $LTAC_{harvest}$ must use biomass carbon stock density $C_{harvest}(t,i)$ values that are estimated using a projection model such as a computer simulation model or a growth table. All projection models must be properly calibrated using field measurements and must estimate the removal of biomass from the harvest areas using the harvest management plan. After the start of the project, the projection model must be re-calibrated using actual harvesting and biomass growth data and the $LTAC_{harvest}$ must be re-calculated at every verification. Any projection model used must have the following characteristics:

- The used models have been prescribed or recommended by designation forest department or related agencies in the country/jurisdiction. For example, growth models or yield project tables listed in forest act/regulations can be used. Alternatively, models that have been found in peer reviewed literature and are from the same region as of the project area can be used. However, such models must be parameterized for the specific conditions of the project area.
- The used models must be clearly documented with respect to the scope of the model, assumptions, known limitations, embedded hypotheses, assessment of uncertainties, and sources for equations, data sets, factors or parameters.
- Simulation software must be based on local data or calibrated for use in the project area. CO2FIX is an example of a simple ready-to-use model that can be easily applied globally. FVS, a different simulation model, has more functionality but requires calibration for use outside of the US (and Canada).

- When no individual simulation model is available, a simple spreadsheet model using IPCC biomass growth estimates or growth estimates based on expert opinion corroborated by local studies and historical practice for the project area can be used. The IPCC biomass tables provide estimate of annual growth and total biomass as a function of different forest types, age-group, and time. When biomass removal is tracked along with the annual growth, biomass remaining in forest can be estimated. Note that this approach gives only linear growth.

8.2.7.2 Calculate Emissions or Sinks on Land on which Harvesting Activities are Implemented

The emissions reductions or removals on the land with harvest activities are calculated using [EQ80].

$$\Delta C_{areaWithHarvest}(t) = \sum_{i=1}^{nrStrata} area_{projectAreaWithHarvest,projectScenario}(t,i) \cdot \left(\frac{C_{harvest}(t_2,i) - C_{harvest}(t_1,i)}{t_2 - t_1}\right) \cdot u_{inventory,harvest}(i) - \sum_{i=1}^{nrFNFtransitions} \sum_{tt=1}^{t} \left(u_{classification} \cdot u_{transition}(i) \cdot \Delta area_{projectAreaWithHarvet,baselineScenario}(t,i) \cdot \left(EF_{AGL}(i) + EF_{AGD}(i,t-tt) + EF_{BG}(i,t-tt) + EF_{SOM}(i,t-tt)\right)\right) - \sum_{i=1}^{nrStrataTransitions} \sum_{tt=1}^{t} \left(u_{stratification} \cdot u_{transition}(i) \cdot \Delta area_{projectAreaWitHarvest,baselineScenario}(t,i) \cdot \left(EF_{AGL}(i) + EF_{AGD}(i,t-tt) + EF_{BG}(i,t-\mathrm{tt}) + EF_{SOM}(i,t-tt)\right)\right) \quad \text{[EQ80]}$$

In the first verification, $C_{harvest}(t_1,i)$ are the carbon stocks at the starting date of the crediting period and $C_{harvest}(t_2,i)$ are the carbon stocks at the time of verification in stratum i . In the successive verifications, $C_{harvest}(t_1,i)$ are the carbon stocks at the preceding verification event and $C_{harvest}(t_2,i)$ are the carbon stocks at the time of verification in stratum i . Furthermore, when a new instance is included in the project area, in the first verification of the added instance, $C_{harvest}(t_1,i)$are the carbon stock at the time of that instance addition. $u_{inventory,harvest}\ (i)$ must be estimated using procedure described in 8.2.5.

where:

$\Delta C_{areaWithHarvest}(t)$	=	Net greenhouse gas emissions or removals in project area with harvest activities during year t. [tCO_2e]
$area_{projectAreaWithHarvest,projectScenario}(t,i)$	=	Size of strata i within the project area with harvest activities during year t under the project scenario. [-]
$C_{harvest}(t,i)$	=	Biomass carbon stock density at time t in stratum i in harvested areas. [$tCO_2\ ha^{-1}$]

$u_{inventory,harvest}(i)$ = Discounting factor for the uncertainty in biomass estimation in harvested areas in stratum i in harvest areas. The most recent $u_{inventory,harvest}(t,i)$ value must for used for discounting the estimate for future years. [-]

$\Delta area_{projectAreaWithHarvet,baselineScenario}(t,i)$ = Hectares undergoing transition i within the project area in the harvest area, under the baseline scenario during year t. [ha yr^{-1}].

$nrStrataTransitions$ = Number of transitions among forest strata. Section 8.1.2.3

$nrFNFtransitions$ = Number of forest/non-forest transitions among land classes or forest strata, meaning transitions in which either the “from” or the “to” class are non-forests. Section 8.1.2.3

$EF_{AGL}(i)$, $EF_{AGD}(i,t-tt)$, $EF_{BG}(i,t-tt)$, and $EF_{SOM}(i,t-tt)$ = Aboveground live, aboveground dead, belowground, and soil emission factor for transition i, and time after transition $t-tt$. Section 8.1.4.5

$u_{stratification}$ = Discounting factor for NERs from avoided degradation, based on the accuracy of stratification, i.e. dividing forest into individual forest biomass classes. Section 8.1.2.7

$u_{classification}$ = Discounting factor for NERs from avoided deforestation, based on the accuracy of classification, i.e. dividing land into broad land use types. Section 8.1.2.7

$u_{transition}(i)$ = Discounting factor for all emission reductions, based on the uncertainty of biomass inventory related to transition i.

8.2.7.3 Quantification of Emissions from Harvesting

The fossil fuel emissions from forest harvesting activities are likely to be less than 5% of the total GHG emissions reductions benefits generated by the project. Considering that emissions from deforestation and forest degradation will be much higher than those associate to timber harvesting, the emissions from fossil fuel during transport and machinery can be considered *de-minimis*. In addition, according to VCS *AFOLU Requirements* Section 4.3.3.fossil fuel emissions from transport and machinery use in the REDD project activities can be considered *de minimis*. Therefore, emissions from harvesting, $GHG_{sources,harvest}(t)$, are considered “0”.

8.3 Leakage

8.3.1 Leakage Categories Included in this Methodology.

Under this methodology, leakage is estimated *ex-ante*, but actual NERs are based on actual leakage calculated with project monitoring data. Leakage does not only occur on forest land outside of the project area, but also on non-forest land, such as woodlands or grassland.

The market leakage assessment only has to be included when illegal logging activities that supply timber to national or international markets as an identified driver. Stopping illegal logging to supply timber products to local communities is going to shift pressures to forested areas close to the project area. As a consequence, emissions due to market-effect leakage will be detected by the monitoring for activity shifting leakage.

However, if the illegal logging activities supply timber products to regional, national or global markets, there is high likelihood of market leakage beyond the detection boundaries of the activity-shifting leakage. Therefore, market leakage $GHG_{marketLeakage}(t)$ from reducing logging activities that supply timber products to regional, national or global markets must be quantified by applying appropriate market leakage discount factor to the total GHG emissions reductions/removals benefits derived from avoiding the deforestation and/or degradation activities that supply timber would otherwise supply timber products to regional, national or global markets in the baseline. The market leakage discount factor must be derived by using procedures for the market leakage discount factors for IFM projects set out in VCS *AFOLU Requirement*.

The procedure to quantify leakage differs between drivers that are geographically constrained and geographically unconstrained drivers (see Table 18).

- *Ex-ante* activity-shifting leakage from the geographically constrained drivers uses a factor-approach based on rural appraisals and expert knowledge; *ex-post* leakage from these drivers is based on the remotely sensed deforestation/degradation rates in the leakage area.
- *Ex-ante* activity-shifting leakage from the geographically unconstrained drivers is based on a factor-approach based on rural appraisals and expert knowledge. *Ex-post* activity shifting leakage is based on a factor-approach using conservative assumptions.

Table 18. Distinction between geographically constrained and geographically unconstrained drivers.

Geographically constrained driver categories	Geographically unconstrained driver categories
• Conversion of forest land to cropland for subsistence farming by local communities • Conversion of forest land to settlements	• Conversion of forest land to cropland for subsistence farming by migrants • Conversion of forest land to

by local communities • Logging of timber for local enterprises and domestic use • Fuelwood collection or domestic and local industrial energy needs • Cattle grazing in forests • Extraction of understory vegetation • Forest fires not part of natural ecosystem dynamics[13]	settlements by migrants • Logging of timber for commercial on-sale • Wood collection for commercial on-sale of fuelwood and charcoal production

8.3.2 Estimate Leakage from Geographically Constrained Drivers

Leakage from geographically constrained drivers is estimated *ex-ante* by calculating deforestation and forest degradation rates in the area adjacent to the project area subject to leakage, i.e. the leakage belts.

- First, calculate the leakage induced increase in deforestation/degradation due to project activities.
- Subsequently, demarcate the location and the size of the leakage belts using a GIS analysis.
- Next, estimate forest strata-specific deforestation and forest degradation rates in the leakage belts. Calculate first the total deforestation and degradation rates in the leakage belts by adding the leakage-induced increases in deforestation/degradation to the baseline deforestation/ degradation rates in the leakage belts. Estimate then forest strata-specific deforestation and forest degradation rates using the land use model previously calibrated (Section 8.1.5) for every time t of the crediting period.

8.3.2.1 Calculate the Leakage-Induced Increase in Deforestation and Forest Degradation Rates

$$\Delta D_{LK,DF}(t) = RelativeLeakageImpact_{DF}(t) \cdot D_{projectArea,baselineScenario,DF}(t) \quad \text{[EQ81]}$$

$$\Delta D_{LK,DG}(t) = RelativeLeakageImpact_{DG}(t) \cdot D_{projectArea,baselineScenario,DG}(t) \quad \text{[EQ82]}$$

13 Not all forest fires are a source of leakage, only the forest fires caused by displaced agents such as hunters or beekeepers. The cause of the fire is not specified in the name of the leakage source, however, since, in practice, it is impossible to determine the source of fire. Any statistically significant increase in fire occurrence relative to a 10-yr baseline period must be considered as leakage.

where:

$\Delta D_{LK,DF}(t)$ and $\Delta D_{LK,DG}(t)$	=	Leakage induced increase in deforestation and forest degradation rates during year t of the crediting period. [ha yr^{-1}]
$RelativeLeakageImpact_{DF}(t)$ and $RelativeLeakageImpact_{DG}(t)$	=	Total relative impact of leakage on the decrease in GHG emissions due to project activities for deforestation and forest degradation respectively for year t of the crediting period. [-]
$D_{projectArea,baselineScenario,DF}(t)$, and $D_{projectArea,baselineScenario,DG}(t)$	=	Baseline rate of deforestation/degradation within the project area during year t of the crediting period. [ha yr^{-1}]

The relative impact of leakage is quantified by *ex-ante* leakage cancellation factors, which express the driver-specific relative amount of leakage for the amount of deforestation or degradation that is avoided. This quantity describes the proportion of the (expected) gross emission reductions inside the project area that are lost again due to leakage outside of the project area. Only changes that are directly attributed to project activities must be included in the cancellation rate. For example, if preventing illegal encroachment within the project area by patrolling saves 500 ha of forest per year, but directly leads to an increased deforestation outside of the project area of 300 ha, the achieved GHG emissions reductions benefits are cancelled due to leakage. The cancellation of GHG emissions reductions benefit is 60%. Once the leakage cancellation rates $leakage(d)$ are fixed for every driver d, the $RelativeLeakageImpact$ can be calculated as following:

$$RelativeLeakageImpact_{DF}(t) = \sum_{d=1}^{nrCDrivers} leakage_{constrained}(d) \cdot RelativeDriverImpact_{DF}(t,d) \quad \text{[EQ83]}$$

$$RelativeLeakageImpact_{DG}(t) = \sum_{d=1}^{nrCDrivers} leakage_{constrained}(d) \cdot RelativeDriverImpact_{DG}(t,d) \quad \text{[EQ84]}$$

where:

$RelativeLeakageImpact_{DF}(t)$ and $RelativeLeakageImpact_{DG}(t)$	=	Total relative impact of leakage on the decrease in GHG emissions due to project activities for deforestation and forest degradation respectively at time t. [-]
$nrCDrivers$	=	Number of geographically constrained drivers. [-]

$leakage_{constrained}(d)$	=	Leakage cancellation rate for avoiding deforestation/degradation of geographically constrained driver d. [-]
$RelativeDriverImpact_{DF}(t,d)$ and $RelativeDriverImpact_{DG}(t,d)$	=	Relative impact of a driver d on deforestation and forest degradation, respectively at time t of the crediting period. [-]

Every driver is assigned a leakage cancellation rate based expert knowledge, social assessments and past project experience. Summarize all cancellation rates for each driver in a separate table for avoided deforestation or avoided forest degradation. Any variable with subscript "allowed" indicates that the amount contained in that variable is allowed under the project. Similarly, variables with subscript "project" and "baseline" respectively indicate amount demanded under project and baseline. For example, as part of the REDD project strategy, measures can be put in place to reduce the allowed extraction of certain forest products and reduce the demand for these forest products. Any demand for forest products which cannot be eliminated and cannot be met by the allowed production can cause leakage. Leakage must be calculated as a function of baseline demand, project demand and project supply. If the project intervention does not expect any reduction in demand under the project scenario, any parameter with subscript "project" must be equal to corresponding parameters with subscript "baseline". Similarly, if no deforestation and/or degradation parameter is allowed/expected under project scenario then parameter with subscript "allowed' must be set to "0" in these calculations.

8.3.2.1.1 Leakage Cancellation Rate for Conversion of Forest Land to Cropland for Subsistence Farming by Participating Communities

$$leakage_{constrained}(cropland\ conversion\ by\ participating\ communities) = \frac{\Delta area_{cropLand,project} - \Delta area_{cropLand,allowed}}{\Delta area_{cropLand,baseline} - \Delta area_{cropLand,allowed}} \quad \text{[EQ85]}$$

Where:

$leakage(cropland\ conversion)$	=	Leakage cancellation rate for avoiding deforestation/degradation due to conversion of forest land to settlements. [-]
$\Delta area_{cropLand,baseline}$	=	Area that would be converted to cropland by participating communities under the baseline scenario. [ha yr^{-1}]
$\Delta area_{cropLand,project}$	=	Area that will be converted to cropland by participating communities under the project scenario after reduction in demand for cropland conversion. [ha yr^{-1}]

$\Delta area_{cropLand,allowed}$	=	Area that will be converted to cropland within the project area under the project scenario as defined in the management plan or project document. [ha yr^{-1}]

If the data are missing to calculate $leakage(cropland\ conversion)$, use a conservative rate of 100%. This is allowed because no *ex-post* NERs are dependent on this rate estimated. If the project does not anticipate or allow any conversion after the project start date then, $\Delta area_{cropLand,allowed}$ must be "0".

8.3.2.1.2 Leakage Cancellation Rate for Conversion of Forest Land to Settlements by Local Communities

$$leakage_{constrained}(settlement\ conversion) = \frac{\Delta area_{settlement,project} - \Delta area_{settlement,allowed}}{\Delta area_{settlement,baseline} - \Delta area_{settlement,allowed}} \quad \text{[EQ86]}$$

where:

$leakage_{constrained}(settlement\ conversion)$	=	Leakage cancellation rate for avoiding deforestation/degradation due to conversion of forest land to settlements. [-]
$\Delta area_{settlement,baseline}$	=	Area that would be converted to settlements by participating communities under the baseline scenario. [ha yr^{-1}]
$\Delta area_{settlement,project}$	=	Area that will be converted to settlements by participating communities under the project scenario after reduction in demand for settlement to conversion. If reduction in demand is not applicable, then this must be equal to $area_{settlement,baseline}$. This area is required by communities. [ha yr^{-1}]
$\Delta area_{settlement,allowed}$	=	Area that will be converted to settlements within the project area under the project scenario as defined in management plan/project document. [ha yr^{-1}]

If the data are missing to calculate $leakage(settlement\ conversion)$, use a conservative rate of 0.9. This is allowed because no *ex-post* NERs are dependent on this rate estimated.

8.3.2.1.3 Leakage Cancellation Rate for Conversion of Forest Land to Infrastructure

$$leakage_{constrained}(infrastucture\ conversion) = \frac{\Delta area_{infrastucture\ ,project} - \Delta area_{infrastucture\ ,allowed}}{\Delta area_{infrastucture\ ,baseline} - \Delta area_{infrastucture\ ,allowed}} \quad [EQ87]$$

where:

$leakage_{constrained}(infrastucture\ conversion)$	=	Leakage cancellation rate for avoiding deforestation/degradation due to conversion of forest land to infrastructure. [-]
$\Delta area_{infrastucture\ ,baseline}$	=	Area that would be converted to infrastructure under the baseline scenario. [ha yr^{-1}]
$\Delta area_{infrastucture\ ,project}$	=	Area that will be converted to infrastructure under the project scenario after reduction in demand for infrastructure development. If reduction in demand is not applicable, then this must be equal to $\Delta area_{infrastructure,baseline}$. [ha yr^{-1}]
$\Delta area_{infrastucture\ ,allowed}$	=	Area that will be converted to infrastructure within the project area under the project scenario as defined in management plan/project document. [ha yr^{-1}]

If the data tocalculate $leakage(infrastructure\ conversion)$ is not available, use a conservative rate of 100 %. If the similar project activities have proven to achieve 100% reduction in demand for infrastructure development elsewhere in the reference region or in areas similar to reference region in the same jurisdiction as the location of project area, then $leakage(infrastructure\ conversion)$ can be set to 0%. If the project does not anticipate or allow any conversion for infrastructure after the project start date then, $\Delta area_{infrastructure,allowed}$ must be “0”.

8.3.2.1.4 Leakage Cancellation Rate for Logging of Timber for Local Enterprises and Domestic Use.

The timber needed for local and domestic use is non-elastic. If the project activities allows extraction of timber from forest, then the leakage is “0” and if the project activities does not allow extraction of timber for such uses, then the leakage cancellation rate is 100%. For any value less than 100%, sufficient proof must be provided to justify lower leakage rate and must be assessed by the validation/verification body. In order to justify a lower leakage, the project proponent must be able to demonstrate a lower demand for timber products or supply from the sources that are not causing deforestation within the country boundary such as managed forest lots.

$$leakage_{constrained}(domestic\ timber) = 0 - \ 100\% \quad \text{[EQ88]}$$

8.3.2.1.5 Leakage Cancellation Rate for Fuelwood Collection for Domestic and Local Industrial Energy Needs

Estimate the leakage cancellation rate as:

$$leakage_{constrained}(fuel\text{-}wood) = \frac{DFW_{project} - DFW_{allowed}}{DFW_{baseline} - DFW_{allowed}} \quad \text{[EQ89]}$$

where:

$leakage_{constrained}(fuel\text{-}wood)$	=	Leakage cancellation rate for avoiding deforestation/degradation of fuelwood collection for domestic and local energy needs. [%]
$DFW_{baseline}$	=	Biomass (dry matter) of fuelwood collected by project participants under the baseline scenario. [$m^3\ yr^{-1}$]
$DFW_{project}$	=	Biomass (dry matter) of fuelwood collected by project participants under the project scenario after any adjustments to demand. [$m^3\ yr^{-1}$]
$DFW_{allowed}$	=	Biomass (dry matter) of allowed fuelwood collection in the project area under the project scenario as defined in a management plan/project document. [$m^3\ yr^{-1}$]

An example of applying this equation is given here for illustration. Assuming that collection of fuel-wood for domestic uses is one of the drivers of deforestation and under the baseline, the demand for fuel-wood within participating communities is equivalent to 100 arbitrary units ($DFW_{baseline} = 100$). As part of project activities, a forest management plan and land use planning will be in place. These plans streamline the extraction and limit the amount of wood that can be harvested from the forest. When it is allowed to harvest only 80 units of fuel-wood (as part of project activity) in the REDD project area ($DFW_{allowed} = 80$) without implementing any energy efficiency measures, the demand will remain constant under the project scenario ($DFW_{project} = 100$), causing a leakage of 20 units or 100%, because:

$$leakage_{constrained}(fuel\text{-}wood) = \frac{100 - 80}{100 - 80} = 100\%$$

However, when the project implementation reduces the demand for forest products itself, such as by increasing the efficiency and reducing the demand from 100 to only 90 units, $DFW_{project} = 90$), then there is leakage of 10 units or 50%, since:

$$leakage_{constrained}(fuel\text{-}wood) = \frac{90-80}{100-80} = 50\%$$

A number of project activities may be implemented to decrease the need for the resource either directly (e.g., the introduction of fuel-efficient woodstoves) or indirectly by providing alternative sources for the resource (e.g., solar stoves instead of woodstoves) must be used. Estimate $B_{projectScenario}$ as:

$$DFW_{project} = \sum_{i=1}^{nrfuelWoodReductionActions} adoption(i) \cdot \big(1 - efficiency(i)\big) \cdot DFW_{baseline} \quad \text{[EQ90]}$$

where:

$nrfuelWoodReductionActions$	=	The number of project activities that reduce the need for fuelwood. E.g., introduction of fuel-efficient woodstoves, biogas plants. [-]
$adoption(i)$	=	Adoption rate of project activity i which reduces fuelwood consumption. [-]
$efficiency(i)$	=	Rate at which project activity i reduces fuelwood consumption. [-]
$DW_{baseline}$	=	Biomass (dry matter) of fuelwood collected in the project area in the baseline scenario. [Mg DM yr^{-1}]

8.3.2.1.6 Leakage Cancellation Rate for Cattle Grazing in Forests.

Cattle grazing will be reduced or avoided as part of project activities by replacing in-forest grazing activities with stall feeding. Livestock feeds will be supplied by intensification of agricultural activities and farm woodlot management. When stall feeding is used and there is no displacement of grazing activities, there is no leakage from grazing. The leakage from displacement of grazing activities must be estimated using the latest version of the CDM A/R Methodological Tool *Estimation of GHG emissions related to displacement of grazing activities in A/R CDM project activity*.

$$leakage_{constrained}(grazing) = 0 - 100\% \quad \text{[EQ91]}$$

8.3.2.1.7 Leakage Cancellation Rate for Extraction of Understory Vegetation.

Understory vegetation extraction that is required by communities for purposes such as roofing, livestock bedding and poles needs to be quantified and alternatives should be provided. Non-biomass alternatives for roofs could help defray the displacement of biomass extraction in leakage belts. Similarly, intensification of agriculture and farm wood management can provide alternatives to understory vegetation extraction.

$$leakage_{constrained}(VG) = \frac{VG_{project} - VG_{allowed}}{VG_{baseline} - VG_{allowed}} \quad \text{[EQ92]}$$

where:

$leakage_{constrained}(VG)$	=	Leakage cancellation rate for avoiding deforestation/degradation of understory vegetation extraction. [-]
$VG_{baseline}$	=	Biomass (dry matter) of understory vegetation extraction by project participants under the baseline scenario. [Mg DM yr^{-1}]
$VG_{project}$	=	Biomass (dry matter) of understory vegetation extraction by project participants under the project scenario. [Mg DM yr^{-1}]
$VG_{allowed}$	=	Biomass (dry matter) allowed as understory vegetation extraction under the project scenario. This amount is typically fixed in a management plan. [Mg DM yr^{-1}]

A number of project activities may be implemented to decrease the demand of understory vegetation (e.g., the introduction of alternative roofing material, biomass from intensification of agriculture). Estimate $VG_{project}$ as:

$$VG_{project} = \sum_{i=1}^{nrVGReductionActions} adoption(i) \cdot \left(1 - efficiency(i)\right) \cdot VG_{baseline} \quad \text{[EQ93]}$$

where:

$nrVGReductionActions$	=	The number of project activities that reduce the need for understory vegetation extraction. [-]
$adoption(i)$	=	Adoption rate of project activity i which reduces understory vegetation extraction.[-]
$efficiency(i)$	=	Rate at which project activity i reduces fuelwood consumption. [-]
$VG_{baseline}$	=	Biomass (dry matter) of understory vegetation extraction. [Mg DM yr^{-1}]

8.3.2.1.8 Leakage Cancellation Rate for Forest Fires Not Part of Natural Ecosystem Dynamics.

Most forest fires that are avoided through fire prevention activities and education will not lead to increased occurrence of forest fires outside of the project area. Select a conservative leakage cancellation rate between 0-100%. For example, fires induced by hunters or beekeepers may be partially or fully displaced by patrolling the project areas. Substantiate the selected rate based on rational arguments, field observations and scientific literature.

$$leakage_{constrained}(forest\ fires\ by\ participating\ communities) = 0 - 100\% \qquad [EQ94]$$

8.3.2.2 Demarcate the Leakage Belts

Leakage from drivers that are geographically constrained will remain close to the project areas. Leakage from these drivers is monitored in an *ex-ante* fixed geographical region around each discrete project area parcel (a leakage belt). Note that the leakage areas must contain both forest and non-forest land. The leakage belts are identical for all geographically constrained drivers (see Table 18). A correct *ex-ante* demarcation of each leakage belt is crucial to accurately account for the GHG benefits of the REDD project since the leakage belt is the area where leakage from geographically constrained drivers will be monitored and deducted from the actual NERs. The size and location[14] of the leakage belts is determined using a cost-of-transportation-based GIS approach and social assessments. Use the following steps:

- Determine the average “cost” to move across an LULC class, forest stratum, or road/track. The relative costs must be calculated by reciprocating the maximal speed for every class or road category and relevant mode of transportation, and therefore represent the fastest time it takes to cross a set distance. The speeds were analyzed in Section 8.1.3.3.
- Using a GIS, generate a raster map of the reference region in which every pixel contains the cost to cross this pixel, based on the class or roads/tracks on this pixel. The cost to cross areas that are not accessible to agents of deforestation must be set to an arbitrary large value. Examples of inaccessible areas include protected areas, national parks, economic land concessions, and large plantations. These must have been excluded already from the reference region.
- This map must have an identical resolution as the remote sensing images of the historical reference period.
- Using the cost map, generate a cost-distance map of the reference region in which every pixel contains the cost (time) to reach the nearest point of the project area.
- For every agent of deforestation/degradation, estimate the extra time this agent is willing to take to move its deforestation activities from the project area to the nearest accessible forest. Determine this value using social assessments by asking what the extra time is that a single household would have to spend if the project area is not accessible anymore.
- Select the area in the cost-distance map that is accessible from the boundary of the project area within the maximal time determined in the previous step multiplied by a

14 Note that the leakage belt encompasses both forest land and non-forest land.

factor 1.5.[15] This area must contain both forest and non-forest land. Therefore, when different agents and drivers of deforestation are active, the most mobile agent of deforestation must determine the size of a leakage belt. Note that the leakage area should be fully encompassed within the reference region. Increase the size of the reference region, if necessary, to accommodate the defined leakage belts.

8.3.2.3 Calculate the Forest Strata-specific Deforestation and Degradation Rates in the Leakage Belts

Once the leakage area is demarcated, the total deforestation/ degradation rates in the leakage belts are calculated using:

$$D_{leakageArea,baselineScenario,DF}(t) = D_{projectArea,baselineScenario,DF}(t)\frac{size_{leakageArea}}{size_{projectArea}} \quad \text{[EQ95]}$$

$$D_{leakageArea,baselineScenario,DG}(t) = D_{projectArea,baselineScenario,DG}(t)\frac{size_{leakageArea}}{size_{projectArea}} \quad \text{[EQ96]}$$

$$D_{leakageArea,projectScenario,DF}(t) = \Delta D_{LK,DF}(t) + D_{leakageArea,baselineScenario,DF}(t) \quad \text{[EQ97]}$$

$$D_{leakageArea,projectScenario,DG}(t) = \Delta D_{LK,DG}(t) + D_{leakageArea,baselineScenario,DG}(t) \quad \text{[EQ98]}$$

where:

$D_{leakageArea,baselineScenario,DF}(t)$ and $D_{leakageArea,baselineScenario,DG}(t)$	=	Baseline rate of deforestation/degradation within the leakage area at time t of the crediting period. [ha yr^{-1}]
$D_{projectArea,baselineScenario,DF}(t)$ and $D_{projectArea,baselineScenario,DG}(t)$	=	Baseline rate of deforestation/degradation within the project area at time t of the crediting period. [ha yr^{-1}]
$size_{leakageArea}$	=	Size of the leakage area. [ha]
$size_{projectArea}$	=	Size of the project area. [ha]
$D_{leakageArea,projectScenario,DF}(t)$ and $D_{leakageArea,projectScenario,DG}(t)$	=	Rate of deforestation/degradation within the leakage area under the project scenario at time t of the crediting period. [ha yr^{-1}]
$\Delta D_{LK,DF}(t)$ and $\Delta D_{LK,DG}(t)$	=	Leakage induced increase in deforestation and forest degradation rates during year t of the crediting period. [ha yr^{-1}]

[15] The factor of 1.5 takes into account that an agent of deforestation that is living close to the project area and who used to rely on the project area for certain activities may shift the activities to a forest in the opposite direction of the project area. However, this effect will gradually decrease. With a factor of 1.5, 95% of all potential leakage is captured.

- The total deforestation and forest degradation rates in the leakage area are calculated by adding the leakage-induced increase in deforestation/degradation rates to the baseline deforestation/ degradation rates. The baseline deforestation and forest degradation rates are calculated by taking the size-wise proportion of the deforestation/degradation rates in the project area under the baseline scenario. Add the total deforestation and forest degradation rates in the leakage area in two separate tables such as Table 15.
- Subsequently, estimate the forest strata-specific deforestation and forest degradation rates for every year of the crediting period using the land use model previously calibrated (Section 8.1.5).

8.3.3 Estimate Leakage from Geographically Unconstrained Drivers

Activity-shifting leakage from geographically unconstrained drivers is quantified using a factor approach in both the *ex-ante* and *ex-post* cases. All leakage from reducing logging of timber for commercial on-sale or wood collection for commercial on-sale of fuelwood and charcoal production is considered through the 'market leakage evaluations' mechanism from the VCS *AFOLU Requirements* document. The only other geographically unconstrained drivers are conversion of forests by migrants to either cropland or settlements outside of the leakage belts. Conversion of forest land to cropland or settlements by migrants or other people outside of the participating communities must be minimized with leakage prevention activities[16] such as the creation of alternative livelihoods and the intensification of land-use. The emissions from leakage are calculated by first quantifying the area of the leakage by multiplying the area of deforestation and degradation that is avoided with a leakage factor. Next, this area of leakage is multiplied with an average emission factor (EF_{forest}), a representative emission factor for the entire forest strata within the project area (i.e. average emission factor excluding non-forest strata) to calculate emissions from leakage by unconstrained drivers. This approach is fully conservative: in contrast to the deforestation by geographically constrained agents, it is not possible to predict in which forests the deforestation through leakage from unconstrained drivers will take place.

The following equation is to be used:

$$GHG_{\mathrm{otherLeakageSources}}(t) =$$

$$+EF_{forest} \cdot D_{projectArea,baselinScenario,DF} \cdot \sum_{d=1}^{nrUDrivers} leakage_{unconstrained}(d) \cdot RelativeDriverImpact_{DF}(t,d)$$

$$+EF_{forest} \cdot D_{projectArea,baselinScenario,DG} \cdot \sum_{d=1}^{nrUDrivers} leakage_{unconstrained}(d) \cdot RelativeDriverImpact_{DG}(t,d)$$

[EQ99]

16 A list of the allowed leakage prevention activities and the associated applicability criteria can be found in Step 12, section 8.3.4.

where:

$GHG_{otherLeakageSources}(t)$	=	GHG emissions from leakage due to unconstrained geographic drivers during year t of the crediting period. [tCO_2e]
EF_{forest}	=	Emission factor related to leakage. If comprehensive national-level statistics on biomass densities are available, EF_{forest} must be calculated based on the average biomass of the country, if local data is not available. Sources of the data allowed are (1) academic research papers and (2) studies and reports published by the forestry administration or other organizations, including the FAO's Forest Resource Assessment reports, (3) the upper range of biomass in the GPG-LULUCF (2003) Table 3A.1.2. [tCO_2e]
$D_{projectArea,baselinScenario,DF}$ and $D_{projectArea,baselinScenario,DG}$	=	Baseline rate of deforestation and forest degradation respectively within the project area during year t of the crediting period. [ha yr^{-1}]
$nrUDrivers$	=	Number of geographically unconstrained drivers that are not covered by market leakage, i.e., "Conversion of forest land to cropland for subsistence farming by migrants" and "Conversion of forest land to settlements by migrants"
$leakage_{unconstrained}(d)$	=	Leakage cancellation rate for avoiding deforestation/degradation from geographically unconstrained drivers such as area of cropland conversion displaced beyond the leakage belts relative to the area of cropland conversion avoided within the project area. Unless a lower rate can be justified, a default rate of 100% must be used. The burden of proof lies with the project developer[17]. Valid sources to substantiate a smaller leakage rate include social assessments, scientific literature, and reports from civil society or governments. Sources have to be reliable and based on scientific methods and a good statistical design.

[17] For example, REDD Project participants can demonstrate that different measures to reduce leakage in the country are effective. Evidence from other areas could be used to substantiate a smaller leakage rate after it is demonstrated that the circumstances are similar.

$RelativeDriverImpact_{DF}(t,d)$ and $RelativeDriverImpact_{DG}(t,cd)$	=	Relative impact of the geographically unconstrained driver d at time t of the crediting period. [-]

Calculate values for $GHG_{otherLeakageSources}(t)$ for every year of the project crediting period and report in the overview table.

8.3.4 Estimate Applicability of and Emission sources from Leakage Prevention Activities

Leakage can be minimized by implementing a number of leakage prevention activities. Under this methodology, a number of potential leakage prevention activities are allowed. Note that the implementation of potential leakage prevention activities is optional. However, if leakage prevention activities are implemented, they must follow the relevant applicability criteria detailed in Section 4.2 as well as the requirements specified below.

Any significant increase in GHG emissions due to the implementation of leakage prevention activities ($E_{sources,leakagePrevention}(t)$) must be subtracted from the project's overall GHG emissions according to the procedures included within this Section. In addition, as part of the validation, the validation/verification body must analyze that no other significant emissions exist originating from any measure associated with the project and intended to prevent leakage.

The following sources of GHG emissions from leakage prevention activities are included in this methodology:

$$GHG_{sources,leakagePrevention}(t) = \Delta E_{flooded\ rice}(t) + \Delta E_{livestock}(t) \quad \text{[EQ100]}$$

where:

$GHG_{sources,leakagePrevention}(t)$	=	Emission sources from leakage prevention activities during time t of the crediting period. [tCO_2e]
$\Delta E_{flooded\ rice}(t)$	=	Annual difference in GHG emissions due to increased use of flooded rice production systems as agricultural intensification measures during year t of the crediting period. [tCO_2e]
$\Delta E_{livestock}(t)$	=	Annual difference in GHG emissions by enteric fermentation and manure management from increased animal stocking rates as an agricultural intensification measure during year t of the crediting period. [tCO_2e]

The significance of these and other emissions is tested according to the procedures provided in CDM EB31, Appendix 16 to determine whether it must be included. If an emission source is found insignificant, it must be omitted.

8.3.4.1 Check Conditions and Quantify Emissions from Intensification of Annual Cropping Systems

See Section 4.2.4 for a list of applicability conditions related to intensification of annual crop production systems. In addition, intensification of annual crop production systems must only be done by implementing one or more of the following measures:

- Increasing synthetic or organic N inputs.
- The use of fallow crops or shrubs.
- Replacing subsistence crops by cash crops.
- Replacing low-yielding crop varieties by higher-yielding, or less pest-sensitive crop varieties.
- Introduction of irrigation systems, except for flooded rice production systems.

The emissions from intensification of annual cropping systems are considered negligible and considered ‘0’.

8.3.4.2 Check Conditions and Quantify Emissions from Introduction of Flooded Rice Production

8.3.4.2.1 Scope and Applicability

See Section 4.2.5 for a list of applicability conditions when introducing flooded rice production

8.3.4.2.2 Emissions

A simple yet conservative estimate of the CH_4 emissions from flooded rice fields is used to discount emission reductions. Emissions are calculated based on a maximal daily emission rate multiplied with the maximal length of the growing season determined by PRAs. Equation 5.1 of Chapter 5, Volume 4 of IPCC sets out the calculation for estimating total CH_4 emissions from flooded rice fields for a given year. The change in CH4 emissions due to agricultural intensification in flooded rice production systems is estimated by quantifying the annual expansion of flooded rice harvest area. Therefore annual difference in GHG emissions due to increased use of flooded rice production systems must be estimated as:

$$\Delta E_{flooded\ rice}(t) = GWP_{CH4} \cdot \Delta A_{rice}(t) \cdot t_{flooded,max} \cdot EF_{rice,max} \cdot 10^{-6} \quad \text{[EQ101]}$$

where:

t	=	Time after project start. [yr]
$\Delta E_{flooded\ rice}(t)$	=	Annual difference in GHG emissions due to increased use of flooded rice production systems as agricultural intensification measures during year t of the crediting period. [tCO_2e]
GWP_{CH4}	=	Global Warming Potential for CH_4 [-]
$\Delta A_{rice}(t)$	=	Total and cumulative increase in harvested area of rice due to leakage prevention measures since the start of the project and until year t. The increase in area of rice cultivation must be quantified using social assessments [ha yr^{-1}].
$t_{flooded,max}$	=	Maximal period of time a field is flooded [days yr^{-1}]
$EF_{rice,max}$	=	Maximal emission rate for methane. By default, an emission rate of 36 kg CH4 ha^{-1} day^{-1} must be used, which is 25% greater than the maximal value found in a review study comparing 25 studies of CH4 fluxes in rice fields (Le Mer and Roger, 2001). The project proponent may use a smaller emission rate if it can be demonstrate that the rate remains conservative for the project conditions. [kg CH_4 ha^{-1} day^{-1}]

Add annual values of $\Delta E_{flooded\ rice}(t)$ to the summary table of all GHG emissions due to project activities.

8.3.4.3 Estimate GHG Emissions from Increased Livestock Stocking Rates, $\Delta E_{livestock}$

8.3.4.3.1 Scope and Applicability

See Section 4.2.6 for a list of applicability conditions when increasing livestock stocking rates. Livestock stocking rates must be increased through either or both of the following measures:

- Increasing the stocking density of livestock on existing grazing land.
- Moving of cattle to a zero-grazing system, defined as a system of feeding cattle or other livestock in which forage is brought to animals that are permanently housed instead of being allowed to graze.

8.3.4.3.2 Quantification and Monitoring of Emissions from Increased Stocking rates

Use the leakage procedures provided in the latest version of approved CDM methodology AR-AM0006 and as well as the latest version of CDM A/R Tool *Estimation of GHG emissions related to displacement of grazing activities in A/R CDM project activity* to determine the CH_4 and N_2O emissions from livestock, [18]. The sum of variable $LK_{FFL,t}$ within the latest version of CDM methodology AR-AM0006 and the variable $LK_{Displacement,t}$ (minus $LK_{Deforestation,t}$ and $LK_{N2O-Displacement,t}$ which are already accounted in the carbon stock change assessment) within the CDM A/R tool is equivalent to $\Delta E_{livestock}(t)$ within this methodology. Add annual values of $\Delta E_{livestock}(t)$ to the summary table of all GHG emissions due to project activities.

Use the variables list of default parameters and parameters to be monitored from the latest versions of AR-AM0006 and the CDM tool for displacement of grazing activities. Livestock population increases must be quantified using social assessments or peer-reviewed literature, and re-evaluated after every baseline update. Livestock population increases must be monitored using social assessments or peer-reviewed literature.

8.4 Summary of GHG Emission Reduction and/or Removals

8.4.1 Estimate Change in Carbon Stocks in the Long-Lived Wood Product Pool

This methodology considers the carbon in long-lived wood products sequestered for over 100 year as permanently sequestered carbon. First, the carbon in harvested wood products must be calculated for the project and baseline scenarios. Then, the carbon in long-lived wood products must be calculated for the project and baseline scenarios. The net change in carbon in long-lived wood products is then calculated by subtracting the carbon in long-lived wood products under the baseline scenario and the project scenario.

8.4.1.1 Calculate Carbon in Harvested Wood Products.

The carbon in harvested wood products is calculating based on the volume of timber extracted within the project area in both the baseline scenario and the project scenario.

$$C_{HWP,project}(ty,t) = \sum_{h=1}^{H_{PS}} \sum_{j=1}^{S_{PS}} \left(\left(DT_{project}(h,j,ty,t) + CT_{project}(h,j,ty,t) \right) \cdot \rho_{wood,J} \cdot CF \right) \quad \text{[EQ102]}$$

[18] This tool has been approved for A/R CDM projects, but is applicable to REDD projects. All references to “A/R CDM” within this tool should be interpreted as “REDD”.

$$C_{HWP,baseline}(ty,t) = \sum_{h=1}^{H_{PS}} \sum_{j=1}^{S_{PS}} \left(\left(DT_{baseline}(h,j,ty,t) + CT_{baseline}(h,j,ty,t) \right) \cdot \rho_{wood,J} \cdot CF \right)$$

where:

$C_{HWP,project}(ty,t)$ and $C_{HWP,baseline}(ty,t)$	=	Total carbon stock in long-lived wood products within the project boundary for class ty during time t of wood product ty in the project and baseline scenario, respectively [Mg C]
$DT_{project}(h,j,ty,t)$, $DT_{baseline}(h,j,ty,t)$, $CT_{project}(h,j,ty,t)$ $CT_{baseline}(h,j,ty,t)$	=	The volume of timber extracted from within the project boundary during harvest h by species j and wood product class ty during year t in the project and baseline scenario, respectively. DT = domestic timber; CT = commercial timber [m^3].
$\rho_{wood,j}$	=	Wood density of harvested species or species group j [Mg DM m^{-3}]
h	=	1, 2, 3, …, H_{PS} number of harvests [-]
j	=	1, 2, 3, …, S_{PS} harvested tree species [-]
ty	=	Wood product class – defined here as sawn wood (sw), wood-based panels (wp), other industrial round wood (oir), and paper and paper board (ppb).
CF	=	Carbon fraction of wood [Mg C (Mg DM)$^{-1}$] (default value = 0.5)

- Under the baseline scenario $DT_{baseline}$ and $CT_{baseline}$ must be calculated using Section 8.1.3.2 and Table 8. The uncertainty around the estimates of $DT_{baseline}$ and $CT_{baseline}$ must be estimated and/or justified with appropriate methods, such as reported uncertainties from scientific literature, or calculated uncertainties when social assessments are used. In situations when uncertainty cannot be estimated, the most conservative estimate must be used.
- For the *ex-ante* project case, $DT_{project}$ and $CT_{project}$ must be calculated using the procedures in Section 8.2.1.
- *Ex-post*, $DT_{project}$ and $CT_{project}$ must be monitored and quantified using forest operation records (i.e., log books kept as part of forest management plan). The uncertainty around the monitored volume of timber must be explicitly reported.

In case the uncertainty, as quantified by the half-width of the confidence interval, is less than 15% of the volume of timber extracted, no adjustment for uncertainty must be applied. If, however, the uncertainty is greater than 15% of the volume of timber extracted, $C_{HWP,baseline}(ty,t)$ must be adjusted upwards with its associated uncertainty and $C_{HWP,project}(ty,t)$ must be adjusted downwards with its associated uncertainty.

8.4.1.2 Calculate the Carbon in Long-Lived Wood Products

Carbon in long-lived wood products is defined as being sequestered for at least 100 years. Instead of tracking annual emissions through retirement, burning and decomposition, the methodology calculates the proportion of wood products that have not been emitted to the atmosphere 100 years after harvest and assumes that this proportion is permanently sequestered. All factors are derived from Winjum et al. (1998).

$$C_{LWP,project}(t) = \sum_{s,wp,ppb,oir}^{ty} C_{HWP,project}(ty,t) \cdot \left(1 - wwf(ty)\right)\left(1 - slp(ty)\right)\left(1 - fo(ty)\right)$$
$$C_{LWP,baseline}(t) = \sum_{s,wp,ppb,oir}^{ty} C_{HWP,baseline}(ty,t) \cdot \left(1 - wwf(ty)\right)\left(1 - slp(ty)\right)\left(1 - fo(ty)\right) \quad \text{[EQ103]}$$

where:

$C_{LWP,project}(t)$ and $C_{LWP,baseline}(t)$	=	Carbon stock of long-lived wood products at time *t* in the project and baseline scenario, respectively. [Mg C]
$C_{HWP,project}(ty,t)$ and $C_{HWP,baseline}(ty,t)$	=	Total biomass carbon harvested within the project boundary by wood class ty during year t in the project and baseline scenario, respectively [Mg C]
$wwf(ty)$		Fraction of carbon in harvested wood products that is emitted immediately because of mill inefficiency for wood class ty. This can be estimated by multiplying the applicable fraction to the total amount of carbon in different harvested wood product category. The default applicable fraction is 24% and 19% respectively for developing and developed countries (Winjum et al. 1998).
$slp(ty)$	=	Proportion of short lived products. These fractions are 0.2, 0.1, 0.4 and 0.3 respectively for wood class ty, i.e., sawnwood, wood-based panel, paper and paper boards and other industrial round woods as described in Winjum et al. (1998). The methodology assumes that all other classes of wood products are emitted within 5 years.
$fo(ty)$	=	Fraction of carbon that will be emitted to the atmosphere between 5 and 100 years of harvest for wood class ty. See Table 19. [-]
t	=	*1, 2, 3….. t* years elapsed since the start of the project. [yr]
ty	=	Wood product class – defined here as sawnwood (sw), wood-based panels (wp), other industrial round wood (oir),

and paper and paper board (ppb)

Table 19. Proportion of remaining wood products oxidized between 5 and 100 years after initial harvest by wood product class and forest region

Wood product category	Forest region		
	Boreal	Temperate	Tropical
Sawnwood	0.378	0.613	0.850
Wood base panel	0.613	0.850	0.977
Other industrial round wood	0.850	0.977	0.999
Paper and paperboard	0.378	0.613	0.999

Source: Winjum et al. 1998

8.4.1.3 Calculate Net Change in Carbon in Long-Lived Wood Products

The net change in carbon in long-lived wood products is then calculated by subtracting the carbon in long-lived wood products under the baseline scenario and the project scenario.

$$\Delta C_{LWP}(t) = C_{LWP,project}(t) - C_{LWP,baseline}(t) \quad \text{[EQ104]}$$

where:

$\Delta C_{LWP,t}$ = Net carbon stock change in long-lived wood products during year *t* [Mg C]

$C_{LWP,project}(t)$ = Carbon stock in long-lived wood products under the baseline scenario during year *t* [Mg C]

$C_{LWP,baseline}(t)$ = Carbon stock in long-lived wood products under the project scenario during year *t* [Mg C]

8.4.2 Summarize the Projected Land Use Change

- Present a table with the total deforestation and degradation rates under the baseline and project scenarios for the project area and leakage area for every year of the project duration.
- Present tables with the LULC class and forest-strata specific land transitions for the project and leakage area under the baseline and project scenarios.
- Subtract the land transition changes under the baseline scenario from the changes under the project scenario, and multiply with the difference of the appropriate emission factor and baseline net annual increment. Apply all applicable uncertainty discounting factors.
- Calculate values for $GHG_{otherLeakageSources}(t)$ from the procedure in 8.3.3.
- Calculate the net GHG benefits from ANR without taking emission sources into account for every year t of the crediting period.

- Calculate the net GHG benefits from harvested wood products pool.
- Calculate the net GHG benefits from fuel-efficiency activities only if the degradation is not included in the REDD project.
- Calculate the net GHG benefits from areas subject of harvest activities.

8.4.3 Test the Significance of GHG Emissions

In this step, the significance of emission sources is determined. This test has to be carried out at validation for for each of the first ten years of the project crediting period, and the procedure has to be repeated at every baseline update. All insignificant emissions can be omitted from the *ex-ante* calculation of the NERs. The CDM *Tool for testing significance of GHG emissions in A/R CDM project activities* from EB31 appendix 16 should be used to test the significance of GHG emissions.

The sum of increases in emissions that may be excluded must be less than 5% of the emission reductions. If it is determined that a specific GHG emission source will never reach this threshold and will never become significant, it may be omitted from the monitoring plan.

8.4.4 Estimate *Ex-ante* NERs

Use Equation [EQ105] to estimate the *ex-ante* NERs; only use the significant GHG sources as determined in the step above. Prepare a table with all the individual terms of Equation [EQ105]. Calculate the *ex-ante* NERs for every year of the crediting period. After NERs are calculated, use Equation [EQ106] to calculate the VCUs.

Cumulative emissions reductions/removals from ANR activities must account for less than 50% of the cumulative emissions reductions/removals generated by the project. For every year of the crediting period, divide the total emissions reduction from ANR by the total NERs in the overview table, and confirm that the result is less than 50%. Note that *ex-ante* NERs are are calculated and reported for the entire project crediting period but the estimates must be re-validated at every baseline update. (i.e., every ten years.

Net Emission Reductions(NERs)	=		
		ΔGHG from avoided deforestation excluding ANR and harvest areas	❶
		+ ΔGHG from deforestation due to leakage	❷
		+ ΔGHG from avoided degradation	❸
		+ ΔGHG from degradation due to leakage	❹
		+ΔGHG from leakage by unconstrained geographic drivers	❺
		+ ΔGHG from assisted natural regeneration	❻
		+ ΔGHG from changes in long-lived wood products	❼
		+ ΔGHG from improved cookstoves	❽
		+ ΔGHG from other and secondary sources	❾

+ΔGHG from avoided deforestation from areas under harvest ❿

[EQ105]

$$\text{Verified Carbon Units} = \text{NERs} - buffer \cdot (❶ + ❸ + ❻ + ❼ + ❿)$$ [EQ106]

where:

Note that i and tt are simple indices to the summations and do not have any further meaning; t is the year for which the emissions and removals are calculated.

ΔGHG from avoided deforestation:

$$❶ = \sum_{i=1}^{nrFNFtransitions} \sum_{tt=1}^{t} u_{classification} \cdot u_{transition}(i) \cdot \begin{pmatrix} +\Delta area_{projectAreaEAH,projectScenario}(t,i) \\ -\Delta area_{projectAreaEAH,baselineScenario}(t,i) \end{pmatrix} \cdot \left(EF_{AGL}(i) + EF_{AGD}(i,t-tt) + EF_{BG}(i,t-tt) + EF_{SOM}(i,t-tt)\right)$$ [EQ107]

ΔGHG from deforestation due to leakage:

$$❷ = \sum_{i=1}^{nrFNFtransitions} \sum_{tt=1}^{t} u_{classification} \cdot u_{transition}(i) \cdot \begin{pmatrix} +\Delta area_{leakageArea,projectScenario}(t,i) \\ -\Delta area_{leakageArea,baselineScenario}(t,i) \end{pmatrix} \cdot \left(EF_{AGL}(i) + EF_{AGD}(i,t-tt) + EF_{BG}(i,t-tt) + EF_{SOM}(i,t-tt)\right)$$ [EQ108]

ΔGHG from avoided degradation:

$$❸ = \sum_{i=1}^{nrStrataTransitions} \sum_{tt=1}^{t} u_{stratification} \cdot u_{transition}(i) \cdot \begin{pmatrix} +\Delta area_{projectAreaEAH,projectScenario}(t,i) \\ -\Delta area_{projectAreaEAH,baselineScenario}(t,i) \end{pmatrix} \cdot \left(EF_{AGL}(i) + EF_{AGD}(i,t-tt) + EF_{BG}(i,t-tt) + EF_{SOM}(i,t-tt)\right)$$ [EQ109]

ΔGHG from degradation due to leakage: [EQ110]

$$❹ = \sum_{i=1}^{nrStrataTransitions} \sum_{tt=1}^{t} u_{stratification} \cdot u_{transition}(i) \cdot \begin{pmatrix} +\Delta area_{leakageArea,projectScenario}(t,i) \\ -\Delta area_{leakageArea,baselineScenario}(t,i) \end{pmatrix} \cdot \left(EF_{AGL}(i) + EF_{AGD}(i,t-tt) + EF_{BG}(i,t-tt) + EF_{SOM}(i,t-tt)\right)$$

ΔGHG from leakage by unconstrained geographic drivers:

$$❺ = -GHG_{otherLeakageSources}(t) - GHG_{marketLeakage}(t) \quad \text{[EQ111]}$$

ΔGHG from assisted natural regeneration:

$$❻ = C_{ANR}(t) \quad \text{[EQ112]}$$

ΔGHG from changes in long-lived wood products:

$$❼ = \frac{44}{12} \cdot \left(C_{LWP,project}(t) - C_{LWP,baseline}(t)\right) \quad \text{[EQ113]}$$

ΔGHG from GHG Emissions Reduction from Cookstove and Fuel Efficiency (CFE):

$$❽ = ER_{CFE}(t) \quad \text{[EQ114]}$$

ΔGHG from other and secondary sources:

$$❾ = -GHG_{fireBreaks}(t) - GHG_{sources,leakagePrevention}(t) - GHG_{sources,ANR}(t) \quad \text{[EQ115]}$$

ΔGHG from avoided deforestation and degradation from areas under harvest [EQ116]

In case:

$$\sum_{i}^{t} \Delta C_{areaWithHarvest}(i) \geq \sum_{i=1}^{nrStrata} area_{projectAreaWithHarvest,projectScenario}(t,i) \cdot LTAC_{Harvest}$$

$$❿ = 0$$

In case the inequality above does not hold, (10) must be:

$$❿ = \Delta C_{areaWithHarvest}(t) \quad \text{[EQ117]}$$

Positive leakage is not allowed. Therefore, values for equations [EQ108] and [EQ110] must be set to “0” if they are found to be greater than 0. In order to avoid over compensation for leakage, the leakage from avoided deforestation and forest degradation i.e., [EQ108], [EQ110], and [EQ111] must be set to ‘0’ if GHG emissions from leakage exceed the total GHG emissions reductions from avoided deforestation and/or forest degradation for each crediting period.

Variable	Explanation
$NERs(t)$	Net emission reductions during time t. Section 8.4.4. [tCO_{2e}]
$VCUs(t)$	Verified Carbon Units generated during year t. [tCO_{2e}]

$buffer$	Buffer withholding percentage according to the latest version of the VCSA*FOLU Non-Permanence Risk Tool* analysis and buffer determination. [-]
$nrFNFtransitions$	Number of forest/non-forest transitions among land classes or forest strata, meaning transitions in which either the “from” or the “to” class are non-forests. Section 8.1.2.3
$nrStrataTransitions$	Number of transitions among forest strata. Section 8.1.2.3
$nrStrata$	Number of strata within the ANR area. Section 8.1.2.3
$\Delta area_{projectAreaEAH,projectScenario}(t,i)$	Hectares undergoing transition i within the project area, excluding ANR and harvest areas, under the project scenario during year t. [ha yr^{-1}]. Section 8.2.3
$\Delta area_{projectAreaEAH,baselineScenario}(t,i)$	Hectares undergoing transition i within the project area, excluding the ANR area and harvest areas, under the baseline scenario during year t. [ha yr^{-1}]. Section 8.1.5.4
$C_{ANR}(t)$	Net anthropogenic greenhouse gas removals due to biomass increase in assisted natural regeneration during year t. [tCO_2e]. Section 8.2.5.2.
$\Delta area_{leakageArea,projectScenario}(t,i)$	Hectares undergoing transition i within the leakage area under the project scenario during year t. [ha yr^{-1}]. Section 8.3.2.3
$\Delta area_{leakageArea,baselineScenario}(t,i)$	Hectares undergoing transition i within the leakage area under the baseline scenario during year t. [ha yr^{-1}]. Section 8.1.5.4
$GHG_{otherLeakageSources}(t)$	GHG emissions from leakage by unconstrained geographic drivers during year ***t***. [$tCO_2e\ yr^{-1}$]
$GHG_{marketLeakage}(t)$	GHG emissions from market leakage during time t. [tCO_{2e}].Section 8.3.1.
$EF_{AGL}(i)$, $EF_{AGD}(i,t-tt)$, $EF_{BG}(i,t-tt)$, and $EF_{SOM}(i,t-tt)$	Aboveground live, aboveground dead, belowground, and soil emission factor for transition i, and time after transition $t-tt$. Section 8.1.4.5
CF	Carbon fraction of wood (use 0.5 by default).
$area_{projectAreaWithHarvest,projectScenario}(t$	Size of strata i within the project area with harvest activities during year t under the project scenario.

$u_{stratification}$	Discounting factor for NERs from avoided degradation, based on the accuracy of stratification, i.e. dividing forest into individual forest biomass classes. Section 8.1.2.7
$u_{classification}$	Discounting factor for NERs from avoided deforestation, based on the accuracy of classification, i.e. dividing land into broad land use types. Section 8.1.2.7
$u_{transition}(i)$	Discounting factor for all emission reductions, based on the uncertainty of biomass inventory related to transition i.
$\Delta C_{\text{ANR}}(t)$	Annual change in carbon stock in all selected carbon pools for forest stratum during year t. Section 8.2.5.3 [EQ72]. [$tCO_2e\ yr^{-1}$]
$u_{inventory,ANR}(i)$	Uncertainty discounting factor around biomass stock densities in transition stratum i within ANR areas. $[-]$
$GHG_{sources,projectArea}(t)$	Annual GHG emissions from implementation of fire-preventing actions as REDD project activities. Section 8.2.4. [$tCO_2e\ yr^{-1}$]
$GHG_{sources,leakagePrevention}(t)$	Emissions from sources of methane, nitrous oxide or fuel-CO_2 from leakage prevention activities during year t. Emission sources within the leakage area are included in Table 1. Section 8.3.4. [$tCO_2e\ yr^{-1}$]
$GHG_{sources,ANR}(t)$	Emissions of sources of methane, nitrous oxide or fuel-CO_2 from assisted natural regeneration activities during year t. Section 8.2.5.5. [$tCO_2e\ yr^{-1}$]
$ER_{CFE}(t)$	Emission reductions from reducing biomass use through high efficiency cookstoves and fuel efficiency activities during year t when degradation is not included in general quantification i.e. [EQ78]. [$tCO_2e\ yr^{-1}$]
$C_{LWPbaseline}(t)$	GHG sink in long-lived wood product in baseline scenario at year ***t*** [Mg C]
$C_{LWPProject}(t)$	GHG sink in long-lived wood product in project scenario at year ***t*** [Mg C]
$CreditingPeriod$	Project crediting period. [year]
$C_{harvest}(t,i)$	Carbon stock density in harvested areas in stratum i at year t. [tCO_2 ha-1]
$LTAC_{Harvest}$	Long term average carbon stock density in harvest areas. [tCO_{2e} ha-1]

$u_{inventory,harvest}(i)$	Uncertainty in estimated carbon stock density in harvest areas in stratum i . [-]
$\Delta C_{areaWithHarvest}(i)$	Net greenhouse gas emissions or removals in project area with harvest activities during year t. [tCO_2e]

9 MONITORING

9.1 Data and Parameters Available at Validation

The following data and parameters are defined for standalone projects. For projects that are nested within a jurisdictional REDD+ program, at the time of validation the project will identify any data or parameters in the project document, if any, that will be adopted from the jurisdictional REDD+ program.

Data/parameter [EA1]:	CF
Data unit:	[Mg C (Mg DM)$^{-1}$]
Description:	Carbon fraction of dry matter in wood
Sources of data:	Default value of 0.5 (IPCC GPG-LULUCF 2003)
Measurement procedures:	
Any comment:	

Data/parameter [EA2]:	E
Data unit:	[-]
Description:	Average combustion efficiency of the aboveground tree biomass
Sources of data (*):	The project proponent must use project-specific measurements where available . Where such measurements are not available, the following data sources may be used in the order described below. • Regionally valid estimates from recognized, peer reviewed sources • Estimates from Table 3.A.14 of IPCC GPG LULUCF • If no appropriate combustion efficiency can be used, use the IPCC default of 0.5
Measurement procedures:	
Any comment:	

Data/parameter [EA3]:	P
Data unit:	[-]

Description:	Average proportion of mass burned from the aboveground tree biomass.
Sources of data:	GPG-LULUCF Table 3A.1.13
Measurement procedures:	
Any comment:	

Data/parameter [EA4]:	GWP_{CH4}
Data unit:	[-]
Description:	Global Warming Potential for CH_4
Sources of data:	GWP values shall be derived from sources specified by the VCS rules
Measurement procedures:	
Any comment:	

Data/parameter [EA5]:	ER_{CH4}
Data unit:	Proportion
Description:	Emission ratios for CH_4
Sources of data:	Table 3A.1.15 in IPCC GPG-LULUCF 2003
Measurement procedures:	IPCC default value of 0.012
Any comment:	

Data/parameter [EA6]:	sc_1
Data unit:	[-]
Description:	First shape factor for the forest scarcity equation; steepness of the decrease in deforestation rate (greater is steeper).
Sources of data:	Statistical fitting procedure. Using remotely sensed forest cover data in heavily deforested areas close to the project area such as neighboring provinces, states or countries
Measurement procedures:	Use procedure from Section 8.1.5.4
Any comment:	

Data/parameter [EA7]:	sc_2
Data unit:	[-]
Description:	Second shape factor for the forest scarcity equation; relative deforested area at which the deforestation rate will be 50% of the initial deforestation rate.

Sources of data:	Statistical fitting procedure. Using remotely sensed forest cover data in heavily deforested areas close to the project area such as neighboring provinces, states or countries
Measurement procedures:	Use procedure from Section 8.1.5.4
Any comment:	

Data/parameter [EA8]:	$wwf(ty)$
Data unit:	[-]
Description:	Fraction of carbon in harvested wood products that are emitted immediately because of mill inefficiency for wood class ty. This can be estimated by multiplying the applicable fraction to the total amount of carbon in different harvested wood product category.
Sources of data:	The default applicable fraction is 24% and 19% respectively for developing and developed countries (Winjum et al. 1998).
Measurement procedures:	
Any comment:	Any new updates from locally generated results can be used instead of the default values.

Data/parameter [EA9]:	$slp(ty)$
Data unit:	[-]
Description:	Proportion of short lived products
Sources of data:	Default values are 0.2, 0.1, 0.4 and 0.3 respectively for wood class ty, i.e., sawnwood, wood-based panel, paper and paper boards and other industrial round woods as described in Winjum et al. (1998).
Measurement procedures:	
Any comment:	Any new updates from locally generated results can be used instead of the default values. The methodology assumes that all other classes of wood products are emitted within 5 years.

Data/parameter [EA10]:	$fo(ty)$
Data unit:	[-]
Description:	Fraction of carbon that will be emitted to the atmosphere between 5 and 100 years of harvest for wood class ty.
Sources of data:	See Table 19 Winjum et al. 1998)
Measurement procedures:	
Any comment:	Any new updates from locally generated results can be used instead

	of the default values.

Data/parameter [EA11]:	$\rho_{wood,j}$
Data unit:	[Mg DM m^{-3}]
Description:	Average basic wood density of species or species group j
Sources of data:	GPG-LULUCF Table 3A.1.9. or published data/literature.
Measurement procedures:	
Any comment:	When no species-specific or species-group specific densities are available, an average representative density may be used for all species or species groups.

Data/parameter [EA12]:	BEF_2
Data unit:	[-]
Description:	Biomass expansion factor for converting volumes of extracted round wood to total aboveground biomass (including bark).
Sources of data:	IPCC GPG LULUCF Table 3A.1.10 or published data from scientific peer reviewed literature
Measurement procedures:	
Any comment:	

Data/parameter [EA13]:	$EF_{rice,max}$
Data unit:	[kg CH_4 ha^{-1} day^{-1}]
Description:	Maximal emission factor for methane
Sources of data:	By default, an emission rate of 36 kg CH_4 ha^{-1} day^{-1} must be used, which is 25% greater than the maximal value found in a review study comparing 23 studies of CH4 fluxes in rice fields (Le Mer and Roger, 2001). The project proponent may use a smaller emission rate if it can be demonstrated from empirical data or other supporting information such as published data that the rate remains conservative for the project conditions.
Measurement procedures:	
Any comment:	Only to be included if rice production is increased as a leakage prevention measure.

Data/parameter [EA14]:	$NCV_{biomass}$
Data unit:	[TJ (Mg DM) $^{-1}$]
Description:	Net calorific value of non-renewable biomass that is substituted.

Sources of data:	0.015 TJ (Mg DM) $^{-1}$ IPCC default value.
Measurement procedures:	
Any comment:	

9.2 Data and Parameters Monitored

Where multiple sources of data are provided, the project proponent must use the higher-ranked data sources where available.

9.2.1 Sizes, areas, and transitions

Data/parameter [MN1]:	$size_{projectArea}$, $size_{leakageArea}$. $size_{referenceregion}$, $size_{referenceForest}$
Data unit:	[ha]
Description:	Size of project area, leakage area, reference region, and forest area in the reference region
Sources of data:	Project design
Measurement procedures:	
Frequency of monitoring:	$size_{projectArea}$ and $size_{leakageArea}$ may be adjusted during crediting period per the rules for grouped projects and updated at verification, but only for the additional instances that were added after the project start date..
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN2]:	$\Delta area_{projectAreaEAH,projectScenario}(t,i)$
Data unit:	[ha yr^{-1}]
Description:	Hectares undergoing transition i within the project area, excluding ANR and harvest areas, under the project scenario during year t. [ha yr^{-1}]. Section 8.2.3
Sources of data:	Remote sensing analysis
Measurement procedures:	Follow the procedures described in Section 8.2.3
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN3]:	$\Delta area_{projectAreaEAH,baselineScenario}(t,i)$
Data unit:	[ha yr^{-1}]
Description:	Hectares undergoing transition i within the project area, excluding the ANR area, and harvest areas, under the baseline scenario for year t.
Sources of data:	Land-use change modeling
Measurement procedures:	Follow the procedures described in Section 8.1.5.4
Frequency of monitoring:	At least once before every baseline. For added instances, may be recalculated at verification.
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN4]:	$\Delta area_{projectAreaWithANR,baselineScenario}(t,i)$
Data unit:	[ha yr^{-1}]
Description:	Hectares undergoing transition i within the leakage area under the project scenario for year t.
Sources of data:	Land-use change modeling
Measurement procedures:	Follow the procedures described in Section 8.1.5.4
Frequency of monitoring:	At least once before every baseline update. For added instances, may be recalculated at verification.
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN5]:	$\Delta area_{leakageArea,projectScenario}(t,i)$
Data unit:	[ha yr^{-1}]
Description:	Hectares undergoing transition i within the leakage area under the project scenario for year t
Sources of data:	Remote sensing analysis
Measurement procedures:	Follow the procedures described in Section 8.1.2.4. In case emissions reductions/removals from avoided degradation are included, this parameter will provide the data required to calculate the activity data to estimate the emissions from both deforestation and forest degradation.
Frequency of monitoring:	At least once before verification
QA/QC procedures to be	

applied:	
Any comment:	

Data/parameter [MN6]:	$\Delta area_{leakageArea,baselineScenario}(t,i)$
Data unit:	[ha yr^{-1}]
Description:	Hectares undergoing transition i within the leakage area under the baseline scenario during year t
Sources of data:	Land-use change modeling
Measurement procedures:	Follow the procedures described in Section 8.1.5.4
Frequency of monitoring:	Once every baseline update. May also be updated at the time of instance inclusion that requires new leakage area.
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN7]:	$\Delta area_{historical}(CS_1 \rightarrow CS_2, t_1 \rightarrow t_2)$
Data unit:	[ha yr^{-1}]
Description:	Area of transition from LULC class or forest stratum 1 to 2 from time 1 to 2 during the historical reference period
Sources of data:	Remote sensing analysis
Measurement procedures:	Calculate based on the remote sensing-based classification and stratification procedures detailed in Section 8.1.2
Frequency of monitoring:	At least once before every baseline update
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN8]:	$RFRGrate(CS_1 \rightarrow CS_2)$
Data unit:	[yr^{-1}]
Description:	Relative annual forest cover increase and regeneration factor for the transition from class or stratum 1 to 2.
Sources of data:	Remote sensing analysis
Measurement procedures:	Calculate based on the remote sensing-based classification and stratification procedures detailed in Section 8.1.2. Multiply with 100 to obtain a forest cover increase and regeneration rate in percentage per year.
Frequency of monitoring:	At least once before every baseline update
QA/QC procedures to be applied:	

Any comment:	It can be used for producing baseline transition matrix for new instances to be added into the project area.

Data/parameter [MN9]:	$area_{historical}(CS_1, t_1)$
Data unit:	[ha]
Description:	Total area of LULC class or forest stratum 1 at time 1
Sources of data:	Remote sensing analysis
Measurement procedures:	Calculate based on the remote sensing-based classification and stratification procedures detailed in Section 8.1.2
Frequency of monitoring:	At least once before every baseline update
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN10]:	$area_{biomassLoss}(i)$
Data unit:	[ha yr^{-1}]
Description:	Total annual area of LULC class i that was cleared for creating firebreaks
Sources of data:	Records of implemented activities or management plan
Measurement procedures:	
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN11]:	$area_{fireBiomassLoss}(i)$
Data unit:	[ha yr^{-1}]
Description:	Annual area of forest stratum i that was cleared by using prescribed burning
Sources of data:	Records of implemented activities or management plan
Measurement procedures:	
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN12]:	$area_{fireBiomassLoss,ANR}(t, i)$

Data unit:	[ha]
Description:	Area of biomass removed by prescribed burning within ANR stratum i during year t
Sources of data:	Records of implemented activities
Measurement procedures:	Only to be included if ANR activities are implemented.
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN13]:	$area_{projectAreaWithANR,projectScenario}(t,i)$
Data unit:	[ha]
Description:	Amount of land on which ANR activities are planned under the project scenario for year t and in stratum i
Sources of data:	Records of implemented activities
Measurement procedures:	Only to be included if ANR activities are implemented.
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN14]:	$area_{harvest}(t,i)$
Data unit:	[ha]
Description:	Area of forest in harvest stratum i that is harvested at time t.
Sources of data:	Project Description or Forest/Harvest Management Plan
Measurement procedures:	
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN15]:	$area_{projectAreaWithHarvest,projectScenario}(t,i)$
Data unit:	[ha yr^{-1}]
Description:	Size of strata i within the project area with harvest activities during year t under the project scenario.
Sources of data:	Remote sensing analysis

Measurement procedures:	Follow the procedures described in Section 8.1.5.4
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN16]:	$\Delta area_{projectAreaWithHarvest,baselineScenario}(t,i)$
Data unit:	[ha yr^{-1}]
Description:	Hectares undergoing transition i within the harvest areas under under the baseline scenario during year t.
Sources of data:	Land-use change modeling
Measurement procedures:	Follow the procedures described in Section 8.1.5.4
Frequency of monitoring:	At least once before every baseline update
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN17]:	$BetaReg_{DF}(t)$and $BetaReg_{DG}(t)$
Data unit:	[ha yr^{-1}]
Description:	Beta regression model describing the relationship between time and deforestation/degradation rate in the reference region during the historical reference period.
Sources of data:	Historic forest degradation and deforestation modeling
Measurement procedures:	Procedure described in Section 8.1.5.1 or similar approach from peer-reviewed scientific literature.
Frequency of monitoring:	At least once every baseline update
QA/QC procedures to be applied:	
Any comment:	

9.2.2 Locations, Descriptions, Qualitative, and Social Data

Data/parameter [MN18]:	Area under agricultural intensification
Data unit:	[ha]
Description:	Size of the area of agricultural intensification separated for each agricultural intensification measure
Sources of data:	Participatory rural appraisals
Measurement procedures:	Calculate based on areas of cropland in the leakage and project areas

	Only to be included if agricultural intensification activities are implemented.
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN19]:	Yields under agricultural intensification
Data unit:	[Mg ha^{-1}]
Description:	Harvested yield for agricultural intensification practices
Sources of data:	Participatory rural appraisals
Measurement procedures:	Only to be included if agricultural intensification activities are implemented.
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

9.2.3 Data on Drivers and Actions

Data/parameter [MN20]:	$CFW_{baseline}$
Data unit:	[m^3 yr^{-1}]
Description:	Annual volume of fuelwood gathering for commercial sale and charcoal production in the baseline scenario
Sources of data (*):	1. Participatory rural appraisals 2. Recent (<10 yr) literature in the reference region 3. Recent (<10 yr) literature in an area similar to the reference region
Measurement procedures:	If emission reductions from avoided degradation were excluded due to insufficient accuracy, in which case $u_{classification} = 0$, and emission reductions from fuel-efficient woodstoves are included, $CFW_{baseline}$ may only be measured using the first option, social assessments.
Frequency of monitoring:	At least once before every baseline update
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN21]:	$DFW_{baseline}$

Data unit:	[m^3 yr^{-1}]
Description:	Annual volume of fuelwood gathered for domestic and local energy in the baseline scenario
Sources of data (*):	• Participatory rural appraisals • Recent (<10 yr) literature in the reference region • Recent (<10 yr) literature in an area similar to the reference region
Measurement procedures:	If emission reductions from avoided degradation were excluded due to insufficient accuracy, in which case $u_{classification} = 0$, and emission reductions from fuel-efficient woodstoves are included, $DFW_{baseline}$ may only be measured using the first option, social assessments.
Frequency of monitoring:	At least once before every baseline update
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN22]:	$DFW_{project}$
Data unit:	[m^3 yr^{-1}]
Description:	Biomass (dry matter) of fuelwood collected by project participants under the project scenario.
Sources of data (*):	1. Participatory rural appraisals 2. Recent (<10 yr) literature in the reference region 3. Recent (<10 yr) literature in an area similar to the reference region
Measurement procedures:	If emission reductions from avoided degradation were excluded due to insufficient accuracy, in which case $u_{classification} = 0$, and emission reductions from fuel-efficient woodstoves are included, $DW_{baseline}$ may only be measured using the first option, social assessments.
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN23]:	$DFW_{allowed}$
Data unit:	[m^3 yr^{-1}]
Description:	Biomass (dry matter) of allowed fuelwood collection in the project area under the project scenario. This amount is typically fixed in a management plan. [m3 yr-1]
Sources of data (*):	Forest management plan

Measurement procedures:	
Frequency of monitoring:	At least once before every baseline update
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN24]:	$VG_{baseline}$
Data unit:	[m^3 yr^{-1}]
Description:	Biomass (dry matter) of understory vegetation extraction by project participants under the baseline scenario. [Mg DM yr-1]
Sources of data (*):	1. Participatory rural appraisals 2. Recent (<10 yr) literature in the reference region 3. Recent (<10 yr) literature in an area similar to the reference region
Measurement procedures:	Calculate by multiplying the number of households involved in extraction of vegetation with the average annual extraction rate by household for different vegetation types
Frequency of monitoring:	At least once before every baseline update
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN25]:	$VG_{project}$
Data unit:	[Mg DM yr-1]
Description:	Biomass (dry matter) of understory vegetation extraction by project participants under the project scenario.
Sources of data (*):	1. Participatory rural appraisals 2. Recent (<10 yr) literature in the reference region 3. Recent (<10 yr) literature in an area similar to the reference region
Measurement procedures:	Calculate by multiplying the number of households involved in extraction of vegetation with the average annual extraction rate by household for different vegetation types
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN26]:	$VG_{allowed}$
Data unit:	[Mg DM yr-1]
Description:	Biomass (dry matter) of allowed as understory vegetation extraction under the project scenario. This amount is typically fixed in a management plan
Sources of data (*):	Forest management plan
Measurement procedures:	
Frequency of monitoring:	At least once before every baseline update
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN27]:	$CT_{baseline}(h, j, ty, t)$
Data unit:	[m^3 yr^{-1}]
Description:	Annually extracted volume of harvested timber round-wood for commercial on-sale under the baseline scenario during harvest h by species j and wood product class ty during year t
Sources of data (*):	1. Participatory rural appraisals conducted by the project proponent. 2. Recent (<10 yr) literature in the reference region 3. Recent (<10 yr) literature in an area similar to the reference region 4. Recent (<10 yr) non peer-reviewed reports by local organizations
Measurement procedures:	
Frequency of monitoring:	At least once before every baseline update
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN28]:	$CT_{allowed}$
Data unit:	[m^3 yr^{-1}]
Description:	Annually allowed volume of harvested timber round-wood for commercial on-sale under the project scenario
Sources of data (*):	Project document and/or management plan
Measurement procedures:	
Frequency of monitoring:	At least once before every baseline update
QA/QC procedures to be	

applied:	
Any comment:	Estimate volume for mixture of species

Data/parameter [MN29]:	$CT_{project}(h, j, ty, t)$
Data unit:	[m^3 yr^{-1}]
Description:	Annually extracted volume of harvested timber round-wood for commercial on-sale inside the project area under the project scenario during harvest h by species j and wood product class ty during year t.
Sources of data (*):	Project design, surveys, statistical records.
Measurement procedures:	
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN30]:	$DT_{baseline}(h, j, ty, t)$
Data unit:	[m^3 yr^{-1}]
Description:	Annually extracted volume of timber for domestic and local use, round wood under the baseline scenario during harvest h by species j and wood product class ty during year t.
Sources of data (*):	1. Participatory rural appraisals conducted by the project proponent 2. Recent (<10 yr) literature in the reference region 3. Recent (<10 yr) literature in an area similar to the reference region 4. Recent (<10 yr) non peer-reviewed reports by local organizations
Measurement procedures:	
Frequency of monitoring:	At least once before every baseline update
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN31]:	$DT_{allowed}$
Data unit:	[m^3 yr^{-1}]
Description:	Annually allowed volume of harvested timber round-wood for domestic and local use under the project scenario
Sources of data (*):	Project document and/or management plan

Measurement procedures:	
Frequency of monitoring:	At least once before every baseline update
QA/QC procedures to be applied:	
Any comment:	Estimate volume for mixture of species

Data/parameter [MN32]:	$DT_{project}(h, j, ty, t)$
Data unit:	[m^3 yr^{-1}]
Description:	Annually extracted volume of timber for domestic and local use, round wood inside the project area under the project scenario during harvest h by species j and wood product class ty during year t.
Sources of data (*):	Project design, surveys, statistical records.
Measurement procedures:	
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	

Data/parameter [MN33]:	$contribution_{DF}(d)$ and $contribution_{DG}(d)$
Data unit:	[-]
Description:	Relative contribution of driver i respectively to total deforestation and forest degradation.
Sources of data:	Calculated using procedure described in 8.1.3.
Measurement procedures:	
Frequency of monitoring:	At least once before baseline update.
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN34]:	$RelativeDriverImpact_{DF}(t, d)$ and $RelativeDriverImpact_{DG}(t, d)$
Data unit:	[-]
Description:	Relative impact of the geographically unconstrained driver d at time t of the crediting period respectively on deforestation and forest degradation.
Sources of data:	Calculated using procedure described in 8.2.2.
Measurement procedures:	
Frequency of monitoring:	At least once before baseline update.

QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN35]:	$leakage_{unconstrained}(d)$
Data unit:	[-]
Description:	Leakage cancellation rate for avoiding deforestation/degradation from geographically unconstrained drivers.
Sources of data:	Valid sources to substantiate a smaller leakage rate include social assessments, scientific literature, and reports from civil society or governments. Sources have to be reliable and based on scientific methods and a good statistical design.
Measurement procedures:	
Frequency of monitoring:	At least once before baseline update.
QA/QC procedures to be applied:	
Any comment:	Unless a lower rate can be justified, a default rate of 100% must be used.

Data/parameter [MN36]:	$effectiveness(a, d)$
Data unit:	[-]
Description:	Effectiveness of every project activity a in decreasing any driver of deforestation d relative to that driver's contribution to deforestation and forest degradation,
Sources of data:	Relevant academic literature or documented expert opinion.
Measurement procedures:	
Frequency of monitoring:	At least once before baseline update.
QA/QC procedures to be applied:	
Any comment:	The $effectiveness(a, d)$ factor represents the maximal effectiveness during the crediting period.

Data/parameter [MN37]:	$\Delta A_{rice}(t)$
Data unit:	[ha]
Description:	Annual increase in harvested area of rice due to leakage prevention measures.
Sources of data:	Project design decision
Measurement procedures:	Only to be included if rice production is increased as a leakage prevention measure.

Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN38]:	$t_{flooded,max}$
Data unit:	[days yr^{-1}]
Description:	Maximal period of time a field is flooded
Sources of data:	Participatory rural appraisals or expert opinion
Measurement procedures:	Only to be included if rice production is increased as a leakage prevention measure.
Frequency of monitoring:	At least once before baseline update
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN39]:	$GR_{baseline}$
Data unit:	[-]
Description:	Number of grazing animals of type g within the project boundary baseline
Sources of data:	1. Local agricultural records 2. Social assessments conducted by the project proponent
Measurement procedures:	Calculate by multiplying the number of animals taking into account different types of grazing animals.
Frequency of monitoring:	At least once before baseline update
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN40]:	$GR_{allowed}$
Data unit:	[-]
Description:	Number of grazing animals of type g allowed for grazing within the project boundary in the project scenario
Sources of data:	Project management plan
Measurement procedures:	Calculate by multiplying the number of animals taking into account different types of grazing animals.
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN41]:	$Fuelwood(t)$, $Fuel(t)$
Data unit:	$[m^3\ yr^{-1}\ HH^{-1}]$
Description:	Average annual volume of biomass fuel consumed by households in the absence of the project activity in year t for cooking purpose.
Sources of data:	Social assessments results or wood energy statistics applicable to the project
Measurement procedures:	
Frequency of monitoring:	At least once every baseline update
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN42]:	$HH_{non-CFE}(t)$
Data unit:	[-]
Description:	Total number of household in the project area that collect biomass fuel from the project area and do not use CFE in year t.
Sources of data:	Social assessments results or wood energy statistics applicable to the project
Measurement procedures:	*Ex-post,* this value must be obtained from socio-economic survey.
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN43]:	η_{old}
Data unit:	[-]
Description:	Efficiency of the project cookstoves or appliances.
Sources of data:	Default value of 0.10 for three stone stove or conventional stove that lacks improved combustion air supply mechanism and flue gas ventilation systems i.e., without a grate as well as a chimney; for rest of the systems 0.2 default value may be used.
Measurement procedures:	Measured using representative sampling method or based on referenced literature values. Use weighted average values if more than one type of systems are used. If measured, the procedure must comply with the Water Boiling Test (WBT) based on VITA 1985 - the 'International Standards'.
Frequency of monitoring:	At least once every baseline update
QA/QC procedures to be	

applied:	
Any comment:	

Data/parameter [MN44]:	η_{new}
Data unit:	[-]
Description:	Efficiency of the baseline cookstoves or appliances.
Sources of data:	1. Values obtained from the manufacturer of the stove. 2. Calculated from field testing using ISO standards.
Measurement procedures:	Measured using representative sampling method or based on referenced literature values. Use weighted average values if more than one type of systems is used.
Frequency of monitoring:	• If the stoves used are manufactured by a recognized company that is still in business and provides a warranty for the stoves stated life, then the monitoring must be done during every baseline update. • If the manufacturer does not provide any warranty or the manufacturer of the stove is no longer in the business, then the efficiency must be monitored annually using the water boiling test (WBT) protocol carried out in accordance with national standards (if available) or international standards or guidelines as specified in the latest version of Approved CDM Methodology – AMS.II.G. *Energy efficiency measures in thermal applicants of non-renewable biomass*. Biennial monitoring (i.e. monitoring once every two years) may be chosen, if the project proponent are able to demonstrate that the efficiency of the cookstove does not drop significantly as compared to the initial efficiency of the new device, over a time period of two years of typical usage. • Finally, if the conservativeness of the used efficiency can be demonstrated, the monitoring frequency can be once every baseline update. Demonstration of the conservativeness must be based on historical efficiency data for the type of stoves showing how efficiency declines from the initial efficiency level through the life of the stoves and the lowest efficiency value must be used for that type of stove.
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN45]:	$U_{CFE}(t)$
Data unit:	[-]
Description:	Fraction of cumulative usage rate for technologies in project scenario in year t.

	[-]
Sources of data:	Social assessments or wood energy statistics applicable to the project
Measurement procedures:	Cumulative adoption rate and drop off rate revealed by usage surveys [-].
Frequency of monitoring:	Annual
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN46]:	$DF_{LeakageCFE}(t)$
Data unit:	[-]
Description:	Leakage discount factor applicable to GHG emissions reduction benefits from CFE activities [-]
Sources of data:	1. Social assessments or wood energy statistics applicable to the project. 2. Default value of 0.95 following AMS.II.G CDM methodology.
Measurement procedures:	Leakage related to the non-renewable biomass saved by the project activity must be assessed based on surveys of users and the areas from which woody biomass saved under the project by non-project households that previously used renewable energy or efficient appliances must be considered. If this leakage assessment quantifies an increase in the use of non-renewable biomass, that is attributable to the project activity, then biomass used in the baseline must be adjusted by a factor ($DF_{LeakageCFE}$) to account for the leakage.
Frequency of monitoring:	Annual
QA/QC procedures to be applied:	
Any comment:	If the default value of 0.95 is used, no survey is required.

Data/parameter [MN47]:	$EF_{non-CO2,fuel}$, $EF_{CO2,fuel}$
Data unit:	[t CO_2 TJ^{-1}]
Description:	Respectively, non--CO2 emission factor of the fuel that is reduced and CO2 emission factor for the substitution of non-renewable biomass by similar consumers.
Sources of data:	Social assessments or wood energy statistics applicable to the project
Measurement procedures:	Emission factor can include a combination of emission factors from fuel production, transport, and use. Both CO_2 and Non-CO2 of the fuel such as emissions factors for charcoal can be estimated from project specific monitoring or alternatively by researching a conservative wood to charcoal production ratio (from IPCC, credible

	published literature, project-relevant measurement reports, or project-specific monitoring) and multiplying this value by the pertinent emission factor of wood.
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN48]:	EF_{forest}
Data unit:	[t CO_2e]
Description:	Emission factor related to leakage.
Sources of data:	1. If comprehensive national-level statistics on biomass densities are available, EF_{forest} must be calculated based on the average biomass of the country. 2. If local data is not available. Sources of the data allowed are (1) academic research papers and (2) studies and reports published by the forestry administration or other organizations, including the FAO's Forest Resource Assessment reports, (3) the upper range of biomass in the GPG-LULUCF (2003) Table 3A.1.2.
Measurement procedures:	
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

9.2.4 Data on Organic Matter and Carbon Densities

Data/parameter [MN49]:	$OM_o(i)$
Data unit:	[Mg DM ha-1]
Description:	Plant-derived organic matter of LULC class or forest stratum i in pool o. [Mg DM ha-1]
Sources of data:	Field measurements using sampling plots in forest strata or LULC classes.
Measurement procedures:	The average biomass stock density in applicable organic matter pools: aboveground tree - $OM_{AGT}(i)$, aboveground non-tree - $OM_{AGNT}(i)$, lying dead wood - $OM_{LDW}(i)$, standing dead wood $OM_{SDW}(i)$, belowground $OM_{BG}(i)$, and soil organic matter $OM_{SOM}(i)$
Frequency of monitoring:	At least once before every baseline update
QA/QC procedures to be	Follow uncertainty deduction procedures described in methodology.

applied:	Re-measure plots by independent teams.
Any comment:	Summed across multiple pools and divided into $OM_{plant}(i)$ and $OM_{soil}(i)$

Data/parameter [MN50]:	$proportion_{DF}(d)$ and $proportion_{DG}(\mathrm{d})$
Data unit:	[-]
Description:	Proportion of the gradual carbon loss that leads to deforestation or forest degradation, respectively, due to driver d
Sources of data:	Estimate using the procedure detailed in Table 9.
Measurement procedures:	
Frequency of monitoring:	At least once before every baseline update
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN51]:	$C(t,i)$
Data unit:	[Mg C ha^{-1} yr^{-1}]
Description:	Carbon stock density at time □ in stratum □.
Sources of data:	Estimate within the biomass inventory plots
Measurement procedures:	
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	Used in estimating change in carbon stock density such as in ANR areas.

Data/parameter [MN52]:	$f_{allometric}(y)$
Data unit:	Equation
Description:	Allometric relationship to convert a tree metric such as DBH or tree height into biomass
Sources of data (*):	1. Allometric equations developed by the project proponent 2. Allometric equations developed locally by groups other than the project proponent **3.** Allometric equations developed for forest types that are similar to the ones in the project as found in found in Tables 4.A.1. and 4.A.2. of the GPG LULUCF
Measurement procedures:	

Frequency of monitoring:	May be updated at baseline update
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN53]:	$f_{belowground}(y)$
Data unit:	Equation
Description:	Relationship between aboveground and belowground biomass, such as a root-to-shoot ratio
Sources of data (*):	1. A relationship calculated from destructive sampling data obtained within the project area 2. A relationship obtained from the local/national studies that closely reflect the conditions of the project activity 3. Standard root-to-shoot ratios as found in Table 4.4 of the IPCC GPG-LULUCF 2003
Measurement procedures:	
Frequency of monitoring:	May be updated at baseline update
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN54]:	$C_{Harvest}(t,i)$
Data unit:	Mg C ha-1
Description:	Biomass carbon stock density at time t in stratum i in harvested areas.
Sources of data:	Field inventory
Measurement procedures:	Generic procedure is described in Section 8.1.4.4. Estimate must be made from plots located areas where harvesting takes place.
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	Carbon stocks in harvested strata must come from sampling. It may be necessary to include additional plots in harvested strata for a precise estimation of carbon stocks. The exact measurement of aboveground and below tree carbon must follow international standards and follow IPCC GPG LULUCF 2003. These measurements are explained in detail in CDM approved methodology AR-AM0002 *Restoration of degraded lands through afforestation/reforestation*.

Data/parameter [MN55]:	$CE_{inventory,harvest(t,i)}$
Data unit:	[-]
Description:	Combined error in estimate of average biomass stock density in harvest areas in stratum i at time t.
Sources of data (*):	Field inventory
Measurement procedures:	Generic procedure is described in Section 8.1.4.4. Estimate must be made from plot located in areas where harvesting takes place.
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	Uncertainty estimate in carbon stocks in harvested strata must come from sampling of plots in harvested areas.

Data/parameter [MN56]:	$CE_{inventory,ANR(t,i)}$
Data unit:	[-]
Description:	Combined error in estimate of average biomass stock density in ANR areas in stratum i at time t.
Sources of data (*):	Field inventory
Measurement procedures:	Procedure is described in Section 8.2.5.3.
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	Uncertainty estimate in carbon stocks in harvested strata must come from sampling of plots in ANR areas.

Data/parameter [MN57]:	$u_{classification}$
Data unit:	[-]
Description:	Discounting factor for NERs from avoided deforestation, based on the accuracy of classification, i.e. dividing land into broad land use types.
Sources of data:	
Measurement procedures:	Section 8.1.2.7
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN58]:	$u_{stratification}$
Data unit:	[-]

Description:	Discounting factor for NERs from avoided degradation, based on the accuracy of stratification, i.e. dividing forest into individual forest biomass classes. Section 8.1.2.7
Sources of data:	
Measurement procedures:	Section 8.1.2.7
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

Data/parameter [MN59]:	$u_{transition}(i)$
Data unit:	[-]
Description:	Discounting factor for the emission factor for the transition from LULC class or forest stratum 1 to class 2 according to the uncertainty of the biomass inventory.
Sources of data:	
Measurement procedures:	Section 8.1.2.4.3
Frequency of monitoring:	At least once before verification
QA/QC procedures to be applied:	
Any comment:	

9.3 Description of the Monitoring Procedures

This methodology requires the following monitoring components for calculating actual NERs:

- Monitoring of drivers of deforestation, project activities and emission sources related to REDD project activities inside and outside of the project area.
- Monitoring LULC class and forest strata transitions in the project area, leakage area, and reference region using remote-sensing technologies, and validated with ground-truthing data.
- Monitoring carbon stock densities in LULC classes and forest strata.
- Monitoring carbon stock increases in the area on which ANR are performed.
- Monitoring of carbon stock in long-lived wood products.
- Monitoring of natural disturbances.
- Monitoring of cookstoves and fuel efficiency activities.
- Monitoring of harvesting activities.

A monitoring report is produced which contains all of the information above, and which outlines the calculations for actual NERs generated. At each monitoring event, the project proponent must confirm that there are GHG projects in the project area and a formal statement to that effect must be included in the monitoring report.

Given that any natural disturbance is fully accounted as part of the on-going monitoring during the crediting period, any loss of biomass during the credited period must also accounted for and reported in the monitoring report regardless of the cause of the loss. However, where an event that qualifies as a loss event occurs and VCUs have previously been issued, project proponent must follow the applicable VCS rules.

The project proponent must follow the requirements below for monitoring project activities.

9.3.1 Calculation of *Ex-post* Actual Net GHG Emission Reductions

A monitoring report must contain the *ex-post* values of the actual net GHG emission reductions. Actual net NERs must be based on Equation [EQ105]; actual VCUs must be based on Equation [EQ106].

9.3.2 Calculation of *Ex-post* GHG Emissions and Changes in Sinks Under the Project Scenario Inside the Project Area

The changes in carbon sinks under the project scenario in the project area must be calculated based on remote sensing change analysis and field measurements. Carbon stock densities must be re-measured at least once before every baseline update using ground-based biomass inventories, as described in Section 8.1.4.4. However, carbon stock densities may be measured more frequently. For the calculation of the NERs, the most recent values of the carbon stock densities must be used. Therefore, if new carbon stock densities are available, values for the emission factors must be updated and the new values must be reported in the monitoring report based on the procedure in Section 8.1.4.

- Acquire (a) remote sensing image(s) between validation or the last verification and the current date, and use the same procedure as used for the baseline to produce (a) land use, land cover, and forest cover map(s). As explained in Section 8.1.2.5, if any part of the project area is covered in clouds or cloud shadows, its GHG accounting should be postponed on that portion of the project area in this monitoring period until cloud-free imagery in this portion of the project area is available. The postponed NERs may be added to the NERs generated in the subsequent monitoring period. Note that if a different remote sensing data source is used than for the historical baseline analysis, the provisions in Section 9.3.9 must be followed.

- Execute an image classification on the acquired image according to the procedures in Section 8.1.2.4. If emissions reductions/removals from avoided degradation are included, apply exactly the same stratification model as the one used for validation. Perform an accuracy assessment of the LULC classification as described in Section 8.1.2.4 using data from field sampling and independent remote sensing data. Ensure that the accuracy of the LULC classification is equal or greater to the average accuracy achieved for the historical remote sensing. The same $u_{classification}$ used for ex-ante calculations must be used ex-post until the next baseline update. When additional biomass plots were measured, update $u_{stratification}(i)$, all relevant emission factors as well as $u_{transition}(CS1 \rightarrow CS2)$.

- Compare the changes in between consecutive map(s) since the last time the project was verified and until the current map of land use, land cover, and forest cover. For the project area where no ANR or harvesting activities were performed, produce (a) land transition matrix/matrices between the consecutive map(s) since the last verification.

- Annualize the land transition matrix/matrices by dividing the land transition rates by the duration in between the two states represented by the maps. The annual rates of land transition changes for the project area on which no ANR activities are planned is $\Delta area_{projectAreaEAH,projectScenario}(t,i)$.

- For the ANR and harvesting areas, in which increases in forest biomass are quantified using biomass inventories, follow the procedures in Sections 8.2.5 and 8.2.7, respectively.

- The project proponent may choose to increase the number of sampling plots during the crediting period or replace previous plots when the biomass plots are located on land that has been deforested or lost through some other cause.

9.3.3 Calculation of *Ex-post* GHG Emissions and Changes in Sinks Under the Project Scenario

Outside the Project Area (Leakage)

Similar to Section 8.3.1, a distinction is made between the calculation of leakage from geographically constrained drivers and leakage from geographically unconstrained drivers. See Section 8.3.1 for a distinction between these two categories.

9.3.3.1 Calculation of Ex-post Leakage from Geographically Constrained Drivers

The land-use and land cover changes[19] in the leakage belts and leakage area must be calculated using exactly the same remote sensing change analysis as for the project area:

- Acquire (a) remote sensing image(s) between validation or the last verification and the current date, and use a similar procedure as used for the baseline to produce (a) land use, land cover, and forest cover map(s) in the leakage belts.

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19 These land-use and land cover (LULC) changes do not only include deforestation and forest degradation, but also LULC changes on non-forest land such as the conversion of woodlands to grasslands due to fuelwood collection.

- Compare the changes in between consecutive map(s) since the last time the project was verified and until the current map of land use, land cover, and forest cover. Produce (a) land transition matrix/matrices between the consecutive map(s) since the last verification for the leakage area.
- Annualize the land transition matrix/matrices by dividing the land transition rates by the duration in between the two states represented by the maps. The annual rates of land transition changes for the leakage area is $\Delta area_{leakageArea,projectScenario}(t,i)$.

However, in case the project proponent can justify in the monitoring report that observed change in deforestation and/or forest degradation in the leakage area compared to deforestation and/forest degradation in baseline in the leakage area is not caused by project activities, but rather through some external factor, the project proponent are allowed to adjust the baseline rate of deforestation and forest degradation within the leakage area as explained in this paragraph. This justification may include the case when in the monitoring period the deforestation and/or forest degradation rate in the reference region is higher than the monitored rate of deforestation and forest degradation within the leakage area. Under this case, the project proponent may adjust the baseline rate of deforestation and/forest degradation rate in the leakage area before calculating the geographically constrained leakage. The rate of deforestation and/or forest degradation within the leakage area under the baseline is adjusted by first estimating the rate of deforestation and/or forest degradation in the reference region through remote sensing, and then using this rate as the total rate of deforestation (and/or forest degradation) in estimating the adjusted baseline rate of deforestation and forest degradation for the monitoring period within the leakage areas following the procedures described in Section 8.1.5.4. All other variables and inputs to the procedure in Section 8.1.5.4 must remain the same as the values used at validation or last baseline update.

Once the project proponent elects to adjust the baseline rate of deforestation and/or forest degradation in the leakage area, the project proponent must continue to demonstrate that the adjusted rate is valid for the next monitoring period, or readjust the baseline rate of deforestation and/or forest degradation in leakage areas relevant to that monitoring period until the next baseline update.

9.3.3.2 Calculation of Ex-post Leakage from Geographically Unconstrained Drivers

Activity-shifting leakage from geographically unconstrained drivers must be quantified *ex-post* using a factor approach in which the leakage cancellation factors, set at validation following the procedure in Section 8.3.3, are used.

9.3.3.3 Calculation of Ex-post Emission Sources from Leakage Prevention Activities

Actual emissions from sources from leakage prevention activities, $GHG_{sources,leakagePrevention}(t)$, must be calculated using the equations in Section 8.3.4, but with monitored data.

9.3.4 Monitoring of CFE Activities

Any CFE appliances that have been brought from outside the project boundary does not qualify for emission removals/reductions as this can cause potential leakage. Similarly, non-operational appliances must be excluded. If the baseline appliances still continue to operate on the top of project cookstoves (i.e. CFE appliances are secondary), the project proponent must ensure that the fuelwood consumption of those stoves is excluded from the estimation of baseline emissions.

The GHG emissions reductions benefits from CFE activities must also be excluded once the project site is no longer threatened by the fuel-wood collection activities. This can happen either as a result of effective implementation of the REDD projects or as a result of reduced household energy needs. The following are indicators of such shifts and must be monitored periodically.

- Trend showing decrease in the time spent or distance travelled by users (or drivers of deforestation and degradation or fuel-wood suppliers) for gathering fuelwood.
- Survey results, national or local statistics, studies, maps or other sources of information such as remote sensing data that show that carbon stock are not depleting in the project area and leakage belt i.e. when fraction of non-renewable biomass (f_{NRB}) is 0.
- Decreasing trend in fuel-wood price indicating abundance of fuelwood.

9.3.5 Monitoring of Long-Term Average Carbon Stock in Harvest Areas

- The long term average carbons stock density, i.e., $LTAC_{Harvest}$, in the harvest areas must be updated at least once every verification period and at every baseline update using the most recent forest inventory carried out in the harvest areas. The procedure to estimate $C_{harvest}(i)$ and $u_{inventory\ ,harvest}(i)$ is as described in Section 8.1.4.4 but the estimates are based on only the plots located in harvest areas.
- The project proponent must use the log-book for timber product harvest in the project area. When the actual harvest differs from the estimated harvest by more than 15% then $LTAC_{Harvest}$ must be updated and NERs adjusted accordingly i.e., to safeguard from over issuance of emissions reductions/removals have occurred due to the change in $LTAC_{Harvest}$.
- The harvest plan/description in PD must be updated with any changes in the harvest plan.

9.3.6 Monitoring Grouping of Project Area Parcels

Where new project area parcels are added subsequent to project validation, information on the new project area parcels must be included in the monitoring report as per VCS rules on grouping. In addition, the following conditions must be met and documented in the monitoring report.

The following conditions must be met before a new project area parcel can be added to an existing project:

- If the new project area and leakage area are located entirely within the existing reference region boundary and the size of the total new project area (ie, cumulative since the beginning of the project) is less than half of the size of the reference region, that area can be added to the existing project area without the need to update the reference region and the baseline. However, if a new project area is not inside the existing reference region boundary, or the size of the total new project area is greater than half the size of the reference region, a new reference region must be created. This must only be done when the baseline is updated.
- The new project area must pass the similarity to the reference region test outlined in Table 3. The similarity must be demonstrated for the new project area as a whole and not for each individual parcel.
- Leakage must be re-assessed for all new project instances, including activity-shifting, market leakage and ecological leakage assessments. The boundaries of existing leakage belts can be expanded or new leakage belts can be demarcated around the new project area parcels. The new leakage belts must remain located within the boundary of the reference region. If new project parcels are added within the leakage belts, the boundaries of existing leakage belt must be reassessed.

9.3.7 Monitoring Addition of New Project Activities

Despite the implementation of REDD activities, it is possible that some deforestation may still occur in the project area during the project crediting period. This deforestation can be either a catastrophic or non-catastrophic reversal as defined by the VCS. In case a reversal event occurs within the project area after the start of the crediting period, the project proponent must follow the VCS *AFOLU Requirements* for treatment of areas that suffer losses of forest cover . However, this methodology allows addition of new ANR activities (see 8.2.5) on deforested or degraded forest areas to incentivize good forest management, accelerate forest re-growth, and enable the project proponent to recuperate part of the suffered losses under the following conditions.

Where ANR activities are added in existing project areas after the project is validated, the new ANR activities must be described in the monitoring report and the following requirements must be met and demonstrated in the monitoring report.

- Only areas that were forest at the start of the project but become deforested or degraded after the start of the project are eligible regardless of whether the reversal occurred due to anthropogenic or non-anthropogenic reasons such as a natural disaster.

9.3.8 Update of the Sampling Design of Biomass Inventory Plots

If the project proponent have set-up permanent sampling plots in the project area, it is likely that during the crediting period, permanent forest sampling plots will have to be abandoned due to unforeseen deforestation or natural disasters. Similarly, with continuous increases in forest carbon stocks, additional sample plots must be required to accurately account for forest carbon stocks. In such cases, new permanent sampling plots must be established, or the sampling procedure must be switched to temporary sampling plots and measured following the procedure in this methodology. Ex-post emission reductions/removals must be calculated using the most recent emission factors that are calculated using the most up-to-date set of biomass inventories.

9.3.9 Updates to Baseline Net GHG Removals by Sinks

Once the baseline (calculated *ex-ante*) is validated, it is fixed for ten years and must be re-assessed and updated every ten years. The updated baseline must be validated at the subsequent verification as per VCS *AFOLU Requirements*.

Baseline updates must follow the procedures in Section 8, using updated values for all variables indicated as such in the monitoring table. The following exceptions to the procedures of Section 8 must be followed:

- The baseline must be re-calculated for the entirety of the crediting period, meaning from the start of the crediting period until the end of the crediting period. However, only the *ex-ante* NERs and baseline calculations until the next baseline update will be validated. Note that the re-calculation of previous years is necessary to understand the baseline state in the project area at the time of the baseline update.
- The new historical reference period used for the baseline update extends from the original start date of the historical reference period to the time at which the baseline update event is scheduled. In other words, all intermediate values for deforestation and forest degradation rates from the beginning of the historical reference period until the current time must be included. During the crediting period, the graphs of deforestation and forest degradation rates versus time will contain an increasing number of points.
- In addition, after the start of the crediting period, the reference region must exclude project areas and leakage belts. If after project start, new areas within the reference region become protected, these must be excluded from the updated reference region. Protected areas include:
    - National parks that are effectively protected.
    - Areas under conservation that are effectively protected.
    - Areas under a logging or economic land concession where access is effectively being restricted.
    - Large plantations that are effectively protected.
- Allometric equations used for biomass stock density calculations may be revised during a baseline update.

- The project proponent must use the same remote sensing data sources and analysis procedures as were used for project design or in the previous baseline update. However, if improved (i.e., spectral resolution of minimally 20% higher) data sources and remote sensing data analysis procedures become available to the project participants during the crediting period, or if the sensors used for the previous *ex-ante* baseline calculations become unavailable, changing the procedures previously used is allowed under the following conditions:
- Any change in data sources and analysis procedures must be duly explained and recorded. The Standard Operations Procedure for remote sensing analyses must be updated when a new sensor is used and the baseline is updated.
- Similar spectral bands (e.g., Red, Green, Blue, NIR, SWIR, MIR, etc.) used for classification from the original sensor must be present in the alternative sensor. A formal comparison of the sensors must be added to the baseline update Section within the monitoring report.
- If a new sensor is used and the baseline is not updated, the spectral resolution must be down-sampled to the spectral resolution of the original sensor, so that the same remote sensing procedure used during the baseline calculation can be used. Demonstrate that the classification results of the images from the previous sensor and the new sensor are comparable.
- Full resolution may only be used forward-looking after a baseline update and if sufficient historical images of the higher resolution are available to calculate the baseline, according to the procedures in Table 5. As a consequence, the inclusion of forest degradation based on higher-resolution data may only occur during a baseline update.
- The discounting factors $u_{stratification}$ and $u_{classification}$ must be updated during the baseline update period based on the classification and stratification accuracies for the period until the baseline update.
- The relative forest cover increase and regeneration rates may only be updated using data that is less than 10 years old.
- Summarize all updated baseline land transitions. Update the *ex-ante* NERs using the updated baseline estimates, and present an updated version of the overview table in the monitoring report.

Similarly, all requirements for biomass inventories, social surveys, etc. that were included in Section 8 must be followed.

9.3.10 Procedures for Verification of Allometric Equations

Every time one or more new $f_{allometric}$ equations are proposed, the proposed equation(s) must be verified according to the following criteria:

- The proposed equation(s) must have an r^2 value of greater than 0.5 (50%) and a p-value that is significant at 95% confidence level as reported in the source publications.

- The proposed equation(s) was developed from trees where the largest and smallest DBH (or any other tree metric used in the equation) of the trees fall within the range of the metric of the trees within the project areas.
- If the proposed equation(s) was/were derived from data solely from within the reference region then such equations can be used. If the proposed equation(s) was/were derived outside of the reference region, the project proponent must justify the similarity in climatic, edaphic, geographical and species composition between the project area and the location from where the equations were derived. The source publication must include an estimate of the uncertainty or sufficient data to estimate the uncertainty. If this uncertainty is within ±15% of the mean values and is not biased in a non-conservative manner (i.e., the equation(s) do(es) not systematically overestimate the project net anthropogenic removals by sinks), the equation(s) may be used.
- For any other equations that do not satisfy criteria (d) or if new equations or equations which do not have estimate of uncertainty are to be used, then one of the following two steps must be carried out:
- Step 1:Destructive Sampling
    - Selecting at least 5 trees covering the range of DBH (or any other tree metric used in the allometric equation) existing in the project area, and felling and weighing the aboveground biomass to determine the total (green) weight of the stem an branch components
    - Extracting and immediately weighing subsamples from each of the green stems and branch component, followed by oven drying at 105°C to determine dry biomass.
    - Determine the total dry weight of each tree from the green weights and the averaged ratios of wet and dry weights of the stem and branch components.
- Step 2: Limited Measurements.
    - Select at least 10 trees per species or species group distributed across the project area.
    - Calculate volume of tree from basal and top diameters and tree height. Multiply by species-specific density to gain biomass of bole. Add an additional 20 percentage of weight to approximately cover the biomass of branches.

If the biomass of the measured trees is within ±15% of the mean values predicted by the selected default allometric equation, and is not biased – or if biased towards the conservative side (i.e., equation underestimates of the project net anthropogenic removals by sinks), then mean values from the equation may be used. However, if the biomass of the measured trees is not within ±15% of the mean values predicted by the selected default allometric equation, estimated biomass must be further discounted with the relative average half-width of the confidence interval of the model.

Note – The project proponent must follow the remote sensing procedures provided in

Section 8.1.4.1 and should refer to guidance provided in Appendix 1 for procedures with regard to conducting social assessments, , QA/QC procedures and on verification of allometric equations.

APPENDIX 1: ADDITIONAL GUIDANCE

1.1 Guidance for Social Assessments

Social assessments must be conducted to collect social information regarding project conditions. For most data items that are to be collected within the methodology, personal interviews with individual households are preferred; these are referred to as "household surveys". However, for data items that are more challenging to quantify such as forest fires and forest encroachment, semi-structured focus group discussions with representative community members are more appropriate; these are referred to as "participatory rural appraisals". The sample size for household surveys can be based on a comparatively small proportion of the target population (UN 2008). The required number of household surveys must be selected so that a minimal confidence level of 95%. The exact number of surveys can be determined using the formula in Krejcie and Morgan (1970). In case of semi-structured interviews in participatory rural appraisals; at least 10 focus group discussions must be conducted. Further guidelines for carrying out these appraisals can be found in Cochran (1977), Freudenberger (1994), Top et al. (2004) and UN (2008). The following steps should be followed for designing and conducting surveys.

- Assemble all information that must be collected and determine the goals of the questionnaire. Identify all information that is required by the methodology.
- Determine the target group of the questionnaire, and sub-divide the group into different strata. Strata should be defined according to geography, household size, age, gender, etc. Take proper care to avoid the selection of a biased target group.
- Determine the total sample size and the number of samples required in each stratum. Identify the population in each of the strata categories defined in the previous step. Set quotas, a minimal number of surveys from each of the sample strata. Surveys must be collected until the quotas have been reached.
- Create your questionnaire. Transform the required data into neutral, simple and systematic questions. If possible and relevant, generate a set of expected answers. Include partially redundant questions to ensure consistency of data. Include space for some sketch mapping, if relevant. Expected answers could be complemented with graphs, figures, maps and pictures. Allow a "not applicable" or "uncertain" category. Group questions logically according to their contents and leave difficult or sensitive questions until near the end of a survey.
- Choose interviewing methodology and develop a standard operations procedure for interviewing. Include QA/QC procedures such as re-sampling a randomly selected sub-group by different experts, and the requirement to take geo-tagged pictures. All surveys must contain date, time, location, and name of the expert who conducted the survey. In addition, include a Section on how to introduce the purpose of the questionnaires to the interviewees.
- Pre-test the questionnaire and methodology, and adjust the questionnaire and its methodology, if necessary. More specifically, if questions are multiple choices (discrete), ensure that all potential answers are included.

- Train experts for conducting interviews. Through instruction, role playing exercises, and test sessions followed by immediate feedback, train experts to conduct interviews. Experts should be properly trained in explaining the broader scope of the social assessments.
- Conduct interviews and enter data. Make sure a copy is made of all surveys and put in a secure archive. Furthermore, all surveys should be scanned and stored electronically to avoid loss of data. Surveys should be immediately evaluated and if systematic problems arise, the survey must be adjusted or experts conducting the interviews should be re-trained. Make sure that experts are accompanied by an experienced supervisor for at least 10% of the interviews throughout the surveying campaign, and not only in the beginning of the campaign.
- Analyze the data.
- Produce reports.

1.2 Guidance for Quality Assurance and Quality Control

To ensure the precise, verifiable and transparent calculation of net NERs, a quality assurance and quality control (QA/QC) procedure must be implemented. The stipulations in the *IPCC 2003 Good Practice Guidance for Land Use, Land-Use Change and Forestry* on quality assurance/quality control (QA/QC) were followed within this methodology, and should be followed by the project proponent when designing a QA/QC plan.

1.2.1 QA/QC for Field Measurements

QA/QC should be conducted as follows:

- Persons involving in the field measurement work should be fully trained in the field data collection and data analyses.
- List all names of the field teams and the project leader and the dates of the training sessions.
- Record which teams have measured each sampling plot. Record that was responsible for each task.
- Develop Standard Operating Procedures (SOPs) for each step of the field measurements and adhere to these at all times, both *ex-ante* and *ex-post.*
- Put a mechanism in place to correct potential errors or inadequacies in the SOPs by a qualified person.
- Verify that plots have been installed and measured correctly, by having approximately 10% of all plots re-measured by an independent team. If the deviation between measurement and re-measurement is larger than 5%, investigate the source of the error, record and correct.

1.2.2 QA/QC for Data Entry, Documentation and Analyses

QA/QC should be conducted as follows:

- Review the entry of data into the data analyses spreadsheets by an independent source.
- Archived all original data sheets safely. Electronic data must be backed up adequately on durable media.
- Ensure that all files are named appropriately. Ensure that all database fields, spreadsheet headings or cells are adequately documented in such a way that it can be verified independently.
- Verify calculations for trivial errors such as unit conversion errors.
- If parameters are common between analyses (e.g., emission factors), ensure that consistent values are used.
- Check for consistency among time series data. Identify outliers as soon after the actual measurement as possible. Investigate the cause of the outlying observation, and correct if needed.
- Compare estimates from field measurements or social appraisals with literature values.
- An SOP for non-biomass monitoring must be developed and adhered to at all times.

1.2.3 QA/QC for Remote Sensing Analyses

QA/QC should be conducted as follows:

- Develop Standard Operating Procedures (SOPs) for each step of the remote sensing analyses and adhere to these at all times, both *ex-ante* and *ex-post*.
- Use ground-truthing data to validate the LULC classification and forest stratification. Use confusion matrices and accuracy indices to analyze and quantify the accuracy of the classification.
- Use visual interpretation of high-resolution satellite imagery to complement the medium resolution imagery.
- Check for consistency among time series data. If outliers are present (e.g., in deforestation quantities), analyze the cause and correct if errors were made.
- Compare estimates of deforestation and forest degradation rates with relevant estimates from the literature.

1.2.4 QA/QC for Land Use Change Modeling

QA/QC should be conducted as follows:

- Split the available data in 2/3 for calibration purposes, and 1/3 for validation purposes. Never use the same data for calibration and validation.
- Report a measure for the accuracy of the land use change model.

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APPENDIX 3: DOCUMENT HISTORY

Version	Date	Comment
v1.0	3 Dec 2010	Initial version released
v2.0	21 Oct 2013	• Revisions were made to accommodate a wider range of drivers of deforestation and degradation as well as a wider range of project activities. • Simplifications were made in the procedures to determine historical LULC transition rates and the area of the reference region. • Quantification of carbon in above ground non-tree pools and soil carbon pools have been incorporated. • The decay of carbon in belowground biomass and soil carbon pools have been quantified such that immediate release of carbon is not assumed.
v2.1	24 Jan 2014	• A procedure to determine a leakage cancellation rate for the conversion of forest land to infrastructure has been incorporated. • Revisions were made to align all market leakage procedures with the discount factor approach set out in *AFOLU Requirements v3.4.*
v2.2	17 Mar 2017	• Incorporated 10 December 2014 errata which removed unnecessary applicability conditions related to data requirements for determining the baseline scenario (Section 4.1.1) • Clarified that GWP values shall be derived from sources specified by the VCS rules (Sections 8.2.4, 8.2.5.5, 8.3.4.2.2, 9.1)

VCS Methodology

VM0007

REDD+ Methodology Framework (REDD-MF)

Version 1.5

9 March 2015

Sectoral Scope 14

Methodology developed by:

Table of Contents

1 SOURCES

This methodology is comprised of a number of modules and tools each of which has been assigned an abbreviated title (eg, *CP-AB*) which are referenced throughout the modules and tools. This methodology uses the latest versions of the following methodologies, modules and tools:

Methodologies:

- CDM methodology *AR-ACM0003 Afforestation and reforestation of lands except wetlands*

Carbon pool modules:

- *VMD0001 Estimation of carbon stocks in the above- and belowground biomass in live tree and non-tree pools (CP-AB)*
- *VMD0002 Estimation of carbon stocks in the dead-wood pool (CP-D)*
- *VMD0003 Estimation of carbon stocks in the litter pool (CP-L)*
- *VMD0004 Estimation of carbon stocks in the soil organic carbon pool (mineral soils) (CP-S)*
- *VMD0005 Estimation of carbon stocks in the long-term wood products pool (CP-W)*

Baseline modules:

- *VMD0006 Estimation of baseline carbon stock changes and greenhouse gas emissions from planned deforestation and planned degradation (BL-PL)*
- *VMD0007 Estimation of baseline carbon stock changes and greenhouse gas emissions from unplanned deforestation (BL-UP)*
- *VMD0008 Estimation of baseline emission from forest degradation caused by extraction of wood for fuel (BL-DFW)*
- *VMD0041 Estimation of baseline carbon stock changes and greenhouse gas emissions in ARR project activities on peat and mineral soil (BL-ARR)*
- *VMD0042 Estimation of baseline soil carbon stock changes and greenhouse gas emissions in peatland rewetting and conservation project activities (BL-PEAT)*

Leakage modules:

- *VMD0009 Estimation of emissions from activity shifting for avoiding planned deforestation and planned degradation (LK-ASP)*
- *VMD0010 Estimation of emissions from activity shifting for avoiding unplanned deforestation (LK-ASU)*
- *VMD0011 Estimation of emissions from market-effects (LK-ME)*
- *VMD0012 Estimation of emissions from displacement of fuelwood extraction (LK-DFW)*

- *VMD0043 Estimation of emissions from displacement of pre-project agricultural activities (LK-ARR)*
- *VMD0044 Estimation of emissions from ecological leakage (LK-ECO)*

Emissions modules (applicable to baseline, project scenario and leakage):

- *VMD0013 Estimation of greenhouse gas emissions from biomass and peat burning (E–BPB)*
- *VMD0014 Estimation of emissions from fossil fuel combustion (E-FFC)*
- CDM tool *Estimation of direct N_2O emissions from nitrogen application (E-NA)*

Monitoring modules:

- *VMD0015 Methods for monitoring of greenhouse gas emissions and removals in REDD project activities (M-REDD)*
- *VMD0045 Methods for monitoring greenhouse gas emissions and removals in ARR project activities on peat and mineral soil (M-ARR)*
- *VMD0046 Methods for monitoring of soil carbon stock changes and greenhouse gas emissions and removals in peatland rewetting and conservation project activities (M-PEAT)*

Miscellaneous modules:

- *VMD0016 Methods for stratification of the project area (X-STR)*
- *VMD0017 Estimation of uncertainty for REDD+ project activities (X-UNC)*

Tools:

- CDM *Tool for testing significance of GHG emissions in A/R CDM project activities (T-SIG)*
- CDM *Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities (T-ADD)*
- VCS *AFOLU Non-Permanence Risk Tool* (T-BAR)

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

This REDD+ Methodology Framework document is the basic structure of a modular REDD+ methodology. It provides the generic functionality of the methodology, which frames pre-defined modules and tools that perform a specific function. It constitutes, together with the modules and tools it calls upon, a complete REDD+ baseline and monitoring methodology.

The modules and tools called upon in this document are applicable to project activities that reduce emissions from planned (APD) and unplanned (AUDD) deforestation, for activities that reduce emissions from forest degradation, for afforestation, reforestation and revegetation activities (ARR), or combinations of these, as well as to any of these activities when they occur on peatland and are combined with peatland rewetting or conservation (being sub-categories of wetland restoration and conservation - WRC). Hereafter in this module and all other modules in methodology VM0007 applied to avoiding planned deforestation projects, “planned deforestation” refers to both planned deforestation and planned degradation.

The reference to this methodology and the modules used to construct the project-specific methodology must be given in the project description (PD).

Identification of the Most Plausible VCS-eligible Activity(s)

To identify the type of VCS-eligible REDD+ project activity use the following decision tree. The decision tree must be used to provide a broad indication of likely baseline type and applicability. Ultimately the relevant baseline modules (*BL-UP* – avoiding unplanned deforestation; *BL-PL* – avoiding planned deforestation and planned degradation; *BL-DFW* – avoiding forest degradation (fuelwood/charcoal); *BL-ARR* - degraded land suited for ARR; and, where applicable, *BL-PEAT* – peatland) must be applied with relevant applicability conditions and criteria.

Provide all the necessary evidence to demonstrate the type of eligible activity as given in each module.

A project can include areas subject to different eligible activities (eg, Area A = avoiding planned deforestation; Area B = avoiding unplanned deforestation; Area C = avoiding degradation; Area D = reforestation; Area E = peatland rewetting and reforestation). In such cases the areas that are eligible for different categories must be captured by different strata and clearly delineated, and the procedures outlined below applied to each of them separately. Projects may combine WRC with REDD or WRC with ARR in a single area, in which case they must apply concomitantly the procedures for both categories.

The demonstration of eligibility must be reported in the PD.

Tables 1 below provides a decision tree for identifying the types of REDD+ and ARR project activities eligible under this methodology.

Table 1: Decision Tree for Determining REDD Project Activity Type and ARR Suitability

<table>
<tr><td colspan="4">Is the forest land expected to be converted to non-forest land in the baseline case, or expected to be subject to authorized conversion to a managed tree plantation in the baseline case?</td></tr>
<tr><td colspan="2">YES[1]</td><td colspan="2">NO</td></tr>
<tr><td colspan="2">Is the land legally authorized and documented to be converted to non-forest or a managed tree plantation?</td><td colspan="2">Is the forest in the baseline expected to degrade by fuelwood extraction or charcoal production?</td></tr>
<tr><td>YES[2]</td><td>NO</td><td>YES</td><td>NO</td></tr>
<tr><td>Avoiding planned deforestation/planned degradation</td><td>Avoiding unplanned deforestation</td><td>Avoiding forest degradation</td><td>Proposed project is not a VCS REDD[3] activity currently covered by the</td></tr>
<tr><td colspan="4">Is part of the land non-forest land or with degraded forest?</td></tr>
<tr><td colspan="2">YES</td><td colspan="2">NO</td></tr>
<tr><td colspan="2">Suitable for ARR</td><td colspan="2">No additional activity</td></tr>
</table>

If the project area includes peatland already drained or that would be drained in the baseline case, project must combine the project activities identified above with the WRC category, as set out in Table 2 below.

Table 2: Determination of WRC Combined Categories

<table>
<tr><th colspan="2">Baseline Scenario</th><th rowspan="2">Project Activity</th><th rowspan="2">Combined Categories</th></tr>
<tr><th>Pre-Project Condition</th><th>Land Use</th></tr>
<tr><td rowspan="2">Drained peatland</td><td>Non-forest</td><td>Rewetting and conversion to forest/revegetation</td><td>WRC+ARR</td></tr>
<tr><td>Forest with deforestation/degradation</td><td>Rewetting and avoiding deforestation/degradation</td><td>WRC+REDD</td></tr>
<tr><td>Undrained peatland</td><td>Forest with deforestation/degradation</td><td>Avoiding drainage and deforestation/degradation</td><td>WRC+REDD[4]</td></tr>
</table>

REDD+ projects under the methodology are divided between the following activity types: avoiding unplanned deforestation/degradation due to collection of wood for fuel and production of charcoal (AUDD), avoiding planned deforestation (APD), forest rehabilitation (ARR), and peatland

[1] If the answer is "yes", evidence must be provided based on the application of the appropriate baseline module (BL-PL for APD and BL-UP for AUDD).
[2] If the answer is "yes", evidence must be provided based on the application of the BL-PL module. Project are required to show legal permissibility to deforest, suitability of project area for conversion and intent to deforest.
[3] If degradation is occurring through legal or sanctioned timber production then this is an eligible IFM activity.
[4] Includes Avoiding Unplanned Wetland Degradation and Avoiding Planned Wetland Degradation.

rewetting and conservation (RWE). Projects can be REDD, REDD+ARR, WRC+ARR, WRC+REDD+ARR. Improved forest management (IFM) is not covered by this methodology.

In Table 3 below the modules and tools are listed and it is indicated when use of modules/tools is mandatory under each activity type. Where any of these project activities take place on peatland, the project must adhere to both the respective project category modules and the relevant WRC modules, unless the expected emissions from the soil organic carbon pool or change in the soil organic carbon pool in the project scenario is deemed below *de minimis*. The tool T-SIG must be used to justify the omission of carbon pools and emission sources.

Table 3: Determination of When Module/Tool Use is Mandatory (M) or Optional (O)

	Module	Avoiding Unplanned Deforestation/ Degradation	Avoiding Planned Deforestation	Avoiding Degradation (Fuelwood / Charcoal)	ARR	REDD or ARR on Peatland
Always Mandatory	**REDD-MF**	M	M	M	M	M
	M-REDD	M	M	M	-	←
	M-ARR	-	-	-	M	←
	M-PEAT	-	-	-	-	M
	T-ADD	M	M	M	M	M
	T-BAR	M	M	M	M	M
	X-UNC	M	M	M	M	M
	X-STR	M	M	M	X***	M
Baselines	**BL-UP**	M	-	-	-	←
	BL-PL	-	M	-	-	←
	BL-DFW	-	-	M	-	←
	BL-ARR	-	-	-	M	←
	BL-PEAT	-	-	-	-	M
Leakage	**LK-ASU**	M	-	-	-	←
	LK-ASP	-	M	-	-	←
	LK-DFW	-	-	M	-	←
	LK-ARR	-	-	-	M	←
	LK-ECO	-	-	-	-	M
	LK-ME	(m)[1]	(m)[1]	(m)[2]	-	←
Pools*	**CP-AB**	M	M	M	X***	←
	CP-D	(m)[3]	(m)[3]	(m)[3]	X***	X****
	CP-L	O	O	O	X***	X****

	CP-S	O	O	O	X***	X****
	CP-W	(m)¹	(m)¹	-	-	←
Emissions *	**E-BPB**	M	M	M	X**	M
	E-FFC	O	O	O		←
	E-NA	(m)⁴	O	O	-	X

← See instructions under REDD and ARR categories

M Modules marked with an M are fully mandatory: the indicated modules and tools must be used

O Modules marked with an O are fully optional: the indicated pools and sources can be included or excluded as decided by the project but if included in the baseline they must also be included in the project scenario

X Modules marked with an X are excluded

(m)[1] Mandatory where the process of deforestation involves timber harvesting for commercial markets

(m)[2] Mandatory where fuelwood or charcoal is harvested for commercial markets

(m)[3] Mandatory if this carbon pool is greater in baseline (post-deforestation/degradation) than project scenario and significant; otherwise can be conservatively omitted

(m)[4] Mandatory where leakage prevention activities include increases in the use of fertilizers

* VCS requirements and the tool T-SIG must be used to justify the omission of carbon pools and emission sources

** Procedures provided in M-ARR.

*** Procedures provided in BL-ARR and M-ARR.

**** Procedures provided in BL-PEAT and M-PEAT.

3 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions apply to this methodology:

Baseline Period
The period of time with a fixed baseline (10 years), applicable to REDD and WRC baselines

Expert Judgment
Judgment on methodological choice and choice of input data and to fill gaps in the available data, to select data from a range of possible values or on uncertainty ranges as established in the *IPCC 2006 Good Practice Guidance*. Obtaining well-informed judgments from domain experts regarding best estimates and uncertainties of inputs to the quantification of emission reductions is an important aspect in various procedures throughout this methodology. The guidance provided

in Chapter 2, Volume 1 (Approaches to Data Collection) must be used, in particular, Section 2.2 and Annex 2A.1 of the *IPCC 2006 Guidelines for National Greenhouse Gas Inventories*.

Historical Reference Period

The historical period prior to the project start date that serves as the source of data for defining the baseline

4 APPLICABILITY CONDITIONS

This REDD+ Methodology Framework is a compilation of modules and tools that together define the project activity and necessary methodological steps. By choosing the appropriate modules, a project-specific methodology can be constructed. The justification of the choice of modules and why they are applicable to the proposed project activity must be given in the PD.

Specific applicability conditions exist for each module and must be met for the module to be used.

This methodology includes forest degradation caused only by extraction of wood for fuel. No modules are included for activities to reduce emissions from forest degradation caused by illegal harvesting of trees for timber.[5]

Use of this methodology is subject to the following applicability conditions, noting the project must also comply with the applicability conditions of the applied modules and tools:

4.1 General

All land areas registered under the CDM or under any other GHG program (both voluntary and compliance-oriented) must be transparently reported and excluded from the project area. The exclusion of land in the project area from any other GHG program must be monitored over time and reported in the monitoring reports.

4.2 REDD

4.2.1 All REDD Activity Types

REDD activity types applicable under the following conditions:

- Land in the project area has qualified as forest (following the definition used by VCS) at least 10 years before the project start date.
- If land within the project area is peatland and emissions from the soil carbon pool are deemed significant, the relevant WRC modules (see Table 1) must be applied alongside other relevant modules.
- Baseline deforestation and forest degradation in the project area fall within one or more of the following categories:

[5] Illegal timber harvest may be occurring in the project area in the baseline but conservatively no benefit can be calculated for preventing timber harvests, and any emissions arising from timber harvests in the project case must be monitored and deducted from calculated project net emission reductions.

- Unplanned deforestation (VCS category AUDD);
- Planned deforestation/degradation (VCS category APD);
- Degradation through extraction of wood for fuel (fuelwood and charcoal production) (VCS category AUDD).

- Leakage avoidance activities must not include:
  - Agricultural lands that are flooded to increase production (eg, paddy rice);
  - Intensifying livestock production through use of feed-lots[6] and/or manure lagoons.[7]

4.2.2 Unplanned Deforestation

Unplanned deforestation activities are applicable under the following conditions:

- Baseline agents of deforestation must: (i) clear the land for settlements, crop production (agriculturalist) or ranching, where such clearing for crop production or ranching does not amount to large scale industrial agriculture activities[8]; (ii) have no documented and uncontested legal right to deforest the land for these purposes; and (iii) be either residents in the Reference Region for Deforestation (cf. section 1 below) or immigrants. Under any other condition this methodology must not be used.
- If, in the baseline scenario of avoiding unplanned deforestation project activities, post-deforestation land use constitutes reforestation, this methodology may not be used.

4.2.3 Planned Deforestation/Degradation

Unplanned deforestation/degradation activities are applicable under the following condition:

- Conversion of forest lands to a deforested condition must be legally permitted.

4.2.4 Degradation (Fuelwood/Charcoal)

Degradation activities are applicable under the following conditions:

- Fuelwood collection and charcoal production must be non-renewable[9] in the baseline period.
- If degradation is caused by either illegal or legal tree extraction for timber, this methodology cannot be used.

[6] Feedlots are defined as areas in which naturally grazing animals are confined to an area which produces no feed and are fed on stored feeds.
[7] Anaerobic lagoons that function as receptacles for animal waste flushed from animal pens. Anaerobic organisms present in the manure and the environment decompose the waste in the lagoon.
[8] Small-scale / large-scale agriculture to be defined and justified by the project.
[9] As defined in Module BL-DFW

4.3 ARR

ARR activities are applicable under the following conditions:

- The project area is non-forest land or land with degraded forest.
- The project scenario does not involve the harvesting of trees. Therefore, procedures for the estimation of long-term average carbon stocks are not provided.
- The project scenario does not involve the application of nitrogen fertilizers.

Note, where project activities on wetlands are excluded by the applicability conditions of applied modules or tools, these can be disregarded for the purpose of their use within this methodology, as quantification procedures for the peat soil are provided in modules *BL-PEAT* and *M-PEAT*.

4.4 WRC

WRC activities are applicable under the following conditions:

- This methodology is applicable to rewetting drained peatland (RDP) and conservation of undrained and partially drained peatland (CUPP) activities on project areas that meet the VCS definition for peatland[10]. The scope of this methodology is limited to domed peatlands in the tropical climate zone.
- Fire reduction projects on peatland that exclude rewetting as part of the project activity are not eligible.
- Rewetting of drained peatland and conservation of undrained or partially drained peatland may be implemented in combination with REDD project activities. REDD project activities on peatland must not increase drainage.
- Rewetting of drained peatland may be implemented as a separate activity or in combination with ARR project activities. ARR activities must not enhance peat oxidation and therefore this activity requires at least some degree of rewetting.

5 PROJECT BOUNDARY

The following categories of boundaries must be defined:

1) The geographic boundaries relevant to the project activity;
2) The temporal boundaries;
3) The carbon pools that the project will consider;
4) The sources and associated types of greenhouse gas emissions that the project will affect.

[10] RDP (Rewetting of Drained Peatland) and CUPP (Conservation of Undrained or Partially Drained Peatland) project activities are both sub-categories of Restoration of Wetland Ecosystems (RWE) and Conservation of Intact Wetlands (CIW) of the Wetlands Restoration and Conservation (WRC) project category.

5.1 Geographical Boundaries

5.1.1 General

The spatial boundaries of a project must clearly be defined, so as to facilitate accurate measuring, monitoring, accounting, and verifying of the project's emissions reductions and removals. The REDD project activity may contain more than one discrete area of land. When describing physical project boundaries, the following information must be provided per discrete area:

- Name of the project area (eg, compartment number, allotment number, local name); Unique ID for each discrete parcel of land;
- Map(s) of the area (preferably in digital format);
- Geographic coordinates of each polygon vertex along with the documentation of their accuracy (from a geo-referenced digital map – data must be provided in the format specified / required by the VCS).
- Total land area; and
- Details of land holder and user rights.

The geographical boundaries of a project are fixed (*ex-ante*) and cannot change over the project lifetime (*ex-post*). Where multiple baselines exist (eg, planned deforestation, unplanned deforestation, forest degradation, degraded land) there must be no overlap in boundaries between areas appropriate to each of the baselines. Thus two project types cannot occur on the same piece of land, other than those including a WRC component (ie, combined REDD+WRC, ARR+WRC).

5.1.2 REDD

The boundary of the REDD activity must be clearly delineated and defined and include only land qualifying as forest for a minimum of 10 years prior to the project start date.

In REDD project activities, various kinds of boundaries must be distinguished, depending on the REDD category (planned or unplanned deforestation, forest degradation), ie, in case of:

- Avoiding planned deforestation: project area and proxy area(s). Refer to module *BL-PL* for the detailed procedures to define these boundaries.
- Avoiding unplanned deforestation: project area, reference regions for deforestation, and leakage belt area. Refer to module *BL-UP* for definitions and the detailed procedures to define these boundaries.
- Avoiding forest degradation: Refer to module *BL-DFW* (for degradation due to removals for wood fuel or charcoal) for the detailed procedures to define these boundaries.

Methods for establishing the boundaries of areas subject to leakage from activity shifting are provided in the following modules:

- For avoiding planned deforestation/degradation: module *LK-ASP*
- For avoiding unplanned deforestation: module *BL-UP*

5.1.3 ARR

The project area must not have been not cleared of native ecosystems to create GHG emissions reductions/removals. Such proof is not required where such clearing took place prior to the 10-year period prior to the project start date. Areas that do not meet this requirement must be excluded from the project area.

5.1.4 WRC

The project area must not have been not drained or converted to create GHG emissions reductions/removals. Such proof is not required where such draining or conversion took place prior to 1 January 2008. Areas that do not meet this requirement must be excluded from the project boundary.

The maximum eligible quantity of GHG emission reductions in WRC project activities on peatland is limited to the difference between the remaining peat carbon stock in the project and baseline scenarios after 100 years. If a significant difference at the 100-years mark cannot be demonstrated, the project area is not eligible for carbon crediting. The assessment must be executed ex ante using conservative parameters. Procedures are provided in module *X-STR*.

5.2 Temporal Boundaries

The following temporal boundaries must be specified:

5.2.1 Start Date and End Date of the Historical Reference Period

REDD

The historical reference period is the temporal domain from which information on historical deforestation is extracted, analyzed and projected into the future. A historical reference period must be defined for all eligible REDD categories. The starting date of this period must be between 9 and 12 years in the past and the end date must be within two years of project start date.

WRC

While developing WRC baselines, project must reference a period of at least 10 years for modeling a spatial trend in drainage, taking into account the long-term (20-year) average climate variables, for which procedures are provided in module *BL-PEAT*.

5.2.2 Start Date and End Date of the Project Crediting Period

General

The project crediting period is the period of time for which GHG emissions reductions or removals generated by the project are eligible for crediting with the VCS Program. The project must have a robust operating plan covering this period.

The project crediting period for REDD+ projects must be between 20 and 100 years. The duration of the project activity/crediting period must be reported in the PD.

<u>REDD</u>

Projections of baseline emissions must be presented in the PD for the first 10-year period after the project start date. Emission reductions/removals can only be claimed for 10-year periods for which the baseline is fixed and a monitoring plan has been implemented.

<u>WRC</u>

Projections of baseline emissions from peatland must be presented in the PD for the first 10-year period after the start of the project. Emission reductions/removals can only be claimed for 10-year periods for which the baseline is fixed and a monitoring plan has been implemented.

Peat Depletion Time (PDT)

Peat depletion may be accelerated by peat fires and is attained if the peat has disappeared or if a stable water table inhibits further oxidation of the peat. The PDT for a stratum in the baseline scenario equals the period during which the project can claim emission reductions from rewetting. Procedures for determining the PDT are provided in module *X-STR*.

Since the PDT is part of the baseline assessment, it must be reassessed every 10 years.

5.2.3 Duration of the Monitoring Periods

The minimum duration of a monitoring period is one year and the maximum duration is 10 years.

Baseline projections must be annual and be available for each proposed future verification date.

Data on baseline deforestation and degradation rates, as well as on the hydrological layout and climatic variables in the peatland areas, must be presented as well as data collection for future baseline revision.

5.3 Carbon Pools

5.3.1 General

Any significant decreases in carbon stock in the project scenario and any significant increases in carbon stock in the baseline scenario must be accounted for. In addition, decreases in the baseline scenario and increases in the project scenario can be accounted for. Where ARR or REDD activities take place on peatland, the project must account for expected emissions from the soil organic carbon pool or change in the soil organic carbon pool in the project scenario, unless they are is deemed *de minimis*. The significance of this pool may be determined by using the tool *T-SIG*.

Selection of carbon pools and the appropriate justification must be presented in PD.

5.3.2 REDD

The carbon pools (and corresponding methodology modules) included in or excluded from the boundary of REDD project activities are shown in Table 3.

Harvested wood products and dead-wood must be included when they increase more or decrease less in the baseline than in the project scenario. In all other cases only aboveground biomass is mandatory. If a carbon pool is included in the baseline accounting, it must also be included in project scenario and leakage accounting.

Where the carbon pool in harvested wood products and dead-wood increases more or decreases less in the baseline case than in the project case, the tool *T-SIG* must be used to determine whether significant. Insignificant pools can always be ignored.

5.3.3 ARR

The carbon pools included in or excluded from the boundary of the ARR component are shown in Table 4 below. The selection of carbon pools and the appropriate justification must be provided in the PD.

Table 4: Carbon Pools in Baseline and Project Scenario of ARR Project Activities

Carbon pool	Included?	Justification / Explanation
Aboveground tree biomass	Included	Mandatory pool in ARR project activities
Aboveground non-tree biomass	Included	Carbon stock in this pool may increase in the baseline scenario and may increase or decrease due to the implementation of the project activity
Belowground biomass	Included	Carbon stock in this pool may increase in the baseline scenario and is expected to increase due to the implementation of the project activity
Litter		
On mineral soil	Optional	Given the applicability conditions that the project area for ARR is non-forest land or land with degraded forest and that the project scenario does not involve the harvesting of trees, the litter carbon pool will increase due to project implementation. It is therefore conservative not to include litter. If included, litter must be accounted for using procedures in modules *CP-L*, *BL-ARR* and *M-ARR*.

On peatland	Optional	This pool is not mandatory on peatland but may be included. Given the applicability conditions that the project area for ARR is non-forest land or land with degraded forest and that the project scenario does not involve the harvesting of trees, the litter carbon pool will increase due to project implementation. It is therefore conservative not to include litter. If included, litter must be accounted for using procedures in modules *CP-L*, *BL-ARR* and *M-ARR*.
Dead wood		
On mineral soil	Optional	Given the applicability conditions that the project area for ARR is non-forest land or land with degraded forest and that the project scenario does not involve the harvesting of trees, the dead wood carbon pool will increase due to project implementation. It is therefore conservative not to include dead wood. If included, dead wood must be accounted for using procedures in modules *CP-D*, *BL-ARR* and *M-ARR*.
On peatland	Optional	This pool is not mandatory on peatland but may be included. Given the applicability conditions that the project area for ARR is non-forest land or land with degraded forest and that the project scenario does not involve the harvesting of trees, the dead wood carbon pool will increase due to project implementation. It is therefore conservative not to include dead wood. If included, dead wood must be accounted for using procedures in modules *CP-D*, *BL-ARR* and *M-ARR*.
Soil		
On mineral soil	Included	Carbon stock in this pool may increase due to the implementation of the project activity and this increase can be assessed as a carbon stock change.
On peatland	Included	Carbon stock in this pool may increase due to the implementation of the project activity but this increase is not accounted for; emissions from soil organic carbon are estimated in modules *BL-ARR* and *M-ARR*.
Wood products	Excluded	This pool is optional as per VCS rules.

5.3.4 WRC

The carbon pools included in or excluded from the boundary of the WRC component are shown in Table 5 below. The selection of carbon pools and the appropriate justification must be provided in the PD.

Table 5: Carbon Pools in Baseline and Project Scenario of WRC Project Activities

Carbon pool	Included?	Justification / Explanation
Aboveground tree biomass	Excluded	Covered under REDD or ARR
Aboveground non-tree biomass	Excluded	Covered under REDD or ARR
Belowground biomass	Included	This pool is not distinguished from the soil pool in WRC procedures
Litter	Excluded	Covered under REDD or ARR
Dead wood	Excluded	Covered under REDD or ARR
Soil	Included	The WRC procedures account for emissions from the soil pool based on proxies and default factors.
Wood products	Excluded	Covered under REDD or ARR

5.4 Sources of GHG Emissions

5.4.1 General

The project must account for any significant increases in emissions of carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) relative to the baseline that are reasonably attributable to the project activity, with additional guidance provided in Tables 6, 7 and 8.

T-SIG may be used to determine whether an emissions source is significant. If a source is included in the estimation of baseline emissions[11], it must also be included in the calculation of project and leakage emissions.

5.4.2 REDD

The GHG emission sources included in or excluded from the boundary of the REDD project activity are shown in Table 6 below. The selection of sources and the appropriate justification must be provided in the PD.

Table 6: GHG Sources Included In or Excluded From the REDD Project Boundary

Sources	Gas	Included?	Justification / Explanation
Biomass burning	CO_2	Excluded	However, carbon stock decreases due to burning are accounted as a carbon stock change

[11] Eg, CH_4 or N_2O emission from agriculture that results from deforestation or fire to clear forest land.

	CH_4	Included	Non-CO_2 gases emitted from woody biomass burning - it is conservative to exclude in the baseline but must be included in the project case if fire occurs.
	N_2O	Included	
Combustion of fossil fuels	CO_2	Included	Can be neglected if excluded from baseline accounting.
	CH_4	Excluded	Potential emissions are negligible
	N_2O	Excluded	Potential emissions are negligible
Use of fertilizers	CO_2	Excluded	Potential emissions are negligible
	CH_4	Excluded	Potential emissions are negligible
	N_2O	Included	Can be excluded if excluded from baseline accounting except in the situation where fertilizer use is enhanced as a leakage avoidance mechanism.

5.4.3 ARR

The GHG emission sources included in or excluded from the boundary of the ARR component are shown in Table 7 below. The selection of sources and the appropriate justification must be provided in the PD.

Table 7: GHG Sources Included In or Excluded From the ARR Project Boundary

Sources	Gas	Included?	Justification / Explanation of choice
Burning of woody biomass	CO_2	Excluded	However, carbon stock decreases due to burning are accounted as a carbon stock change
	CH_4	Included	Burning of woody biomass for the purpose of site preparation, or as part of forest management, is allowed
	N_2O	Included	Burning of woody biomass for the purpose of site preparation, or as part of forest management, is allowed

Table 7 with the selection of sources and the appropriate justification must be presented in the PD.

5.4.4 WRC

The GHG emission sources included in or excluded from the boundary of the WRC component are shown in Table 8 below. The selection of sources and the appropriate justification must be provided in the PD.

Table 8: GHG Sources Included In or Excluded From the WRC Project Boundary

Sources	Gas	Included?	Justification / Explanation
Oxidation of drained peat	CO_2	Included	Considered under carbon pools
	CH_4	Included	Required unless *de minimis* or conservatively omitted
	N_2O	Excluded	Excluded as per applicability condition in module *BL-PEAT*
Peat combustion	CO_2	Included	Procedures provided in module *E-BPB*
	CH_4	Included	Procedures provided in module *E-BPB*
	N_2O	Included	Procedures provided in module *E-BPB*
Combustion of fossil fuels	CO_2	Excluded	Deemed *de minimis* in VCS *AFOLU Requirements*
	CH_4	Excluded	Deemed *de minimis* in VCS *AFOLU Requirements*
	N_2O	Excluded	Deemed *de minimis* in VCS *AFOLU Requirements*

6 BASELINE SCENARIO

6.1 Determination of the Most Plausible Baseline Scenario

For each of the included project activities, the most plausible baseline scenario must be determined using *T-ADD*, listed in Section 2 above. The tool has been designed for A/R CDM project activities, but is used by this methodology applying the notes provided in Table 9 below.

Table 9: Translation between VCS and CDM Terminology

Where the tool refers to:	It must be understood as referring to:
A/R, afforestation, reforestation, or forestation	REDD, ARR or WRC project activity
Net greenhouse gas removals by sinks	Net greenhouse gas emission reductions
CDM	VCS
DOE	VVB
tCERs, lCERs	VCUs

Footnotes 1 and 3 included in T-ADD can be disregarded. In case there is a conflict between the CDM tool requirements and the VCS rules, the VCS rules must be followed (as set out in VCS *AFOLU Guidance: Additional guidance for VCS Afforestation, Reforestation and Revegetation projects using CDM Afforestation/Reforestation Methodologies*, available on the VCS website.

6.2 Re-assessing the Baseline Scenario

The project baseline must be revised at the following frequencies:

- For planned deforestation projects, the baseline must be revised every 10 years for ongoing planned deforestation.
- For unplanned deforestation, the project baseline must be revised every 10 years from the project start date.
- For degradation, the baseline must be revised every 10 years.
- For WRC areas, the project must, for the duration of the project, reassess the baseline every 10 years and have this validated at the same time as the subsequent verification.

The date of the next scheduled revision must be specified. The starting point for the baseline revision of the project will be forest cover projected to exist at the end of the baseline period. Projections for each baseline revision will be subject to independent verification.

Reassessments must capture changes in the drivers and/or behavior of agents that cause the change in land use and/or land management practices and changes in carbon stocks. The new baseline scenario must be incorporated into revised estimates of baseline emissions. This baseline reassessment must include the evaluation of the validity of proxies for GHG emissions.

For REDD and WRC project activities, *ex-ante* baseline projections beyond a 10-year period are not required. For this assessment the historic reference period is extended to include the original reference period and all subsequent monitoring periods up to the beginning of the current monitoring period.

7 ADDITIONALITY

T-ADD must be used to identify credible alternative land use scenarios and evaluate both the alternatives and the proposed project scenarios and to demonstrate the additionality of the project.

The assessment and demonstration of additionality must be presented in the PD.

Default factors and standards used to ascertain GHG emission data and any supporting data for demonstrating additionality must be publicly available from a recognized, credible source, such as *IPCC 2006 Guidelines for National GHG Inventories* or the *IPCC 2003 Good Practice Guidelines for Land Use, Land-Use Change and Forestry*.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

8.1.1 General

Each activity type included in the project must estimate an individual baseline following the provisions and specific modules mentioned below. Combined activities (ie, ARR or REDD with a WRC component) must develop a unique baseline considering peat as the soil carbon pool and incorporating the resulting emission estimates to the calculation of emissions and carbon stock changes of the ARR and/or REDD activities.

The same procedure must be followed *ex ante* and *ex post*. For parameters that will be monitored subsequent to project initiation, guidance is given in the parameter tables of the relevant modules for the values that must be used in *ex-ante* calculations.

8.1.2 REDD

The baseline of the REDD project activity is estimated *ex ante*. It can be monitored in a reference area (unplanned deforestation) or proxy area (planned deforestation) for the purpose of periodically adjusting the baseline. *Ex-ante* baseline estimations are therefore used in both the *ex-ante* and *ex-post* estimation of net carbon stock changes and greenhouse gas emission reductions.

Methods for estimating net baseline carbon stock changes and greenhouse gas emissions are provided in the following modules:

- For planned deforestation/degradation: module *BL-PL*
- For unplanned deforestation: module *BL-UP*
- For forest degradation from extraction of wood for fuel: module *BL-DFW*

8.1.3 ARR

The baseline net GHG removals must be estimated using module *BL-ARR*.

8.1.4 WRC

Baseline net emissions from the soil (peat) carbon pool in combined projects must be estimated using module *BL-PEAT*.

8.2 Project Emissions

For emissions and removals in the project scenario the following modules must be used:

- For REDD project activities: module *M-REDD*
- For ARR project activities: module *M-ARR*
- For WRC project activities module *M-PEAT*

8.2.1 General

The same procedure must be followed *ex ante* and *ex post*. For parameters that will be monitored subsequent to project initiation, guidance is given in the parameter tables of the relevant modules for the values that must be used in *ex-ante* calculations.

8.2.2 REDD

Methods for estimating net carbon stock changes and GHG emissions in the project scenario are provided in module *M-REDD*.

8.2.3 ARR

The net GHG removals in the project scenario must be estimated using module *M-ARR*.

8.2.4 WRC

Net GHG emissions from the soil (peat) carbon pool in the project scenario in combined projects must be estimated using module *M-PEAT*.

8.3 Leakage

Leakage must be considered for all activities using the following leakage modules:

- For planned deforestation/degradation: module *LK-ASP*
- For unplanned deforestation: module *LK-ASU*
- For fuel-wood/charcoal collection: module *LK-DFW*
- For pre-project agricultural activities: module *LK-ARR*

For WRC project activities that are not combined with REDD or ARR, where pre-project activities may be displaced to undrained or partially drained peatland areas, the procedures provided for activity shifting to peatland areas in module LK-ASP (planned drainage of peatland) or module LK-ASU (unplanned drainage of peatland) must be used.

For WRC projects activities, the following module must be used:

- For ecological leakage: module *LK-ECO*

The significance of leakage and the significance of carbon pools may be determined using *T-SIG*.

Where applicable, leakage due to market effects must be considered using module *LK-ME*. Market effects must be considered where the project leads to a decrease in the production of timber, fuelwood, or charcoal.

Where, pre-project, unsustainable fuelwood collection is occurring within the project boundary, modules *BL-DFW* and *LK-DFW* must be used to determine potential leakage.

Where leakage prevention activities include tree planting, aquacultural intensification, agricultural intensification, fertilization, fodder production, other measures to enhance cropland and/or grazing land areas, leakage management zones or a combination of these, then any significant increase in GHG emissions associated with these activities must be accounted for, unless deemed *de minimis*, as determined using *T-SIG*.

Leakage prevention activities may lead to the increase in combustion of fossil fuels, however, any increase in emissions is considered insignificant.

Where leakage prevention leads to a significant increase in the use of fertilizers, module *E-NA* must be used. *T-SIG* can be used to determine significance.

As per the applicability conditions, leakage prevention may not include the flooding of agricultural lands (eg, for new rice paddies) nor the creation of livestock feedlots and/or manure lagoons. Leakage prevention may also not include the drainage of peatland.

The list of leakage sources with appropriate justification must be presented.

Positive leakage may not be accounted for.

8.4 Summary of GHG Emission Reduction and/or Removals

8.4.1 General

The total net greenhouse gas emissions reductions of the project are calculated as:

$$NER_{REDD+} = NER_{REDD} + NGR_{ARR} + NER_{WRC} \quad (1)$$

Where:

NER_{REDD+}	Total net GHG emission reductions of the REDD+ project activity up to year t^* (t CO_2e)
NER_{REDD}	Total net GHG emission reductions of the REDD project activity up to year t^* (t CO_2e)
NGR_{ARR}	Total net GHG removals of the ARR project activity up to year t^* (t CO_2e)
NER_{WRC}	Total net GHG emission reductions of the WRC project activity up to year t^* (t CO_2e)

Project must present conservative *ex-ante* estimations of the total net GHG emissions reductions of the project activity.

For *ex-ante* estimation for specific parameters project must refer to the parameter tables in the appropriate modules.

8.4.2 REDD

The total net greenhouse gas emissions reductions of the REDD project activity are calculated as follows:

$$NER_{REDD} = \Delta C_{BSL-REDD} - \Delta C_{WPS-REDD} - \Delta C_{LK-REDD} \quad (2)$$

Where:

NER_{REDD}	Total net GHG emission reductions of the REDD project activity up to year *t** ($t\ CO_2e$)
$\Delta C_{BSL\text{-}REDD}$	Net GHG emissions in the REDD baseline scenario up to year *t** ($t\ CO_2e$)
$\Delta C_{WPS\text{-}REDD}$	Net GHG emissions in the REDD project scenario up to year *t** ($t\ CO_2e$)
$\Delta C_{LK\text{-}REDD}$	Net GHG emissions due to leakage from the REDD project activity up to year *t** ($t\ CO_2e$)

$$\Delta C_{BSL,REDD} = \Delta C_{BSL,planned} + \Delta C_{BSL,unplanned} + \Delta C_{BSL,\deg rad-FW/C} \tag{3}$$

Where:

$\Delta C_{BSL\text{-}REDD}$	Net GHG emissions under the REDD baseline scenario up to year *t** ($t\ CO_2e$)
$\Delta C_{BSL,planned}$	Net GHG emissions in the baseline scenario from planned deforestation up to year *t** ($t\ CO_2e$)
$\Delta C_{BSL,unplanned}$	Net GHG emissions in the baseline scenario from unplanned deforestation up to year *t* ($t\ CO_2e$)
$\Delta C_{BSL,degrad\text{-}FW/C}$	Net GHG emissions in the baseline scenario from degradation caused by fuelwood collection and charcoal making up to year *t** ($t\ CO_2e$)

$$\Delta C_{LK-REDD} = \Delta C_{LK-AS,planned} + \Delta C_{LK-AS,unplanned} + \Delta C_{LK-AS,\deg rad-FW/C} + \Delta C_{LK-ME} \tag{4}$$

Where:

$\Delta C_{LK\text{-}REDD}$	Net GHG emissions due to leakage from the REDD project activity up to year *t** ($t\ CO_2e$)
$\Delta C_{LK\text{-}AS,planned}$	Net GHG emissions due to activity shifting leakage for projects preventing planned deforestation up to year *t** ($t\ CO_2e$)
$\Delta C_{LK\text{-}AS,unplanned}$	Net GHG emissions due to activity shifting leakage for projects preventing unplanned deforestation up to year *t** ($t\ CO_2e$)
$\Delta C_{LK\text{-}ME}$	Net GHG emissions due to market-effects leakage up to year *t** ($t\ CO_2e$)
$\Delta C_{LK\text{-}AS,degrad\text{-}FW/C}$	Net GHG emissions due to activity shifting leakage for degradation caused by extraction of wood for fuel up to year *t** ($t\ CO_2e$)

8.4.3 ARR

The total net greenhouse gas removals of the ARR project activity are calculated as follows:

$$NGR_{ARR,t} = \Delta C_{WPS\text{-}ARR} - \Delta C_{BSL\text{-}ARR} - \Delta C_{LK\text{-}ARR} \tag{5}$$

Where:

NGR_{ARR}	Total net GHG removals of the ARR project activity up to year *t** ($t\ CO_2e$)
$\Delta C_{BSL\text{-}ARR}$	Net GHG removals in the ARR baseline scenario up to year *t** ($t\ CO_2e$)
$\Delta C_{WPS\text{-}ARR}$	Net GHG emissions in the ARR project scenario up to year *t** ($t\ CO_2e$)

$\Delta C_{LK\text{-}ARR}$	Net GHG emissions due to leakage from the ARR project activity up to year *t** (t CO_2e)

8.4.4 WRC

The total net GHG emission reduction of the WRC project activity is calculated as follows:

$$NER_{WRC} = GHG_{BSL\text{-}WRC} - GHG_{WPS\text{-}WRC} + Fire\ Reduction\ Premium - GHG_{LK\text{-}ECO} \quad (6)$$

Where:

NER_{WRC}	Total net GHG emission reductions in the WRC project up to year *t** (t CO_2e)
$GHG_{BSL\text{-}WRC}$	Net GHG emissions in the WRC baseline scenario up to year *t** (t CO_2e)
$GHG_{WPS\text{-}WRC}$	Net GHG emissions in the WRC project scenario up to year *t** (t CO_2e)
Fire Reduction Premium	Greenhouse gas emission reduction from peat combustion due to rewetting and fire management up to year *t** (t CO_2e)
$GHG_{LK\text{-}ECO}$	Net GHG emissions due to ecological leakage from the WRC project activity up to year *t** (t CO_2e)

8.4.5 Calculation of VCS Buffer

The number of credits to be held in the AFOLU pooled buffer account is determined as a percentage of the total carbon stock benefits. For REDD project activities, this is equal to the net emissions in the baseline minus emissions from fossil fuel use and fertilizer use minus the net emissions in the project case minus emissions from fossil fuels and fertilizer use. Leakage emissions do not factor into the buffer calculations.

For REDD projects, the calculation of the net change in carbon stocks applied in this methodology includes an adjustment for emissions from fossil fuel combustion and direct N_2O emissions and excludes emissions from biomass burning. Besides other GHG fluxes, biomass burning involves a carbon stock change. The procedure, therefore, provides a conservative (larger) estimate of the buffer withholding.

For WRC project activities – where carbon stock changes are not estimated – the proxy for the net change in carbon stocks applied in this methodology is NER_{WRC}. As this proxy includes all net GHG emissions reductions it provides a conservative (larger) estimate of the buffer.

Since GHG emission reductions from ARR are unlikely to differ greatly from the net change in carbon stocks, the proxy for the net change in carbon stocks applied in this methodology is NGR_{ARR}. As this proxy includes all GHG emissions reductions and removals it provides a conservative (larger) estimate of the buffer withholding.

$$Buffer_{Total} = Buffer_{Planned} + Buffer_{Unplanned} + Buffer_{Degrad-FW/C} + Buffer_{WRC} + Buffer_{ARR} \quad (7)$$

$$Buffer_{Planned} = \left(\left(\Delta C_{BSL,Planned} - \sum_{t=1}^{t^*_{BSL}} \sum_{i=1}^{M_{Planned}} \left(E_{FC,i,t} + N_2O_{direct,i,t} \right) \right) - \left(\Delta C_{P,Planned} - \sum_{t=1}^{t^*_{P}} \sum_{i=1}^{M_{Planned}} \left(E_{FC,i,t} + N_2O_{direct,i,t} \right) \right) \right) \times Buffer\% \quad (8)$$

$$Buffer_{Unplanned} = \left(\left(\Delta C_{BSL,Unplanned} - \sum_{t=1}^{t^*_{BSL}} \sum_{i=1}^{M_{Unplanned}} \left(E_{FC,i,t} + N_2O_{direct,i,t} \right) \right) - \left(\Delta C_{P,Unplanned} - \sum_{t=1}^{t^*_{P}} \sum_{i=1}^{M_{Unplanned}} \left(E_{FC,i,t} + N_2O_{direct,i,t} \right) \right) \right) \times Buffer\% \quad (9)$$

$$Buffer_{Degrad-FW/C} = \left(\left(\Delta C_{BSL,Degrad-FW/C} - \sum_{t=1}^{t^*_{BSL}} \sum_{i=1}^{M_{Degrad-FW/C}} \left(E_{FC,i,t} + N_2O_{direct,i,t} \right) \right) - \left(\Delta C_{P,Degrad-FW/C} - \sum_{t=1}^{t^*_{P}} \sum_{i=1}^{M_{Degrad-FW/C}} \left(E_{FC,i,t} + N_2O_{direct,i,t} \right) \right) \right) \times Buffer\% \quad (10)$$

$$Buffer_{ARR} = NGR_{ARR} \times Buffer\% \quad (11)$$

$$Buffer_{WRC} = NER_{WRC} \times Buffer\% \quad (12)$$

Where:

$Buffer_{Total}$	Total permanence risk buffer withholding (t CO_2e)
$Buffer_{Planned}$	Buffer withholding for avoiding planned deforestation project activities (t CO_2e)
$Buffer_{Unplanned}$	Buffer withholding for avoiding unplanned deforestation project activities (t CO_2e)
$Buffer_{Degrad-FW/C}$	Buffer withholding for avoiding degradation through extraction of fuelwood project areas (t CO_2e)
$Buffer_{ARR}$	Buffer withholding for ARR project activities (t CO_2e)
$Buffer_{WRC}$	Buffer withholding for WRC project activities (t CO_2e)
$\Delta C_{BSL,Planned}$	Net GHG emissions in the baseline from planned deforestation (t CO_2e)
$\Delta C_{BSL,Unplanned}$	Net GHG emissions in the baseline from unplanned deforestation (t CO_2e)
$\Delta C_{BSL,Degrad-FW/C}$	Net GHG emissions in the baseline from degradation caused by fuelwood collection and charcoal making (t CO_2e)

ΔC_P	Net GHG emissions within the project area under the project scenario[12] (t CO_2e)
$E_{FC,i,t}$	Emission from fossil fuel combustion in stratum *i* in year *t* (t CO_2e)
$N_2O_{direct\text{-}N,i,t}$	Direct N_2O emission as a result of nitrogen application on the alternative land use within the project boundary in stratum *i* in year *t* (t CO_2e)
Buffer%	Buffer withholding percentage[13] (percent)
NER_{WRC}	Total net GHG emission reductions in the WRC project up to year *t** (t CO_2e)
NGR_{ARR}	Total net GHG removals of the ARR project activity up to year *t** (t CO_2e)
i	1, 2, 3, …*M* strata (unitless)
t	1, 2, 3, …t^* time elapsed since the start of the REDD+ project activity (years)

8.4.6 Uncertainty Analysis

Project must use module *X-UNC* to combine uncertainty information and conservative estimates and produce an overall uncertainty estimate of the total net GHG emission reductions. The estimated cumulative net anthropogenic GHG emission reductions must be adjusted at each point in time to account for uncertainty as indicated in module *X-UNC*[14]. *X-UNC* calculates an adjusted value for NER_{REDD+} for any point in time. This adjusted $Adjusted\_NER_{REDD+}$ must be the basis of calculations at each point in time in equation 13.

8.4.7 Calculation of Verified Carbon Units

To estimate the number of Verified Carbon Units (VCUs) for the monitoring period *T* = *t2-t1*, this methodology uses the following equation:

$$VCU_t = \left(Adjusted\_NER_{REDD+,t_2} - Adjusted\_NER_{REDD+,t_1}\right) - Buffer_{Total} \quad (13)$$

Where:

VCU_t	Number of Verified Carbon Units at year $t = t_2 - t_1$ (VCU)
$Adjusted\_NER_{REDD+,t2}$	Total net GHG emission reductions of the REDD+ project activity up to year t_2 adjusted to account for uncertainty (t CO_2e)
$Adjusted\_NER_{REDD+,t1}$	Total net GHG emission reductions of the REDD+ project activity up to year t_1 adjusted to account for uncertainty (t CO_2e)

[12] The project emissions must be divided between the emissions arising from the respective project areas for planned and unplanned deforestation and degradation through fuelwood extraction/charcoal production.

[13] Buffer withholding percentages are based on the project's overall risk classification, the percentage of carbon credits generated by the approved project activity that must be deposited into the AFOLU pooled buffer account to cover non-permanence related project risks. Buffer withholding percentage must be calculated using T-BAR. Different percentages will likely be calculated for each of the baseline types as relevant.

[14] The allowable uncertainty under this methodology is +/- 15% of NER_{REDD+} at the 95% confidence level. Where this precision level is met then no deduction should result for uncertainty. Where uncertainty exceeds 15% of NER_{REDD+} at the 95% confidence level then the deduction must be equal to the amount that the uncertainty exceeds the allowable level.

$Buffer_{Total}$	Total permanence risk buffer withholding ($t\ CO_2e$)

The adjusted value for NER_{REDD+} to account for uncertainty must be calculated as:

$$Adjusted\_NER_{REDD+} = NGR_{ARR} + (NER_{REDD} + NER_{WRC}) \times (100\% - NER_{(REDD+ERROR)} + 15\%) + 15\%) + 15\%)$$

Where:

$Adjusted\_NER_{REDD+}$	Total net GHG emission reductions of the REDD+ project activities up to year *t** adjusted to account for uncertainty ($t\ CO_2e$)
NER_{REDD}	Total net GHG emission reductions of the REDD project activity up to year *t** ($t\ CO_2e$)
NER_{WRC}	Total net GHG emission reductions of the WRC project activity up to year *t** ($t\ CO_2e$)
NER_{REDD+_ERROR}	Cumulative uncertainty for the REDD+ (REDD and WRC) project activities up to year *t** (percent)
NGR_{ARR}	Total net GHG removals of the ARR project activity up to year *t** ($t\ CO_2e$)

For details see module *X-UNC*.

9 MONITORING

9.1 Data and Parameters Available at Validation

Data / Parameter	$\Delta C_{BSL,degrad-FW/C}$
Data unit	$t\ CO_2e$
Description	Net greenhouse gas emissions in the baseline from degradation caused by fuelwood collection and charcoal making
Equations	3
Source of data	Module *BL-DFW*
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See module *BL-DFW*
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	$\Delta C_{BSL,planned}$
Data unit	$t\ CO_2e$

Description	Net greenhouse gas emissions in the baseline from planned deforestation
Equations	3
Source of data	Module *BL-PL*
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See module *BL-PL*
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	$\Delta C_{BSL,unplanned}$
Data unit	t CO_2e
Description	Net greenhouse gas emissions in the baseline from unplanned deforestation
Equations	3
Source of data	Module *BL-UP*
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See module *BL-UP*
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	$\Delta C_{BSL-ARR}$
Data unit	t CO_2e
Description	Net GHG removals in the ARR baseline scenario up to year *t**
Equations	5
Source of data	Module *BL-ARR*
Value applied	N/A
Justification of choice of data or description of measurement methods	See module *BL-ARR*

and procedures applied	
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	$GHG_{BSL-WRC}$
Data unit	t CO_2e
Description	Net GHG emissions in the WRC baseline scenario up to year *t**
Equations	6
Source of data	Module *BL-PEAT*
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See module *BL-PEAT*
Purpose of Data	Calculation of baseline emissions
Comments	N/A

9.2 Data and Parameters Monitored

Data / Parameter:	$\Delta C_{WPS-REDD}$
Data unit:	t CO_2e
Description:	Net GHG emissions in the REDD project scenario up to year *t**
Equations	2
Source of data:	Module *M-REDD*
Description of measurement methods and procedures to be applied:	See module *M-REDD*
Frequency of monitoring/recording:	See module *M-REDD*
QA/QC procedures to be applied:	See module *M-REDD*
Purpose of data:	Calculation of project emissions
Calculation method:	See module *M-REDD*
Comments:	

Data / Parameter	$\Delta C_{LK\text{-}AS,degrad\text{-}FW/C}$
Data unit	t CO_2e
Description	Net greenhouse gas emissions due to activity-shifting leakage for degradation caused by extraction of wood for fuel
Equations	4
Source of data	Module *LK-DFW*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	See module *LK-DFW*
Purpose of Data	Calculation of leakage
Comments	

Data / Parameter	$\Delta C_{LK\text{-}AS,planned}$
Data unit	t CO_2e
Description	Net greenhouse gas emissions due to activity shifting leakage for projects preventing planned deforestation
Equations	4
Source of data	Module *LK-ASP*
Value applied	n/a
Justification of choice of data or description of measurement methods and procedures applied	See module *LK-ASP*
Purpose of Data	Calculation of leakage
Comments	

Data / Parameter	$\Delta C_{LK\text{-}AS,unplanned}$
Data unit	t CO_2e
Description	Net greenhouse gas emissions due to activity shifting for projects preventing unplanned deforestation
Equations	4
Source of data	Module *LK-ASU*
Value applied	n/a

Justification of choice of data or description of measurement methods and procedures applied	See module *LK-ASU*
Purpose of Data	Calculation of leakage
Comments	

Data / Parameter	$\Delta C_{LK\text{-}ME}$
Data unit	t CO_2e
Description	Net greenhouse gas emissions due to market-effects leakage
Equations	4
Source of data	Module *LK-ME*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	See module *LK-ME*
Purpose of Data	Calculation of leakage
Comments	

Data / Parameter:	$\Delta C_{WPS\text{-}ARR}$
Data unit:	t CO_2e
Description:	Net GHG emissions in the ARR project scenario up to year *t**
Equations	5
Source of data:	Module *M-ARR*
Description of measurement methods and procedures to be applied:	See module *M-ARR*
Frequency of monitoring/recording:	See module *M-ARR*
QA/QC procedures to be applied:	See module *M-ARR*
Purpose of data:	Calculation of project emissions
Calculation method:	See module *M-ARR*

Comments:	

Data / Parameter:	$\Delta C_{LK\text{-}ARR}$
Data unit:	t CO_2e
Description:	Net GHG emissions due to leakage from the ARR project activity up to year *t**
Equations	5
Source of data:	Module *LK-ARR*
Description of measurement methods and procedures to be applied:	See module *LK-ARR*
Frequency of monitoring/recording:	See module *LK-ARR*
QA/QC procedures to be applied:	See module *LK-ARR*
Purpose of data:	Calculation of leakage
Calculation method:	See module *LK-ARR*
Comments:	

Data / Parameter:	$GHG_{WPS\text{-}WRC}$
Data unit:	t CO_2e
Description:	Net GHG emissions in the WRC project scenario up to year *t**
Equations	6
Source of data:	Module *M-PEAT*
Description of measurement methods and procedures to be applied:	See Module *M-PEAT*
Frequency of monitoring/recording:	See module *M-PEAT*
QA/QC procedures to be applied:	See module *M-PEAT*
Purpose of data:	Calculation of project emissions
Calculation method:	See Module *M-PEAT*
Comments:	See Module *M-PEAT*

Data / Parameter	$GHG_{LK\text{-}ECO}$
Data unit	t CO_2e
Description	Net GHG emissions due to ecological leakage from the WRC project activity up to year *t*
Equations	6
Source of data	Module *LK-ECO*
Value applied	n/a
Justification of choice of data or description of measurement methods and procedures applied	See module *LK-ECO*
Purpose of Data	Calculation of leakage
Comments	

Data / Parameter	$E_{FC,i\ t}$
Data unit	t CO_2e
Description	Emission from fossil fuel combustion in stratum *i* in year *t*
Equations	8, 9, 10
Source of data	Module *E-FFC*
Value applied	n/a
Justification of choice of data or description of measurement methods and procedures applied	See module *E-FFC*
Purpose of Data	Calculation of project emissions
Comments	

Data / Parameter	$N_2O_{direct\text{-}N,i,t}$
Data unit	t CO_2e
Description	Direct N_2O emission as a result of nitrogen application on the alternative land use within the project boundary in stratum *i* in year *t*
Equations	8, 9, 10

Source of data	Module *E-NA*
Value applied	n/a
Justification of choice of data or description of measurement methods and procedures applied	See module *E-NA*
Purpose of Data	Calculation of project emissions
Comments	

9.3 Description of the Monitoring Plan

9.3.1 Development of Monitoring Plan

General

The monitoring plan must address the following monitoring tasks, which must be included in the monitoring plan:

- Monitoring of project implementation
- Monitoring of actual carbon stock changes and greenhouse gas emissions
- Monitoring of leakage carbon stock changes and greenhouse gas emissions
- Estimation of *ex-post* net carbon stock changes and greenhouse gas emissions.

For each of these tasks, the monitoring plan must include the following information:

a. Technical description of the monitoring task.
b. Data to be collected. The list of data and parameters to be collected must be given in PD.
c. Overview of data collection procedures.
d. Quality control and quality assurance procedure.
e. Data archiving.
f. Organisation and responsibilities of the parties involved in all the above.

Uncertainty and Quality Management

Quality management procedures are required for the management of data and information, including the assessment of uncertainty, relevant to the project and baseline scenarios. As far as practical, uncertainties related to the quantification of GHG emission reductions and removals by sinks should be reduced.

To help reduce uncertainties in the accounting of emissions and removals, this methodology uses whenever possible the proven methods from the latest available IPCC guidance documents (GPG-LULUCF and Reporting Guidelines) and peer-reviewed literature. Despite this, potential uncertainties still arise from the choice of parameters to be used. Uncertainties arising from input parameters would result in uncertainties in the estimation of both baseline net GHG emissions and project net GHG emissions – especially when global default factors are used. The project must identify key parameters that would significantly influence the accuracy of estimates. Local values that are specific to the project circumstances must then be obtained for these key parameters, whenever possible. These values should be based on:

- Data from well-referenced peer-reviewed literature or other well-established published sources[15]; or,

- National inventory data or default factors from IPCC literature that has, whenever possible and necessary, been checked for consistency against available local data specific to the project circumstances; or

- In the absence of the above sources of information, expert opinion may be used to assist with data selection. Experts will often provide a range of data, as well as a most probable value for the data. The rationale for selecting a particular data value must be briefly noted.

For any data provided by experts, documentation must also record the expert's name, affiliation, and principal qualification as an expert as well as a 1-page summary CV for each expert consulted, included in an annex.

In choosing key parameters, or making important assumptions based on information that is not specific to the project circumstances, such as in use of default factors, project must select values that will lead to an accurate estimation of net GHG emission reductions, taking into account uncertainties.

If uncertainty is significant, project must choose data such that it indisputably tends to under-estimate, rather than over-estimate, net GHG project benefits.

To ensure that GHG fluxes are estimated in a way that is accurate, verifiable, transparent, and consistent across measurement periods, the project must establish and document clear standard operating procedures and procedures for ensuring data quality. At a minimum, these procedures must include:

- Comprehensive documentation of all field measurements carried out in the project area. This document must be detailed enough to allow replication of sampling in the event of staff turnover between monitoring periods.
- Training procedures for all persons involved in field measurement or data analysis. The scope and date of all training must be documented.
- A protocol for assessing the accuracy of plot measurements using a check cruise and a

[15] Typically, citations for sources of data used should include: the report or paper title, publisher, page numbers, publication date etc. (or a detailed web address). If web-based reports are cited, hardcopies should be included as annexes in the PD if there is any likelihood such reports may not be permanently available.

plan for correcting the inventory if errors are discovered.

- Protocols for assessing data for outliers, transcription errors, and consistency across measurement periods.
- Data sheets must be safely archived for the life of the project. Data stored in electronic formats must be backed up.

Monitoring of Project Implementation

Information must be provided, and recorded, to establish that:

1) The geographic position of the project boundary is recorded for all areas of land. The geographic coordinates of the project boundary (and any stratification or buffer zones inside the boundary) are established, recorded and archived. This can be achieved by field survey (eg, using GPS), or by using georeferenced spatial data (eg, maps, GIS datasets, orthorectified aerial photography or georeferenced remote sensing images).

   The above also applies to the recording of strata, including strata resulting from peatland fires in the project scenario.

2) Commonly accepted principles of land use inventory and management are implemented.

   - Standard operating procedures (SOPs) and quality control/quality assurance (QA/QC) procedures for inventories including field data collection and data management must be applied. Use or adaptation of SOPs already applied in national land use monitoring, or available from published handbooks, or from the latest IPCC guidance documents (GPG–LULUCF, Reporting Guidelines, is recommended;
   - Apply SOPs, especially, for actions likely to cause peat disturbances;
   - The project plan, together with a record of the plan as actually implemented during the project must be available for validation or verification, as appropriate.

REDD

For monitoring changes in forest cover and carbon stock changes, the monitoring plan must use the methods given in module *M-REDD*. All relevant parameters from the modules are to be included in the monitoring plan.

ARR

For monitoring carbon stock changes, the monitoring plan must use the methods given in module M-ARR. All relevant parameters from the modules are to be included in the monitoring plan.

WRC

For monitoring GHG emissions from peatland, the monitoring plan must use the methods given in module *M-PEAT*. All relevant parameters from the modules are to be included as the soil carbon pool in the monitoring plan.

9.3.2 MONITORING

Ex-post monitoring must have two key aspects:

TASK 1. Monitoring according to monitoring plan

TASK 2. Revising the baseline for future project crediting periods

TASK 1: Monitoring According to the Monitoring Plan

Monitoring of Key Baseline Variables

<u>REDD</u>

Information required to periodically reassess the project baseline must be collected during the entire project crediting period. Key variables to be measured are:

- Changes in forest cover in the Reference Regions for Deforestation (RRD) (at a minimum of every 10 years) as specified in module *M-REDD* and where relevant in module *BL-UP*.
- Spatial variable datasets used to model the location of deforestation, as specified in module BL-UP. As a minimum, the variables used in the first baseline assessment must be monitored at the time of the re-assessment to determine if they have changed.
- Where required, carbon stock data as specified in module *M-REDD*.

<u>WRC</u>

In projects with a WRC component, the information required to periodically reassess the project baseline must include changes in the drainage layout and climate variables, as specified in module M-PEAT and, where relevant, module *BL-PEAT*.

Monitoring of Actual Carbon Stock Changes and GHG Emissions

<u>REDD</u>

Changes in forest cover in the project area (and leakage belt for unplanned deforestation), must be measured before each verification as part of the monitoring. Methods must be consistent with the methodology given in module *M-REDD* and any technical guidance specified in the monitoring plan.

Carbon stocks in most cases will not have to be monitored during the baseline period, except in the following cases:

- Where there is an increased accuracy and precision of the *ex-ante* carbon stock estimates, which are also used for *ex-post* calculations. Verifiable evidence must be provided to VCS verifiers that the accuracy and precision of the carbon stock estimates has improved compared to previous estimates. Any change in carbon stock densities will be subject to validation.

- Where emissions reductions/removals are claimed for avoiding forest degradation caused by extraction of wood for fuel or charcoal or carbon sequestration in forest land that would have been deforested in the baseline case. In such cases, the methods described in module *M-REDD*.

Carbon stocks must be reassessed at every baseline revision.

Where emissions are included in the baseline, they must be monitored in the project case, following the methodological procedures described in the emission modules (*E-BPB*, *E-FFC*, and *E-NA*).

The calculations of actual carbon stock changes and greenhouse gas emissions must be reported using transparent procedures.

<u>ARR</u>

Changes in woody biomass carbon stocks in the project area must be measured before each verification as part of the monitoring. Methods must be consistent with the methodology given in module *M-ARR* and any technical guidance specified in the monitoring plan.

<u>WRC</u>

Changes in water depths in the project area (and leakage belt for unplanned deforestation), must be measured before each verification as part of the monitoring. Methods must be consistent with the methodology given in module *M-PEAT* and any technical guidance specified in the monitoring plan.

Monitoring of Leakage

All significant sources of leakage identified are subject to monitoring, following the procedures outlined in the monitoring plan. Such procedures must be consistent with the applicable leakage modules (*LK-ASP*, *LK-ASU*, *LK-ME*, *LK-DFW*, *LK-ARR* and *LK-ECO*). All relevant parameters in the leakage modules must be included in the monitoring plan.

The calculations of leakage carbon stock changes and greenhouse gas emissions must be reported.

TASK 2: Revising the Baseline for Future Project Crediting Periods

Baselines must be revised over time because agents, drivers and underlying causes of deforestation as well as drainage layouts and climate variables change dynamically. The methodological procedure used to update the baseline must be the same as used in the first estimation.

10 REFERENCES

IPCC. 2003. Good Practice Guidance for Land Use, Land Use Change and Forestry. Institute for Global Environmental Strategies (IGES)[16]

IPCC. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Institute for Global Environmental Strategies (IGES) [17]

Additional information can be found in the modules referenced throughout this methodology.

[16] http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html
[17] http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

DOCUMENT HISTORY

Version	Date	Comment
v1.0	3 Dec 2010	Initial version
v1.1	7 Sept 2011	The REDD Methodology Framework was updated to limit the reassessment of the unplanned baseline scenario to every ten years. The methodology was also incremented to reflect a revision to the module for estimation of baseline carbon stock changes and greenhouse gas emission from unplanned deforestation (BL-UP), v2.0, which was approved under the VCS Program on 7 September 2011.
v1.2	31 July 2012	Table 2 was removed to avoid confusion with Table 1. Table 1 is now the exclusive source in the methodology for determining included/excluded pools.
v1.3	20 Nov 2012	The REDD Methodology Framework was updated to include avoided planned degradation as an allowable activity: • Removed the applicability condition "where post-deforestation land use constitutes reforestation this module must not be used" • Renamed "planned deforestation" to "planned deforestation and planned degradation" • Added the text "hereafter in this module, "deforestation" refers to both deforestation and planned degradation" A correction made to equation 8 to appropriately calculate the total VCUs available for issuance.
v1.4	3 May 2013	Applicability condition for unplanned deforestation "where post-deforestation land use constitutes reforestation this module must not be used" was removed. Equations 4, 5 and 6 were revised to appropriately account for the buffer.
v1.5	9 March 2015	Updated to include REDD+ project activities on peatlands as well as activities that include ARR. Methodology now includes six new modules: *VMD0041 BL-ARR*, *VMD0042 BL-PEAT*, *VMD0043 LK-ARR*, *VMD0044 LK-ECO*, *VMD0045 M-ARR*, and *VMD0046 M-PEAT*.

A Global Benchmark for Carbon

Approved VCS Methodology VM0008

Version 1.1

Sectoral Scope 3

Weatherization of Single Family and Multi-Family Buildings

Scope

This methodology provides a procedure to determine net CO_2 emission reductions associated with grouped projects that focus on energy efficiency activities for existing residential dwellings within a set geographic area and building stock.

Methodology Developer

The methodology was developed by the Maine State Housing Authority (MaineHousing) in collaboration with Lucille Van Hook, Lee International, and Climate Focus.

Authors

- Dale McCormick and Stephen Erario, MaineHousing
- Lucille Van Hook, Independent Carbon Consultant
- Cathy Lee, Lee International
- Sandra Greiner and Bamshad Houshyani, Climate Focus

Table of Contents

1 SOURCES

The methodology complies with the principles of:

- ISO 14064: Part 2, "Specification with guidance at the project level for the quantification, monitoring and reporting of greenhouse gas emission reductions and removal enhancements: 2006

The methodology also draws on ideas from the latest version of the following approved CDM tools and standards:

- CDM *Tool for the Demonstration and Assessment of Additionality*
- CDM *Tool to calculate the emission factor for an electricity system*

The methodology also references or draws on ideas, data, and definitions from the following sources:

- ASHRAE building standard 90.1-2004
- IAF Guidance on the Application of ISO/IEC Guide 66 Issue 4 IAF GD:2006
- Marrakesh Accords, Article 48 (c), 2001
- National Manufactured Housing Construction and Safety Standards Act of 1974 section 603
- Nationally recognized weatherization best practice standards, e.g., training curricula, core competencies, and example best practice standards for Weatherization activities offered by Department of Energy Weatherization Assistance Program and the Building Performance Institute
- US Environmental Protection Agency Refrigerants Global Warming Potentials
- US Department of Energy Buildings Energy Data Book

The methodology provides an overview of performance in the sector based on the following sources:

- American Council for an Energy Efficient Economy, *What Have We Learned from Energy Efficiency Financing Programs?*, 2011
- Gigaton Throwdown, *Redefining What's Possible for Clean Energy by 2020,* 2009
- International Energy Agency, *Worldwide trends in Energy Use and Energy Efficiency*, 2008
- McKinsey & Company, *Unlocking Energy Efficiency Potential in the U.S.*, 2009
- US Department of Energy, *Building Energy Data Book*, 2010

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology covers Weatherization of Dwellings, that is, energy efficiency measures directed at reducing the consumption of energy within a Dwelling. Examples include, but are not limited to, adding/improving insulation, air sealing, and replacing Appliances and central heating/cooling components.

Table 1: Additionality and Crediting Baseline Methods

Additionality	Performance Method: Categories A, B, and C Project Method: Category D
Crediting Baseline	Project Method: Categories A, B, C, and D

3 DEFINITIONS

Appliance means a major or minor household Appliance, which includes, but is not necessarily limited to, a refrigerator, microwave, dishwasher, clothes washer or dryer, space heater, and water heater. It does not include heating/cooling systems. An Appliance runs on electricity or another fuel source and is a discreet unit. It must be contained within the Building Envelope to be included in the Project activity.

Building Envelope means the exterior thermal boundary of the physical structure of an individual building. Thermal boundary typically includes the ceiling/roof, wall, floor, attic floor, window, or door that separates the habitable, occupiable, and conditioned spaces from the outdoor weather.

Cooling Degree Days (CDD) measure the cumulative degree difference between the warmer outside temperature and the base temperature of the conditioned space on a daily basis during the cooling season. CDD are determined by summing the daily degree days, which are calculated as the average daily temperature minus the base temperature. The average daily temperature is calculated by summing the daily high temperature and the daily low temperature and dividing by two. The average daily temperature can also be calculated by averaging the daily temperature over shorter time intervals, rather than just the high and low temperature. CDD reported by weather stations are often reported in sixty or thirty minute time intervals. In the US, the cooling base temperature is 78° F.

Dwelling means a single family house, including a mobile home[1], or an apartment within a multi-family building. The following are eligible under the methodology as long as the eligibility requirements in 1.3 are met: single family residential homes, including mobile homes; and multi-family residential homes.[2]

Energy Load means the sum of the heat load, cooling load and the electricity demand per Dwelling. Heat load means the total fuel consumed, including electricity (in BTUs, GJ or kWh) to provide comfort in a conditioned space in a given year. Cooling load means the total electricity, or other fuel type in the case of central cooling systems, consumed (in BTUs, GJ or kWh) necessary to remove heat from the conditioned space to provide comfort in a given year.

Heating Degree Days (HDD) measure the cumulative degree difference between the colder outside temperature and the base temperature of the conditioned space on a daily basis during the heating season. HDD are determined by summing the daily degree days, which are calculated as the base temperature minus the average daily temperature.[3] The average daily temperature is calculated by summing the daily high temperature and the daily low temperature and dividing by two. The average daily temperature can also be calculated by averaging the daily temperature over shorter time intervals, rather than just the high and low temperature. HDD reported by weather stations are often reported in sixty or thirty minute time intervals. In the US, the base temperature is 65° F. In the UK, the base temperature is 15° C.

R-value means a measurement of thermal resistance as expressed by a recognized authority, such as the U.S. Department of Energy, or the American Society of Heating, Refrigerating and Air-

[1] In the United States, mobile homes built later than 1976 are referred to as “manufactured homes” as defined in section 603 of the National Manufactured Housing Construction and Safety Standards Act of 1974. In this methodology, the term “mobile home” also refers to and includes a “manufactured home” when the replacement home is a manufactured home that can be transported and is permanently affixed to a steel chassis.

[2] In the United States, multi-family buildings that are over three stories above grade are considered commercial under the ASHRAE building standard 90.1-2004. These are also covered by the methodology.

[3] For example, a winter day (24 hours) has a low daily temperature of 20°F and a high daily temperature of 35°F. The total HDD for that day are calculated as: 65°F (base temperature) – ((35°F+20°F)/2). The HDD for that day are 37.5. If, the next day is slightly warmer and the daily low is 30°F and the daily high is 38°F, then the HDD for that day are 31. The cumulative HDD for the two days are 68.5. HDD for the heating season are cumulative.

conditioning Engineers (ASHRAE). The R-value of insulation in the floor, walls, ceiling, skirting or any other element will depend on the thickness and specific material of the installed insulation.

Same Building Stock means Dwellings 1) in the same state, province, or region, 2) in the same category (single family or multi-family), and 3) inhabited by the same income group (low-income, middle-income or high-income) as defined by a recognized authority.[4]

U-value means the thermal conductance of a material or, in other words, the total heat transmission in GJ per square meter per hour with a 1°C temperature difference between the inside and the outside. The U-value of the window is the inverse of the R-value or 1/R. The U-value for the make and model of a window can often be found on a window manufacturer's specification sheet included with the window.

Weatherization means energy efficiency measures in Dwellings. Weatherizing shall refer to the act of installing energy efficiency measures in Dwellings.

4 APPLICABILITY CONDITIONS

4.1 Any Dwelling or measures included in a Project shall meet the following conditions:

The condition of the Dwelling shall be and remain adequate for Project activities according to nationally recognized Weatherization best practice standards.[5] Project activities may not result in a violation of health and safety, environmental, or other relevant regulations.

The replacement Appliances and mobile homes must replace functioning Appliances, and/or occupied homes.

The Dwelling must be occupied. Vacancy is permitted on an intermittent basis for up to three months, or if the Dwelling is occupied seasonally on an annual basis.

The capacity of any replacement Appliance or replacement component of a central heating/cooling system shall satisfy the post-retrofit heat load, cooling load and electricity demand ("Energy Load") within the Dwelling.

In the case of heating/cooling systems that serve multiple Dwellings, all residential Dwellings connected to the system shall be included in the Project.

The Project activity must not be mandated, or required by local, state or federal law or regulation.

The Dwelling must meet or exceed the performance benchmark as calculated for the Same Building Stock. As evidenced by data, dwellings exceeding this performance benchmark would, with 90% certainty, not have happened without the intervention created by the Project.

[4] In the US, The Department of Health and Human Services issues guidelines that define the term "low-income" as a multiple of the income level defined as poverty level on an annual basis. For example, the 2009 poverty level was $10,400 for a single person, and $21,200 for a family of four. Households are considered low income if their household income is no more than 200% of poverty level.

[5] For example, in the United States, the Department of Energy Weatherization Assistance Program and the Building Performance Institute provide training curricula, core competencies, and example best practice standards for Weatherization activities, which are available at: http://www.waptac.org/sp.asp?mc=training_resources and http://www.bpi.org/standards.aspx.

4.2 The methodology is applicable to Weatherizing whole buildings, replacing mobile homes or implementing individual energy efficiency measures within existing Dwellings. Applicable interventions fall into one of the following categories:

Category A--All energy retrofit: A combination of energy efficiency measures directed at the Building Envelope (i.e. air infiltration, insulation), improving the efficiency of the central heating and/or cooling system and reducing energy consumption of Appliances (i.e. replacement of refrigerators, air conditioning units, lamps, showerheads).

Category B--Efficiency enhancement of the Building Envelope and central heating and/or cooling system only.

Category C--Replacement of Appliances currently in service.

Category D--Replacement of a mobile home currently occupied.

4.3 The methodology does not cover fuel switching.

4.4 In the case of "replacement" of a mobile home, the word "retrofit" shall be read to mean replacement throughout the methodology.

4.5 The methodology may be applied in any geographic region, provided appropriate data exist to establish the level of the performance benchmark for the Same Building Stock of a Project's geographic region.

4.6 When sampling, the minimum number of Dwellings or Appliances to be sampled shall be the square root of the total number of Dwellings i, or Appliances included in the Project. Statistically sound sampling approaches shall be used. When the control group approach (Approach 3 in Part C. Emission Reductions and Monitoring Parameters) is utilized, the size of the control group shall be the square root of the total number of Dwellings in the Project, but need not exceed 100 Dwellings. In any sampling approach, the following conditions must be met:

1) The sample shall be statistically valid, and may be one of the following:
    a. Simple random sample
    b. Systematic sampling
    c. Stratified sampling within the Same Building Stock
    d. Cluster sampling.
2) The sample must be representative of the population.
3) The data must come from an approved source, i.e. a certified energy auditor, or a nationally recognized data source.
4) Actions that may bias the sample shall be avoided. Sampling shall include Dwellings that are dispersed geographically. For each defined Building Stock included in the Project activity, sampling shall occur. Criteria include region, Dwelling type, and income.

5 PROJECT BOUNDARY

The Project boundary is the Building Envelope of the Dwelling(s) and its heating/cooling equipment.

Table 2: Greenhouse Gas Sources Included and Exclude in the Baseline and Project

The following greenhouse gas sources are included and excluded in the baseline and the Project:

Source		Gas	Included?	Justification/Explanation
Baseline	Grid electricity consumption by cooling systems or other electric Appliances	CO_2	Included	Only CO_2 emissions from grid connected electricity generation shall be accounted for.
		CH_4	Excluded	
		N_2O	Excluded	
		Other	Excluded	
	Fossil fuel consumption by heating systems	CO_2	Included	Only CO_2 emissions from fossil fuel combustion shall be accounted for.
		CH_4	Excluded	
		N_2O	Excluded	
		Other	Excluded	
	Emissions from wood combustion for heat	CO_2	Excluded	Excluded for simplification and to be conservative.
		CH_4		
		N_2O		
		Other		
Project	Grid electricity consumption by cooling systems or other electric Appliances heat	CO_2	Included	Only CO_2 emissions from grid connected electricity generation shall be accounted for.
		CH_4	Excluded	
		N_2O	Excluded	
		Other	Excluded	
	Fossil fuel consumption by heating systems Emissions from wood combustion for	CO_2	Included	Only CO_2 emissions from fossil fuel combustion shall be accounted for.
		CH_4	Excluded	
		N_2O	Excluded	
		Other	Excluded	
	Grid electricity consumption by cooling systems or other electric Appliances	CO_2	Excluded	Excluded for simplification and to be conservative.
		CH_4		
		N_2O		
		Other		
Leakage	Emissions from improper disposal of Appliances (e.g. refrigerators)	CO_2	Included	When the Appliance is not disposed of according to applicable laws and regulations there will be leakage from continued operation. The leakage emissions shall be calculated and excluded from emission reductions as described in the methodology.
		HFC	Included	
		CH_4	Excluded	
		N_2O	Excluded	
		Other	Excluded	

Leakage

Appliances, heating/cooling equipment and/or mobile homes that are replaced shall be properly disposed of and their disposal shall be documented. The disposal documentation shall confirm that: 1) the Appliances have been disposed of in a manner that prevents operation of the Appliance, and 2) the disposal procedure complies with applicable law and regulations. If not documented, CO_2 emissions from continued operation of replaced Appliances, heating/cooling equipment and/or mobile homes and HFC emissions from refrigerators or air conditioners shall be accounted for as leakage.

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

The baseline scenario represents the conditions most likely to occur in the absence of the Project.

Category A--All energy retrofit: the baseline scenario consists of fossil fuel and electricity consumed to satisfy the heat and cooling load and the Appliance plug load prior to Project implementation.

Category B--Efficiency enhancement of the Building Envelope and/or central heating/cooling system: the baseline scenario consists of fossil fuel consumed to satisfy the heat and cooling load prior to Project implementation. Electricity shall only be included when it is a heating or cooling source within the Dwelling. Appliances and their corresponding electricity consumption shall not be included.

Category C--Replacement of Appliances: the baseline scenario consists of electricity consumed by the Appliances to be replaced prior to Project implementation.

Category D--Replacement of a mobile home: the baseline scenario consists of fossil fuel and electricity consumed to satisfy the heat and cooling load and the Appliance plug load of the mobile home to be replaced prior to Project implementation.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

7.1 A Project shall demonstrate additionality for project activities in category A, B, or C using the Performance Method that incorporates the performance benchmark set forth in section 1.3 below. A Project shall demonstrate additionality for project activities in category D using the Project Method.

7.2 The Project Method:

For demonstration of additionality for project activities under category D, the latest version of the CDM “Tool for the Demonstration and Assessment of Additionality” shall be applied, noting the following:

1) The project proponent may choose to complete an investment analysis or a barrier analysis or both.

2) Where the barrier analysis is used, sub-steps 3a and 3b of the above-referenced Tool shall be applied. The Project may rely on any of the barriers listed in the Tool as well as the barriers described below. When a barrier analysis is used, the following guidance applies:

   - Investment barrier: The Project may demonstrate it faces an investment barrier that the VCU revenue stream may help overcome. Such a barrier may be present when activities similar to those proposed in the Project: face a lack of available private capital due to real or perceived risks with the program or process or can only be implemented with the aid of grants, tax incentives, subsidies or non-commercial finance terms. A lack of private capital is defined as a lack of investors or a lack of access to financing at the local, state, provincial or regional level for activities similar to those proposed in the Project.

- Technological barrier: The Project may demonstrate it faces a technological barrier that the VCU revenue stream may help overcome. Such a barrier may result from a less technologically advanced alternative to the technology proposed for the Project activity including an alternative that would lead to higher emissions. The barrier could be due to the performance uncertainty or low market share of the new technology adopted for the Project activity and/or the less technologically advanced alternative would have led to higher emissions: examples a Project may use to demonstrate a technological barrier include, but are not limited to, non-availability of human capacity to operate and maintain the new technology, lack of infrastructure to utilize the new technology, unavailability of the new technology or a high level of technology risk.

- Institutional barrier: The Project may demonstrate it faces financial, organizational, cultural or social barriers that the VCU revenue stream can help overcome. Such a barrier may be based on prevailing practices, institutional resistance to change, lack of adequate funds to offer effective incentives to engage in the Project activity or other factors that impede more effective Project implementation, monitoring or maintenance. Examples a Project may use to demonstrate an institutional barrier include, but are not limited to, absence of an existing trained and qualified workforce, absence of a strong central organization to manage the Project and/or perform the Project activities, absence of suitable tools for monitoring carbon emissions, absence of incentives that can be shown to help to stimulate the Project activity.

7.3. The Performance Method provides as follows:

Category A--All energy retrofit: The percent savings in the pre- and post-retrofit Energy Load of each Dwelling in the Project shall be equal to or greater than the performance benchmark. The performance benchmark is a value above average performance that represents a percent savings in energy consumption that Dwellings are not likely to reach with 90% certainty in the absence of the Project. The average performance is the annual average percent savings in weather normalized energy consumption in Dwellings from the Same Building Stock over the three most recent years for which data are available[6]. Dwellings weatherized as part of the Project may be excluded.

Category B--Efficiency enhancement of the Building Envelope and/or central heating/cooling system: The percent savings in the pre- and post-retrofit Energy Load of each Dwelling in the Project shall be equal to or greater than the performance benchmark. The performance benchmark is the same as defined in Category A. Although Category B comprises measures to the Building Envelope only, the same performance benchmark can be used if the percent savings is calculated for the entire energy consumption of the Dwelling and not just for the consumption of heating and cooling energy. This way, savings achieved under the Project are comparable to overall trends. By broadening the base, savings from the Project are diluted. They would be higher if calculated for the savings in heat and cooling energy alone.

[6] Energy Load shall be used to determine whether the dwelling is additional because the Energy load is established during the energy audit. Energy consumption is used to calculate the mean percent savings within the Same Building Stock because that is the data available. Energy Load and energy consumption may be used in conjunction because energy consumption may be projected based on Energy Load.

The performance benchmark for Category A and Category B, *x*, shall be calculated as follows[7]:

For data following a normal distribution:

The performance benchmark is based on the standard deviation of the sample.

Equation 1

$$x = a + 1.85\sigma$$

Where:
x = Performance benchmark
a = Average performance[8]
σ = Standard deviation (sigma) of the percent savings in the Same Building Stock Energy Load

For data not following a normal distribution:

The performance benchmark is equal to the 90th percentile value within the numerically ordered sample. To calculate the 90th percentile the sample data point values ($v_1, v_{2 \ldots} v_N$) must be ordered from least to greatest. The 90th percentile value is equal to the value of the data point with the rank at which 90% of the data falls below.

Equation 2

a. $$n = (NP_{90}/100) + 0.05$$

b. *x*= the value of the data point at rank n calculated in equation 2a.

Where:
x = Performance benchmark
n = Rank of the ordered data point falling at the 90th percentile
N = Total number of data points included in the sample
P_{90} = *90th percentile*

To be additional, Dwellings must satisfy the following condition:

Equation 3

$$\frac{EL_{\Pr e,i} - EL_{post,i}}{EL_{\Pr e,i}} * 100 \geq x$$

---

[7] Under a normal bell curve distribution, the mean plus or minus 2σ encompasses 95% of the statistical sample. Therefore 97.5% of the data falls below the value *x*, if *x* is calculated as the mean plus 2σ. A 90% likelihood of the data falling below the value *x* is calculated as the mean plus 1.85 σ.

[8] To correct for any potential increase in electricity consumption due to an increase in electric appliances, the statewide percent increase in electricity consumption, as reported by the U.S. Department of Energy or other recognized authority, will be added to the value of the average performance to make the performance benchmark even more rigorous and conservative if such electricity data are reasonably available and it is feasible to do so. For example, in the US the value of the increase in regional electricity consumption may be obtained from the following website: http://apps1.eere.energy.gov/states/state_information.cfm

Where:
$EL_{pre,\,i}$= Pre-retrofit energy load of Dwelling *i*
$EL_{post,\,i}$= Post-retrofit energy load of Dwelling *i*

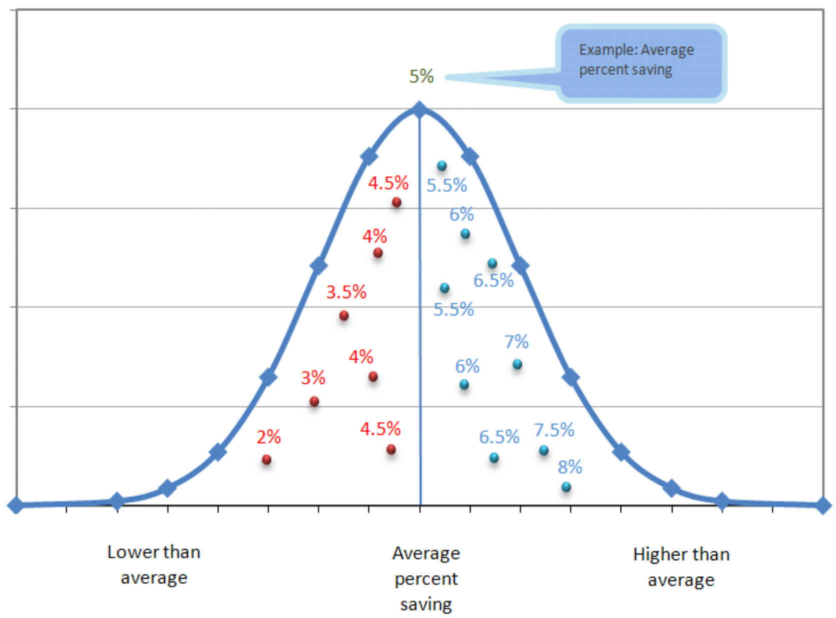

Figure 1. This graph shows the percent savings in energy consumption of buildings and Dwellings within the Same Building Stock. The percent savings is calculated from the change in weather normalized energy consumption in Dwellings from the Same Building Stock over at least the three most recent years for which data are available. The average performance, on which the performance benchmark is based, is calculated from these data. Dwellings with a high percent savings in energy consumption will fall to the right of the average performance, and Dwellings with a low percent savings in energy consumption will fall to the left of the average performance.

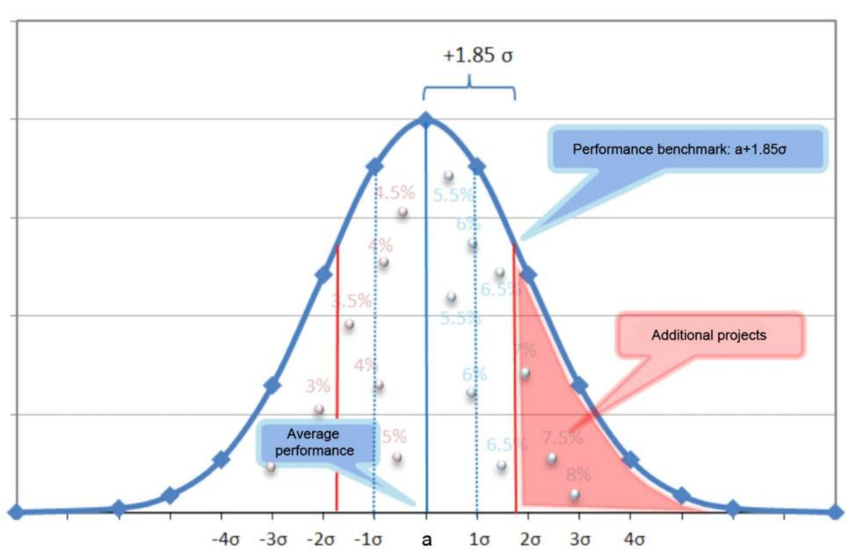

Figure 2. This graph shows how the performance benchmark (vertical red line to the right) is calculated by determining the average performance (vertical solid blue line), defined as the annual average of the percent savings in weather normalized energy consumption in the Same Building Stock over the past three years, and adding 1.85σ . The standard deviation (σ) is calculated from the actual data obtained from the Same Building Stock within the past three years. The numbers along the horizontal axis represent the number of standard deviations from the average value (average performance). For example, the data point 7% falls in line with 2σ, which means that 7% is 2 standard deviations away from the average performance, meaning that 95% of all buildings do not reach a 7% savings in energy consumption or higher .

The parameters to be monitored for calculating the average performance and standard deviation for Category A and Category B are listed in Section 9.

Category C--Replacement of Appliances: the energy consumption of the replacement Appliance shall meet or fall below the performance benchmark. The performance benchmark is a value below the average performance that represents a level of energy consumption per Appliance that Appliances are not likely to reach with 90% certainty in the absence of the Project. The average performance is the annual average energy consumption by existing Appliances of the same Appliance type, as defined by the particular make and model of the Appliance. Appliances replaced as part of the Project may be excluded. National Appliance data may be used due to the uniformity of Appliances available in the market. Data may be further differentiated (i.e. by income class) as appropriate data are available.

The performance benchmark for Category C, *x*, shall be calculated as follows:

For data following a normal distribution:

The performance benchmark is based on the standard deviation of the sample.

Equation 4

$$x = a - 1.85\sigma$$

Where:
x = Performance benchmark
a = Average performance
σ = Standard deviation (sigma) of the annual energy consumption of existing Appliances in operation.

For data not following a normal distribution:

The performance benchmark is equal to the 90th percentile value within the numerically ordered sample. To calculate the 90th percentile the sample data point values ($v_{1,}$ $v_{2...}v_N$) must be ordered from greatest to least. The 90th percentile value is equal to the value of the data point with the rank at which 90% of the data fall below.

Equation 5

a. $n = (NP_{90}/100) + 0.05$

b. x= the value of the data point at rank n calculated in equation 5a.

Where:
x = Performance benchmark
n = Rank of the ordered data point falling at the 90th percentile
N = Total number of data points included in the sample
P90 = 90th percentile

To be additional, Dwellings must satisfy the following condition:

$$a_{rc,\,k} \leq x$$

Where:
x = Performance benchmark
arc, k = Annual energy consumption per appliance of the replacement Appliance, type k

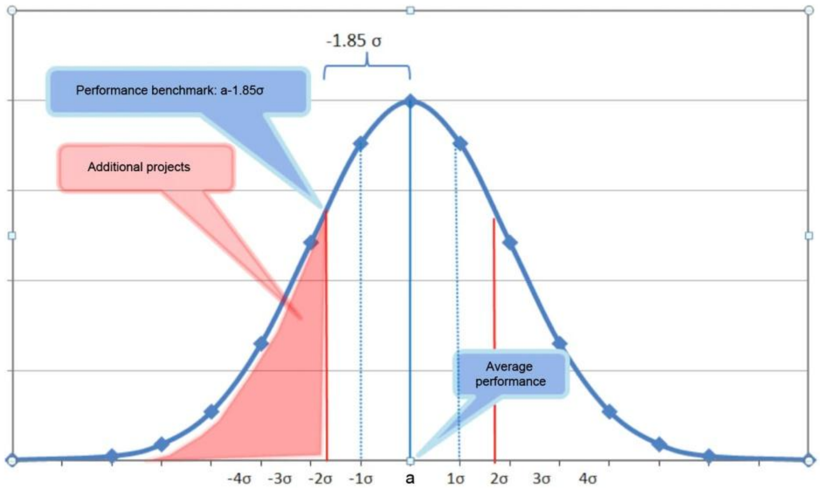

Figure 3. This graph shows how the performance benchmark (vertical red line to the left) is calculated by determining the average performance (vertical solid blue line), defined as the annual average energy consumption by existing Appliances of the same Appliance type and subtracting 1.85σ. The standard deviation (σ) is calculated from the existing Appliance data obtained from the population. The numbers along the horizontal axis represent the number of standard deviations from the average value (average performance). The shaded red section represents replacement Appliances with an annual energy consumption values that fall below the performance benchmark, and are considered additional.

The parameters to be monitored for calculating the average performance and standard deviation for Category C are listed in Section 9.

Category D--Replacement of a mobile home: No performance benchmark is defined.

Performance Benchmark Level

The level of the performance benchmark established using the performance method is based on the rigorous requirement that with 90% certainty, dwellings deemed additional under the methodology would not have reached the improvement in energy efficiency on their own. This is evidenced by performance data of dwellings from the Same Building Stock as defined in the methodology. The methodology formulates a universally applicable approach. The actual value of the performance benchmark (i.e., the 90^{th} percentile of percentage improvement in energy efficiency over the 3 most recent years) then has to be calculated for the specific project area where the methodology is applied. Hence, the same rigour applies wherever the methodology is used. Example case data from the US shows that only a tiny fraction of houses have undergone weatherization in recent years and that on average, energy use is still on the rise, making substantial energy efficiency improvements not a likely occurrence on their own.

The choice of 90% as confidence level for the performance method aligns with or exceeds similar requirements set forth in guidance pertaining to the CDM:

- The Marrakech Accords of the UNFCCC foresee three optional approaches to additionality of CDM projects of which one consists in the formulation of a benchmark. Article 48 (c) defines the benchmark as “The average emissions of similar project activities undertaken in the previous five years in similar social, economic, environmental and technological circumstances, and whose performance is among the top 20 per cent of their category”. The proposed top 10 percent in VM0008 is a more conservative approach.

- VM0008 provides for significant rigour in applying the performance method, far exceeding previous cases of methodologies that were not accepted. For example, a new CDM methodology, 302 “CDM methodology for cement and clinker production facilities based on benchmarking”, was proposed using the top 20 percent performing installations as a performance benchmark for additionality. This methodology has not been accepted by the CDM EB (as time of writing) on several grounds. We chose to be far more stringent in VM0008.

Distribution of Performance in the Sector

There is an abundance of data showing that energy use in existing U.S. buildings is inefficient and increasing over time, and that there are significant barriers to increased penetration of energy efficiency measures. Studies show that the trends in energy use and efficiency are largely similar across the world, although there are some programs (e.g., the United Kingdom Green Deal under the Energy Act of 2011) which target economy-wide energy efficiency program implementation on a large scale.

It is important to note that the level of the performance benchmark is dictated by the performance in a particular geographic area as defined by the Same Building Stock. Therefore, even though there may be programs in different geographic areas that promote residential energy efficiency measures, projects in those locations would still need to exceed the locally applicable performance benchmark.

By extension, in geographic locations where programs exist to promote energy efficiency measures, the performance benchmark can be expected to represent a level of savings that is more stringent than in locations where no such programs exist. The performance method is designed to ensure that the level of the performance benchmark automatically becomes more stringent in geographic locations with increasing levels of residential energy efficiency activities.

The following status quo description for residential buildings in the US serves solely to provide examples of relevant data for the establishment of a Same Building Stock and its particular performance benchmark. The following example case information does not limit the applicability of the performance method to the US. Each performance benchmark must be calculated relative to each Same Building Stock and its particular geographical boundary.

Relative to the US, studies show:

- In 2005, the U.S. housing stock was found to be comprised of dwellings classified by household type as follows: single family (71.7%), multi-family (22.0%) and mobile homes (6.2%). (DOE Building Energy Data Book 2010, Table 2.2.2)
- In 2005, the following average energy intensities were found in each building stock: single family, 106.6 million Btu per household; multi-family, 64.1 million Btu per household; mobile homes, 70.4 million Btu per household. (DOE Building Energy Data Book 2010, Table 2.1.11)
- In 2008, the breakdown in energy use in U.S. residential buildings was approximately: Natural Gas, 35%; Petroleum, 6%, Coal, 35%, Renewables, 8%; and Nuclear, 14%. Projected values are not expected to vary by more than +/- 5% from 2008 to 2035. (DOE Building Energy Data Book 2010, Table 2.1.2)
- There are “significant and persistent barriers” to implementing energy efficiency measures in the U.S. including structural, behavioral, and availability barriers. (McKinsey 2009)
- Rates of U.S. residential energy efficiency program penetration range broadly from 16% to 0.5% or less (American Council for an Energy Efficiency Economy, 2011). On average, less than 5% of homes in the U.S. have undergone an energy-efficiency retrofit. (Gigaton Throwdown 2009)
- Residential sector energy use is projected to increase at 0.4% per year under a business-as-usual scenario between 2008 and 2020. (McKinsey 2009)
- A typical residence uses up to 40% more energy than it needs to operate economically. (Gigaton Throwdown 2009)
- Worldwide residential energy use increased 19% between 1990 and 2005. (International Energy Agency 2008)
- Only weatherization measures that systematically address the thermal envelope or significantly improve the efficiency of end-use appliances are likely to enable a project to exceed a performance benchmark;
  - Evaluations of physical weatherization measures in residential dwellings demonstrate savings of around 20-30%. See, for example: Oak Ridge National Laboratories, ORNL/CON-493, 2005; and Cadmus Group, Efficiency Maine Trust Home Energy Savings Program Final Evaluation Report, 2011.
  - By comparison, evaluations of behavior change programs (e.g., providing information to encourage occupants to turn off unneeded lighting and equipment) demonstrate levels of energy savings ranging from levels not statistically different than 0 to energy savings levels of up to about 3%. See, for example: Navigant, Evaluation Report: OPOWER SMUD Pilot Year 2, 2011; and Energy Center of Wisconsin, Focus on Power-PowerCost Monitor Study, 2010.

Evaluation of the Tradeoff between False Negatives and False Positives

The level of the performance benchmark was determined after careful consideration of the tradeoff between false negatives and false positives.

False negatives, in the context of the methodology, are dwellings that have been excluded by the performance method (found not to be additional) even though the efficiency upgrades to these dwellings would not have occurred in the absence of the Project. False positives are dwellings that are included in the project even though their efficiency upgrades would have happened anyway. The latter can be considered free-riders.

In elaborating the performance method, the team originally intended to develop a performance benchmark value for efficiency that dwellings would have to attain in order to be considered additional, in the form kWh / m2 or a comparable metric. This metric however was shown to create a risk of producing an unacceptable number of false negatives. During stakeholder consultations, Joel Eisenberg, Weatherization Evaluation Consultant for the U.S. Department of Energy acting as Program Manager at Oak Ridge National Laboratory, pointed out that weatherization efforts directed at low income houses typically target the most energy inefficient houses. While the impact of weatherization is large, both in terms of energy savings compared to the baseline and in social impact, these dwellings are unlikely to meet a high energy efficiency standard even after weatherization. To avoid unnecessary and inappropriate disqualification of low income dwellings, the decision was made to elaborate the performance method based on a percentage change rather than an absolute performance level.

In setting the performance benchmark, the 90th percentile was deemed a sufficiently rigorous requirement for exclusion of free-riders. If the performance benchmark were to be established using a higher level, e.g. 95% or even 99%, there would be a significant risk that the level of energy efficiency enhancement to be exceeded by dwellings in the Project would be determined by singular and random occurrences rather than a systematic trend in the population. For instance, there are households which undertake energy efficiency improvements based on personal environmental consciousness, or because residents are particularly handy and can do the work themselves, or because houses are so drafty that air sealing is necessary to improve living comfort. Special cases with high energy efficiency gains are not and should not be considered the norm. To consider these the norm would lead to the perverse result of disqualifying many weatherization projects.

In choosing a benchmark value of 90% that is more rigorous than comparable CDM guidance yet does not allow for rare occurrences to set the performance benchmark, and by focusing on percentage changes in efficiency enhancements rather than absolute levels of efficiency, VM0008 seeks to minimize and optimally balance the tradeoff between false positives and false negatives.

Geographic Scope

When using a performance benchmark for Category A, Category B, or Category C activities, project proponents shall calculate the performance benchmark for each Same Building Stock identified in the project description. While the methodology does not set out a geographic limitation on project location, this requirement restricts each performance benchmark to a specific geographic area defined in a project description (e.g., a state, province or region).

Data Selection and Use

In developing a performance benchmark, project proponents must select and use data sources that meet the following requirements of Section 4.5.6 of the VCS Standard Version 3.3) as modified for the methodology:

1) Data collected directly from primary sources shall comply with relevant and appropriate standards, where available, for data collection and analysis, and be audited at an appropriate frequency by an appropriately qualified, independent organization.
2) Data collected from secondary sources shall be available from a recognized, credible source and must be reviewed for publication by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency.

3) Where sampling is applied in data collection, the project proponent shall demonstrate that sampling results provide an unbiased and reliable estimate of the true mean value (i.e., the sampling does not systematically underestimate or overestimate the true mean value). Project proponents may choose to demonstrate the appropriateness of sampling results based on a qualitative description of data sources and methods, where appropriate.
4) Data shall be publicly available, where appropriate (not confidential). Proprietary data (e.g., data pertaining to individual facilities) may be aggregated, and therefore not made individually publicly available, as there are demonstrable confidentiality considerations. However, sufficient data shall be publicly available to provide transparency and credibility to the dataset.
5) All data shall be made available, under appropriate confidentiality agreements as necessary, to the VCSA and each of the validation/verification bodies assessing the proposed performance benchmark, to allow them to reproduce the determination of the performance benchmark. Data shall be presented in a manner that enables them to independently assess the presented data.
6) All reasonable efforts shall be undertaken to collect sufficient data and the use of expert judgment as a substitute for data shall only be permitted where it can be demonstrated that there is a paucity of data. Expert judgment may be applied in interpreting data. Where expert judgment is used, good practice methods for eliciting expert judgment shall be used (e.g., IPCC 2006 Guidelines for National GHG Inventories).
7) Where data must be maintained in a central repository on an on-going basis (e.g., in a database that holds sector data for use by project proponents in establishing specific performance benchmarks for their projects), there shall be clear and robust custody arrangements for the data and defined roles and responsibilities with respect to the central repository.

Data Maintenance

Project proponents must maintain data used to establish any performance benchmark in a manner that meets the following requirements of Section 4.5.7 of the VCS Standard version 3.3 as modified for the methodology:

The dataset may be documented and contained within the project description, or may be maintained in a separate repository that is referenced by the project description. Datasets documented and contained within the project description are static datasets, where all project activities use the level of the relevant performance benchmark that is specified in the project description. The following applies with respect to datasets maintained in a separate repository:

1) The dataset may be static or dynamic (ie, may or may not be periodically updated).
2) The project description shall establish criteria and procedures for the use of the dataset and for establishing a specific performance benchmark for each Same Building Stock
3) The project description may specify that projects use the level of the performance benchmark metric available at project validation for the duration of their project crediting periods, or may specify that projects use an updated level of the performance benchmark at each verification event. The frequency that data is updated within the dataset shall be determined by the project proponent.
4) It shall be demonstrated that procedures are in place to maintain the dataset in accordance with the applicable requirements set out in Section 7.3, “Data Selection and Use”.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

This section presents five approaches to calculating emission reductions and related monitoring parameters. They are: 1) the adjusted consumption approach, 2) the pre-and post retrofit audit approach,

3) the control group approach, 4) the deemed savings approach, and 5) the mobile homes approach. Equations required to calculate emission reductions under each approach and monitoring parameters applicable to each approach are listed in this section.

Emission reductions are calculated directly under each approach; in other words, baseline and project emissions are not calculated separately under the methodology. This method results in a simplified and accurate estimation of project emissions normalized for weather and electricity correction factors. Leakage is calculated separately under each approach.

Category A--All energy retrofits: calculation of the emission reductions and monitoring shall be based on either:

1. The adjusted consumption approach;
2. The pre- and post-retrofit audit approach; or
3. The control group approach.

Category B--Efficiency enhancements of the Building Envelope and central heating/cooling: calculation of the emission reductions and monitoring shall be based on either:

1. The adjusted consumption approach;
2. The pre- and post-retrofit audit approach; or
3. The control group approach.

In Category B, electricity shall only be included in the calculation of emission reductions when it is a heating or cooling source within the building or Dwelling.

Category C--Appliance replacement: calculation of the emission reductions and monitoring shall be based on:

4. The deemed savings approach.

Category D--Replacement of a mobile home: calculation of the emission reductions and monitoring shall be based on either:

1. The adjusted consumption approach;
3. The control group approach; or
5. The mobile homes approach.

1. Adjusted consumption approach

In the adjusted consumption approach, measured energy consumption pre-retrofit, the baseline consumption, shall be corrected for changes in electricity demand over time and adjusted for Heating/Cooling Degree Days using an Electricity Correction Factor ("ECF") and Heating/Cooling Degree Day Correction Factors ("HDDCF" or "CDDCF" as applicable). A sample may be used to measure energy consumption pre-retrofit. Project consumption of fuel and electricity shall be subtracted from the adjusted baseline consumption. The result shall be multiplied by an emission factor for the fuel or electricity used in the baseline. A control group of non-weatherized, or non-retrofitted, Dwellings shall be monitored as a quality assurance measure.

1.1 Emission reductions in the adjusted consumption approach shall be calculated as follows:

Equation 6

$$ER_y = \sum_{i=1}^{I}(Elec_{b,i} * ECF_y * CDDCF_y - Elec_{p,y,i}) * Elec_{CO2} + \sum_{i,j=1}^{I,J}(F_{b,i,j} * HDDCF_y - F_{p,y,i,j}) * Cal_j * F_{CO2j} - L_y$$

Where:

ER_y = Emission Reduction in year *y* in metric tons ("t") CO_2e/yr

i = Dwelling
$Elec_{b,i}$ = Electricity consumed in the year prior to Project implementation for Dwelling i in kWh (baseline consumption)[9]
$Elec_{p,y,i}$ = Electricity consumed by the Project in year y for Dwelling i in kWh (Project consumption)
ECF_y = Electricity correction factor for year y to be applied to the baseline
$CDDCF_y$ = Cooling degree days correction factor for year y
$HDDCF_y$ = Heating degree days correction factor[10] for year y
$F_{b,i,j}$ = Fuel type j consumed in the year prior to Project implementation for Dwelling i in the appropriate mass, or volume unit (baseline consumption)
$F_{p,y,i,j}$ = Fuel type j consumed by the Project in year y for Dwelling i in the appropriate mass, or volume unit (Project consumption)
Cal_j = Calorific value of fuel type j in GJ/mass or volume
$Elec_{CO2}$ = Grid emission factor in tCO_2e/kWh
$F_{CO2,j}$ = The CO2 emission factor per unit of energy of fuel type j expressed in tCO_2e / GJ
L_y = Leakage in year y
I = Number of Dwellings
J = Number of fuel types
j = Fuel type
y = Any consecutive twelve months during the Project's crediting period, and shall be defined with an integer from 1 on in a consecutive manner

Leakage, L_y, shall be calculated as follows:

Equation 7

$$L_y = L_{CO2,y} + L_{HFC,y}$$

Leakage from continued operation of Appliances, $L_{CO2,y}$, shall be calculated as follows:

Equation 8

$$L_{CO2,y,} = \sum_{k=1}^{K} (a_{np,k,y} * h_k * E_{dem,pre,k}) * Elec_{CO_2} + \sum_{t=1}^{T-1} L_{(y-t),CO2}$$

Where:
$a_{np,k,y}$ = Appliance not properly disposed of Appliance type k in year y
K = Number of Appliance types
$E_{dem,pre,k}$ = Electricity demand of Appliance type k before replacement
h_k = Annual working hours of Appliance type k
$Elec_{CO2}$ = Grid emission factor in tCO2e/kWh
T = Years from beginning of project crediting period

Leakage from improper disposal of refrigerators or air conditioners, $L_{HFC,y}$ shall be calculated as follows:

[9] If multiple dwellings within a single building are served by a single meter, the electricity consumption unit shall change to kWh/m2 and the equation shall be multiplied by the area of each individual dwelling. Consequently, the area of each dwelling shall be recorded and included in the monitoring parameters.

[10] When fossil fuel is the cooling source the CDDCF shall replace the HDDCF in the equation. Conversely, when electricity is the heating source the HDDCF shall replace the CDDCF in the equation.

Equation 9

$$L_{HFC,y} = \sum_{k=1}^{K} a_{np,k,y} * RCC_a * GWP_R * \frac{1t}{1{,}000{,}000g}$$

Where:

RCC_a = Charge capacity of refrigerant gas of replaced cooling Appliance a in grams
GWP_R = Global Warming Potential of refrigerant gas R used in Appliance in tons CO_2equivalent per ton of R

Table 1: GWP for common refrigerant types

Refrigerant Type	**HFC-23**	**HFC-32**	**HFC-125**	**HFC-134a**	**HFC-143a**	**HFC-152a**
GWP 100yr (IPCC 1996)	11700	650	2800	1300	3800	140

Refrigeration equipment often uses blends of HFC refrigerant gases. The GWP of these blends should be calculated based on the proportion of different refrigerants used[11].

1.2 The grid emission factor ($Elec_{CO2}$) shall be calculated in a transparent and conservative manner based on one of the following approaches:

A combined margin, consisting of the combination of operating margin and build margin according to the procedures prescribed in the most recent CDM 'Tool to calculate the emission factor for an electricity system'. The grid emission factor shall be monitored following either the *Ex ante* option or the *Ex post* option within the CDM Tool.

Or

The weighted average emissions (in tCO2e/kWh) of the current generation mix obtained from a regulated source. The data from the most recent year for which data are available shall be used. The grid emission factor shall be monitored annually, and updated as the regulated source publishes data. If the grid emission factor is published later than year *y*, the emission factor from an earlier year, up to three years prior (*y-3*), may be used.

1.3 The ECF represents the trend in electricity demand based on average electricity consumption within a region or state over a period of at least ten years. Historical data from a recognized national authority may be used to determine the ECF. Projected trends in changes in the rate of electricity demand reported by a national authority may also be used as the ECF[12]. The ECF shall be stated as a multiplier. For example, 0.98 represents an electricity consumption growth rate of -2%.

The Electricity Correction Factor ("ECF") is used to update the baseline electricity consumption based on decreases in electricity demand over time. The ECF shall only be applied when it is less than 1 to maintain conservativeness in the emission reduction calculation. This factor shall be applied to the calculation of the emission reductions after Project implementation because electricity consumption in the baseline may not remain the same (see Figure 3). The factor shall be determined from local, regional or national electricity household consumption data from a

[11] Examples of the available compositions of refrigerant blends are available at the U.S. Environmental Protection Agency website: http://www.epa.gov/Ozone/snap/refrigerants/refblend.html
[12] Examples of reported values that may be used as an ECF are available at the Department of Energy website: http://apps1.eere.energy.gov/states/electricity.cfm/state=ME.

government agency, a public utility or regulatory agency, or a recognized energy research organization.

In a situation where overall electricity consumption decreases, the Electricity Correction Factor ensures against over-estimation of emission reductions (see Figure 4).

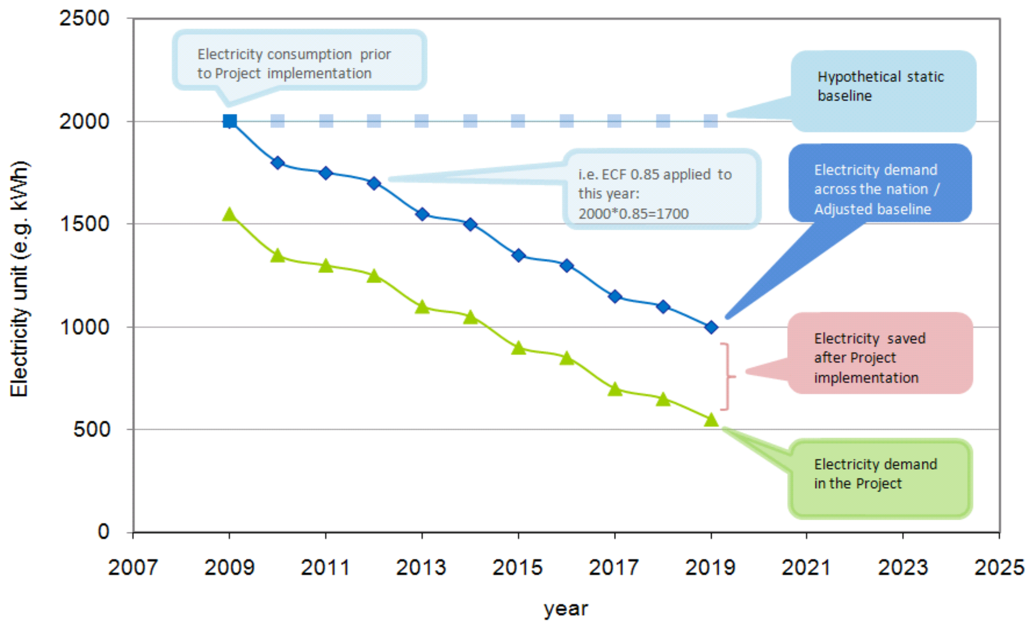

Figure 4 : This graph shows how the adjusted consumption approach takes into account a reduction in electricity consumption over time. Failure to adjust for decreasing consumption over time would result in an over-estimation of emission reductions.

1.4 The Heating/Cooling Degree Day Correction Factors (HDDCF and CDDCF) are used to update the baseline energy consumption annually based on changes in temperature. These factors account for changes in heating/cooling degree days and associated changes in heating and cooling loads (see Figure 3). The factors shall be determined based on data from reputable regional or national meteorological organizations[13].

The Heating Degree Day Correction Factor shall be calculated as follows:

Equation 10

$$HDDCF_y = \frac{HDD_y}{HDD_b}$$

The Cooling Degree Day Correction Factor shall be calculated as follows:

Equation 11

$$CDDCF_y = \frac{CDD_y}{CDD_b}$$

Where:

HDD_y = Heating degree days for year *y* after the retrofit

[13] An example of such organization is the National Oceanic and Atmospheric Administration (NOAA) in the United States.

HDD_b = Heating degree days for one year before the retrofit
CDD_y = Cooling degree days for year *y* after the retrofit
CDD_b = Cooling degree days for one year before the retrofit

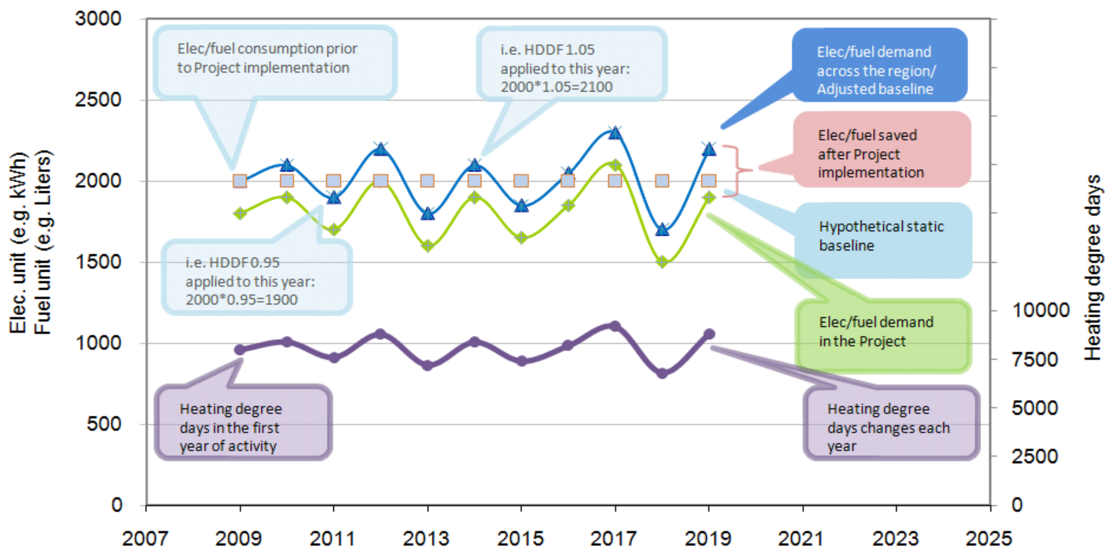

Figure 5: This graph shows how heating degree days affect fuel/electricity consumption over time. Failure to adjust the baseline based on changes in temperature would result in inaccurate calculation of emission reductions.

Quality Assurance

1.5 When using the adjusted consumption approach, a sample group of Dwellings Weatherized as part of the Project shall be monitored to ensure the reduction in energy consumption and resulting reduction in emissions is real. The sample group shall measure the emission reductions resulting from the change in energy consumption. In case of a significant discrepancy between emission reductions calculated according to the approach and emission reductions calculated from the sample group, the adjusted baseline consumption approach shall be calibrated accordingly. The sample size of the sample group shall be established by multiplying 0.6 by the square root of the total number of Dwellings, *i*, or Appliances, included in the Project[14]. Monitoring of the sample group for quality assurance shall occur for two years and shall consist of collecting electricity and fuels bills that represent a twelve month period.

When the data come from two different processes, such as the adjusted consumption calculation and the measurements from the sample group, significant discrepancy is defined on the basis of an independent 2-sample t-test for equality of two means. If the value T of the above statistic obtained from a t-value table or calculation is greater than the corresponding value of the t-distribution for a 95% confidence level and degrees of freedom given by 2n-2, then the null hypothesis of equal means is rejected and the observed discrepancy is concluded to be significant.

A t-test is a standard statistical tool and readily available. One of the t-tests set forth below shall be applied. The particular test shall be determined by the type of samples, samples sizes and assumptions made on the underlying population variances.

[14] The equation for determining the minimum sample size number for quality assurance purposes was taken from the surveillance requirements in the IAF Guidance on the Application of ISO/IEC Guide 66 Issue 4 IAF GD: 2006.

1. An independent 2-sample t-test for samples of equal sizes and equal variances shall be used when the number of observations (data points) in both samples is equal and it can reasonably be assumed that the population variance of both samples is the same.

2. An independent 2-sample t-test for unequal sample sizes and equal variances shall be used when the number of observations (data points) in both samples is not equal and it can reasonably be assumed that the population variance of both samples is the same.

3. An independent 2-sample t-test for unequal sample sizes and unequal variances shall be used when the two data samples are of unequal size and it can be reasonably assumed that the population variance is different. This test is referred to as Welch's t-test.

1.6 The parameters to be monitored in the adjusted consumption approach are listed in Section 9.

2. Pre- and post-retrofit audit approach

Monitoring emission reductions shall be based on the data generated by a pre- and post- retrofit energy audit for a sample of the Dwellings. A pre-retrofit audit shall take place once before Project implementation for every Dwelling and a post-retrofit audit shall take place once after the retrofit has been completed for a sample of the Dwellings. In every multi-family building, a representative sample of the Dwellings shall undergo a pre- and post-retrofit audit. The pre-retrofit audit shall determine the electricity demand and heat load in the baseline. The pre-retrofit electricity demand and heat load shall then be compared to the post-retrofit electricity demand and heat load. This comparison shall provide the Electricity Demand Reduction Factor and the Heat Load Reduction Factor, which shall be used to calculate emission reductions created by the Project.

2.1 To calculate emission reductions, the reduction factors obtained from the pre- and post- energy audit shall be applied to the baseline consumption of electricity and fuel. The result shall then be multiplied by the emission factor of the fuel type. Emission reductions shall be adjusted for changes in electricity demand over time and adjusted for heating/cooling degree days during the project crediting period.

2.2 Energy auditors must be certified by a public authority or a private certification program recognized by a public authority. Energy audits shall be conducted using industry best-practices, cover both fuel and electricity consumption, include diagnostic tests (such as a blower door test, pressure pan test or thermal imaging) and use energy modeling software, or appropriate calculations[15].

2.3 The Electricity Demand Reduction Factor ("EDF") shall be calculated for a sample of the Dwellings as follows:

Equation 12

$$EDF = 1 - \frac{\sum_{s=1}^{S} E_{dem,post,s}}{\sum_{s=1}^{S} E_{dem,pre,s}}$$

[15] In the United States there are several established energy auditing programs that are credible and accepted as industry best practice. Examples include, but are not limited to RESNET HERS rating, Building Performance Institute Audit, Home Performance with Energy Star, Maine Certified Energy Audit. The certification process is a substitute for a single industry standard.

The Heat Load Reduction Factor (HLF) shall be calculated for a sample of the Dwellings as follows:

Equation 13

$$HLF = 1 - \frac{\sum_{s=1}^{S} H_{load,post,s}}{\sum_{s=1}^{S} H_{load,pre,s}}$$

Where:

EDF	= Electricity demand reduction factor (no unit)
$E_{dem,post,s}$	= Electricity demand post-retrofit for Dwelling *s*, kW
$E_{dem,pre,s}$	= Electricity demand pre-retrofit for Dwelling *s*, kW
HLF	= Heat load reduction factor (no unit)
$H_{load,post,s}$	= Heat load post-retrofit for Dwelling *s*, kWh/m^2
$H_{load,pre,s}$	= Heat load pre-retrofit for Dwelling *s*, kWh/m^2
S	= Number of sample Dwellings
s	= sample Dwelling undergoing post retrofit audit

2.4 Emission reductions shall be calculated as follows:

Equation 14

$$ER_y = \sum_{i=1}^{I} Elec_{b,i} * EDF * ECF_y * CDDCF_y * Elec_{CO2} + \sum_{i,j=1}^{I,J} F_{b,i,j} * HLF * HDDCF_y * Cal_j * F_{CO2} - L_y$$

Leakage, L_y, shall be calculated using Equation 7.

Quality Assurance

2.5 When using the pre- and post-audit approach, energy bills based on direct metering of consumption shall be collected for one year pre-retrofit and compared with post-retrofit energy bills based on direct metering of consumption in a sample of Dwellings. When dealing with non-regulated fuels, an acceptable alternative measure shall be compared to that same measure as shown in the post-retrofit audit to ensure the energy savings were achieved. The sample size for quality assurance samples shall be established by multiplying the 0.6 by square root of the total number of Dwellings, *i*, or Appliances, included in the Project. The reduction in demand as calculated in Equation 12 and Equation 13, shall be compared to the reduction in consumption based on directly metered electricity or natural gas consumption data, or in the case of non-regulated fuels an acceptable alternative measure. The sample group shall be tested for a significant discrepancy between the calculated reduction in energy demand as shown in the post-retrofit audit and actual reduction in consumption calculated from directly metered energy bills. When dealing with non-regulated fuels an acceptable alternative measure shall be used, as noted above. If the discrepancy between the two mean values is found to be significant, the mean energy consumption from the directly metered value shall be used to calculate the HLF or EDF.

When the two data samples come from the same Dwelling, significant discrepancy is defined on the basis of a dependent 2-sample t-test for equality of two means. If the t-value of the above statistic obtained from a t-value table or calculation is greater than the corresponding value of the t-distribution for a 95% confidence level and degrees of freedom given by n-1, then the null hypothesis of equal means is rejected and the observed discrepancy is concluded to be significant.

A dependent 2-sample t-test shall be applied to test for the difference of the two means. The two means to be compared shall be from the sample group of weatherized Dwellings, and shall be the mean of the energy demand determined by the post-retrofit audit and the mean of the directly metered energy bill in the case of electricity and natural gas. However, in the case of non-regulated fuels, the two means compared shall be based on an acceptable alternative measure, such as blower door test value as shown in the post-retrofit audit, and the blower door test value recorded one year post-retrofit.

2.6 The parameters to be monitored in the pre-and post-retrofit audit approach are listed in Section 9.

3. Control group approach

In this approach a control group and a sample group shall be defined. The control group shall be comprised of Dwellings from the Same Building Stock that are not, and shall not be Weatherized[16]. The sample group shall be comprised of Dwellings to be Weatherized, or, in the case of mobile homes, replaced. Electricity and fuel bills shall be collected for both groups annually throughout the project crediting period. The control group shall consist of Dwellings that have not been weatherized as part of the Project. The Project shall not prevent or deny Weatherization to any homeowner, or individual for the purpose of maintaining the control group. Instead, as the population of Weatherized Dwellings increases, the control group sample may include different Dwellings as long as the control group contains only non-Weatherized Dwellings.

3.1 The difference in the energy consumption between the control group and the sample group each year will constitute the fuel and electricity savings for all Dwellings in the Project for that year and shall serve as the basis for calculating emission reductions[17].

The sample group shall come from Dwellings included in the Project activity. The control group shall be selected from Dwellings not included in the Project activity and shall have the following requirements in addition to the requirements established in section 1.9 Part A:

1) Participants shall not have the ability to “opt-in” to the control group.
2) Once selected, homeowners shall be required to make their fuel and electricity bills available to the Project. Where appropriate, the homeowner will be requested to sign a waiver granting the Project proponent electronic access to directly metered electricity and gas bills.
3) Dwellings shall be in the Same Building Stock.

3.2 Emission reductions shall be calculated as follows:

[16] The control group sample size must be large enough to be statistically valid. When approaching complete saturation of Weatherized homes, the control group will diminish in size as the number of non-Weatherized homes diminishes. This is a risk that must be weighed when choosing the control group approach. One option for addressing the diminishing control group is to use the control group approach for as long as possible and then switch to the adjusted consumption approach. The control group monitoring will be able to be used as the baseline in the adjusted consumption approach.

[17] Since the energy consumed by retrofitted dwellings shall be directly compared to the energy consumed by non-retrofitted Dwellings within the Same Building Stock and the same year, there is no need to apply the Electricity and Heating/Cooling Degree Day Correction Factors.

Equation 15

$$ER_y = \sum_{b=1}^{B} \{ \{(Elec_{CG,y,b} - Elec_{SG,y,b}) * Elec_{CO2}\} + \sum_{j=1}^{J} \{(F_{CG,y,j,b} - F_{SG,y,j,b}) * Cal_j * F_{CO2j}\} \} * I_b - L_{y,b}$$

Leakage, $L_{y,b}$, shall be calculated for each Building Stock using Equation 7.

Where:

$Elec_{SG,y,b}$ = Mean electricity consumed by sample group Dwellings in Building Stock *b* in year *y*
$Elec_{CG,y,b}$ = Mean electricity consumed by control group Dwellings in Building Stock *b* in year *y*
$F_{SG,y,j.b}$ = Mean fuel type *j* consumed by sample group Dwellings in Building Stock *b* year *y*
$F_{CG,y,j,b}$ = Mean fuel type *j* consumed by control group Dwellings in Building Stock *b* in year *y*
I_b = Number of Dwellings in Building Stock *b*
$L_{y,b}$, = Leakage in Building Stock *b* in year *y*

To ensure conservativeness in the emission reduction calculation approach, a 95% confidence interval, with an alpha value equal to 5% (α =0.05) shall be applied to the fuel and/or electricity consumption within the control group and the sample group, denoted by $Elec_{SG,y,b}$, $Elec_{CG,y,b}$, $F_{SG,y,j,b}$, $F_{CG,y,j,b}$ above. The lower bound of the confidence interval of the control group, and the upper bound of the confidence interval of the sample group shall be the values compared to determine the emission reductions resulting from Project activity.

The 95% confidence interval shall be calculated as follows:

$$\bar{x} - Z_{0.025}(SE) < \mu < \bar{x} + Z_{0.025}(SE)$$

$$SE = \hat{\sigma} / \sqrt{n} \quad \text{and} \quad \hat{\sigma} = s * \sqrt{n/(n-1)}$$

Where:

$\bar{x}$ = the mean energy consumption calculated from the sample
$Z_{0.025}$ = 1.960, established standard value
s = the standard deviation calculated from the sample
n = the sample size
n-1 = the sample size minus one
μ = the mean of the population. This value is not actually calculated, instead it is contained within the upper and lower bounds of the equation.
SE = standard error
$\hat{\sigma}$ = standard deviation that approximates the standard deviation of the population, used to calculate the standard error.

3.3 The parameters to be monitored in the control group approach are listed in Section 9.

4. The deemed savings approach

4.1 Emission reductions for the replacement of Appliances shall be calculated as follows:

4.1.1 The electricity demand (rated capacity) of both the Appliance to be replaced and of the replacement Appliance shall be determined from the nameplate, manufacturer's specification sheet, or direct metering;

4.1.2 The typical annual hours of operation of the Appliance to be replaced in the Project area shall be recorded;

4.1.3 The emission reductions from an individual Appliance shall be calculated by comparing the electricity demand of the replacement Appliance with that of the replaced Appliance, multiplied by annual hours of operation and by the grid emission factor. To account for failed operation of Appliances a correction factor shall be applied.

4.1.4 Emission reductions shall be calculated as follows:

Equation 16

$$ER_y = \sum_{k=1}^{K} a_k (E_{dem.pre,k} - E_{dem.post,k}) * h_k * Elec_{CO2} * Corr_k - L_y$$

Leakage, L_y, shall be calculated using Equation 7.

Where:

$E_{dem,pre,k}$	=Electricity demand of Appliance type *k* before the replacement takes place
$E_{dem.post,,k}$	=Electricity demand of Appliance type *k* after the replacement
h_k	=Annual working hours of the Appliance type *k*
$Corr_k$	=Correction factor for failed operation of each Appliance type *k*
a_k	=Number of Appliances of each Appliance type *k*
K	=Number of Appliance types
k	= Appliance type

4.2 Monitoring shall consist of verifying the operation of a sample of the Appliances within the first year of installation and in three year intervals thereafter.

The parameters to be monitored in the deemed savings approach are listed in Section 9.

5. The mobile homes approach

5.1 Emission reductions for the replacement of mobile homes shall be calculated as follows:

5.1.1 The heat load of both the mobile home to be replaced and of the replacement home shall be determined from best practice heat load modelling. In the case of the home to be replaced, the heat load may be calculated by applying a heat load formula that applies a default energy consumption value determined from statistically significant fuel consumption records[18]. In the case of the replacement home, the heat load shall be modelled taking into account the building specifications. The building specifications may include but are not

[18] The heat load formula shall be based on best practice energy modeling software that takes into account the number of rooms, the metric size of the rooms, the energy load per meter, and the degree days of the region. In the United States, for example, the design heat load calculation that is used to determine fuel award amounts in the national Low Income Home Energy Assistance Program may be used. That equation is: number of rooms multiplied by the square feet per room, multiplied by the BTU consumption per square foot per degree day multiplied by degree days, all divided by 1,000,000 BTUs to yield the MBTU needed to heat/cool the space. In metric the equation would be: number of rooms multiplied by the square meters per room, multiplied by the KJ consumption per square meter per degree day multiplied by degree days, all divided by 1,000,000 KJ to determine the GJ needed to heat/cool the space.

limited to; R-value of insulation in the floor, walls and ceiling, U-value and size of the windows, and the R-value of the skirting.

5.1.2 Emission reductions shall be based on the difference between pre- and post-replacement heat load[19] and pre-and post-replacement size of the mobile home, multiplied by the annual heating/cooling degree days, and both the calorific value and the emission factor of the fuel consumed within the Dwelling[20].

5.1.3 If Appliances are replaced at the same time the mobile home is replaced, the calculation of emission reductions from Appliance replacement shall follow the deemed savings approach. Total emission reductions shall be the sum of emission reductions from the replacement of the mobile home plus the emission reductions from replacement of the Appliances, minus leakage.

5.1.4 Emission reductions shall be calculated as follows:

Equation 17

$$ER_y = \sum_{i=1}^{I}((H_{load,pre,i} * S_{pre,i} - H_{load,post,i} * S_{post,i}) * HDD_y * F_{CO2j}) + ER_{ARy}$$

Note* In a region with a predominantly hot climate, the equation can be changed to incorporate cooling load $C_{load,pre,j}$ and Cooling Degree Days CDD_y, which would replace $H_{load,pre,j}$ and Heating Degree Days HDD_y respectively.

Where:

$H_{load,pre,i}$	= Heat load of mobile Dwelling *i* to be replaced
$H_{load,post,i}$	= Heat load of replacement Dwelling *i*
HDD_y/CDD_y	= Heating/cooling degree days
$S_{pre,i}$	= Size of Dwelling *i* to be replaced in m^2
$S_{post,i}$	= Size of replacement Dwelling *i* in m^2
ER_{ARy}	= Emission reductions from Appliance replacement
I	= Number of Dwellings

Emission reductions from Appliance replacement, ER_{ARy}, shall be calculated using Equation 16.

5.2 The parameters to be monitored in the mobile homes approach are listed in Section 9.

[19] The heat load of a Dwelling shall include cooling load when both heating and cooling are provided by one central system.
[20] When electricity is the central heating/cooling source, the grid electricity factor shall replace both the fuel calorific value (Cal_j) and the fuel emission factor ($F_{CO2,j}$). In this case, the heat load shall be expressed in kWh per square meter per degree day.

9 MONITORING

9.1 Data and Parameters Available at Validation

Table 3. Monitoring parameters for the performance benchmark for Category A and B

Parameter Description	Parameter	Unit	Source	Frequency
Average performance, defined as the annual average percent savings in weather normalized energy consumption in Dwellings within the Same Building Stock.	*a*	Percent	Calculated from regional or national statistics for at least the three most recent 12 month periods for which data are available from Dwellings within the Same Building Stock. A sample of the Dwellings may be used. Percent savings are calculated by comparing year 1 to year 2 and year 2 to year 3[21].	Once per project crediting period
Standard Deviation of the annual percent savings.	σ	-	Calculated from regional or national statistics used to calculate the average performance.	Once per project crediting period

Table 4. Monitoring parameters for the performance benchmark for Category C

Parameter Description	Parameter	Unit	Source	Frequency
Average performance, defined as the annual average electricity consumption by existing Appliances, of the same Appliance type.	*a*	kWh/appliance	Calculated from regional or national statistics for at least the recent 12 month period for which data are available. A sample of the Dwellings may be used.	Once per project crediting period
Standard Deviation of the annual energy consumption of	σ	-	Calculated from regional or national statistics used to	Once per project crediting

[21] Year 1, year 2 and year 3 may have gaps of time in between the years. For example: Year 1 data may cover 2001, year 2 data may cover 2005, and year 3 may cover 2009.

existing Appliances.			calculate the average performance.	period

Table 5. Monitoring parameters for the adjusted consumption approach, pre- and post-retrofit audit approach, control group approach, and mobile homes approach

Parameter Description	Parameter	Unit	Source	Frequency
Grid emission factor for the regional electricity source	$Elec_{CO2}$	tCO_2e/kWh	Obtained from a recognized authority; or calculated by the Project proponent based on raw data obtained from a local, or national electric utility.	As per approach listed in Part C, section 1.2; this parameter could be available at validation or it could change throughout the project crediting period
Calorific value of fuel type *j*	Cal_j	GJ/mass or GJ/volume	Local, regional or national data. If unavailable, IPCC default values may be used.	Once per project crediting period
CO2 emission factor for fuel type *j* (baseline fuel)	F_{CO2j}	tCO_2e / GJ	Local, regional or national data. If unavailable, IPCC default emission factors may be used.	Once per project crediting period

Table 6. Monitoring parameters for replacement of Appliances

Parameter Description	Parameter	Unit	Source	Frequency
Grid emission factor for the regional electricity source	$Elec_{CO2}$	tCO_2e/kWh	Obtained from a recognized authority; or calculated by the Project based on raw data obtained from a local, or national electric utility.	As per approach listed in Part C, section 1.2; this parameter could be available at validation or it could change throughout the project crediting period

9.2 Data and Parameters Monitored

Table 7. Monitoring parameters for the performance benchmark for Category A and B

Parameter Description	Parameter	Unit	Source	Frequency
Pre-retrofit energy load of Dwelling i	$EL_{pre,\ i}$	BTU/m^2	Energy audit	Once
Post-retrofit energy load of Dwelling i	$EL_{post,\ i}$	BTU/m^2	Energy audit	Once

Table 8. Monitoring parameters for the performance benchmark for Category C

Parameter Description	Parameter	Unit	Source	Frequency
Annual energy consumption of the replacement Appliance, type *k*	$a_{rc,\ k}$	kWh/appliance	Nameplate, or manufacturer's specification sheet.	Once

Table 9. Monitoring parameters for the adjusted consumption approach

Parameter Description	Parameter	Unit	Source	Frequency
Electricity consumed in the year prior to Project implementation in Dwelling i (baseline consumption)	$Elec_{b,i}$	kWh/yr	Electricity bills for 12 months pre-retrofit. Bills for a sample of the Dwellings in the Same Building Stock shall be monitored, or bills may be collected for all Dwellings in the Project.	Once
Electricity consumed by the Project in year *y* for Dwelling *i*	$Elec_{p,y,i}$	kWh/yr	Post-retrofit electricity bills	Collected monthly, recorded annually
Fuel type *j* consumed in the year prior to Project implementation for Dwelling *i* (baseline consumption)	$F_{b,i,j}$	Mass or volume per Dwelling per year	Pre- retrofit fuel bills covering a twelve month period. Bills for a sample of the Dwellings in the Same Building Stock shall be monitored, or bills may be collected for all Dwellings in the Project.	Once
Fuel type *j*	$F_{p,y,i,j}$	Mass or	Post- retrofit fuel	Annually

consumed by the Project in year y for Dwelling *i*		volume per Dwelling per year	bills covering a twelve month period[22,23]	
Electricity correction factor for year *y* The ECF is only to be applied in the equation if it is negative.	ECF_y	-	Calculated by the Project based on national energy statistics.	Applied annually
Cooling degree days for year *y*	CDD_y	Degree Days	Regional statistics	Annually
Cooling degree days in the year prior to Project implementation	CDD_b	Degree Days	Regional statistics	Once
Heating degree days for year *y*	HDD_y	Degree Days	Regional statistics	Annually
Heating degree days in the year prior to Project implementation	HDD_b	Degree Days	Regional statistics	Once
Number of fuel types	*J*	-	Project proponent database	Annually
Number of retrofitted Dwellings	*I*	-	Project proponent database	Annually
Continued operation of the installed measures	*C*	-	This parameter will be monitored in the sample of Dwellings selected for quality assurance monitoring. Non-operational measures shall be excluded from ER calculations.	Annually
Replaced Appliance of type *k* not properly disposed of in year *y*	$a_{np,k,y}$	-	Disposal documentation and Project proponent database	Annually
Electricity demand of Appliance *k* before replacement	$E_{dem.pre,k}$	kW	Nameplate, or manufacturer's specification sheet, or direct metering of	Once pre-replacement

[22] Fuel consumption shall be based on fuel purchased as reflected in the billing. Some households may store some fuel, or refill the tank before it is empty. However, the fuel storage level will become inconsequential over time as any fuel purchased to fill the fuel tank above the storage level will be consumed and therefore reflected in the billing upon refueling. Any remaining differences in the filling level, before Project implementation and at the end of the Project lifetime, of individual households will cancel each other out over the entire sample of Dwellings.

[23] In the case where consumed energy for each household cannot be measured separately or in the case of district heating, the temperature in/out and water discharge (flow rate) of the heating system shall be monitored. Fuel consumption monitoring shall take place using the utility company fuel inventory for that specific district heating system.

			the Appliance	
Annual working hours of Appliance *k*	h_k	Hours	Sampling, consumer surveys, or common practice based on local, regional or national data[24]	Once, may be updated
The refrigerant charge capacity of the cooling Appliance not properly disposed of.	RCCa	Grams	Manufacturer's specification sheet on the cooling Appliance.	Once
Type of refrigerant used in the cooling Appliance.	R	-	Manufacturer's specification sheet on the cooling Appliance.	Once
Quality assurance sample group of fuel consumption within the Dwelling	-	Mass or volume per Dwelling per year	Fuel bills covering a twelve month period. Bills for the sample group sample of Dwellings in the Same Building Stock shall be monitored.	Annually, for 2 years
Quality assurance sample group of electricity consumption within the Dwelling	-	kWh/yr	Electricity bills covering a twelve month period. Bills for the sample group sample of Dwellings shall be monitored.	Annually, for 2 years

Table10. Monitoring parameters for pre- and post-retrofit audit approach

Parameter Description	Parameter	Unit	Source	Frequency
Electricity consumed in the year prior to Project implementation in Dwelling *i* (baseline consumption)	$Elec_{b,i}$	kWh/yr	Electricity bills for 12 months pre-retrofit. Bills for a sample of the Dwellings in the Same Building Stock shall be monitored, or bills may be collected for all Dwellings in the Project.	Once

[24] For example, in the United States, the US Department of Energy publishes annual operating hours of common household appliances in the Buildings Energy Data Book. This information is publically available at http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=2.1.16

Electricity demand pre-retrofit for Dwelling *i*	$E_{dem,pre,i}$	kW	Pre-retrofit audit report	Once
Electricity demand post-retrofit for Dwelling *i*	$E_{dem,post,i}$	kW	Post-retrofit audit report	Once
Fuel type *j* consumed in the year prior to Project implementation for Dwelling *i* (baseline consumption)	$F_{b,i,j}$	Mass or volume per Dwelling per year	Pre- retrofit fuel bills covering a twelve month period. Bills for a sample of the Dwellings in the Same Building Stock shall be monitored, or bills may be collected for all Dwellings in the Project.	Once
Heat load pre-retrofit for Dwelling *i*	$H_{load,pre,i}$	kWh/m^2/HDD GJoules/m^2/HDD	Pre-retrofit audit report	Once
Heat load post-retrofit for Dwelling *i*	$H_{load,post,i}$	kWh/m^2/HDD GJoules/m^2/HDD	Post-retrofit audit report	Once
Electricity correction factor for year *y*	ECF_y	-	Calculated by the Project based on national energy statistics.	Applied annually
Cooling degree days for year *y*	CDD_y	Degree Days	Regional statistics. Use localized data when available	Annually
Cooling degree days in the year prior to Project implementation	CDD_b	Degree Days	Regional statistics. Use localized data when available	Once
Heating degree days for year *y*	HDD_y	Degree Days	Regional statistics. Use localized data when available	Annually
Heating degree days in the year prior to Project implementation	HDD_b	Degree Days	Regional statistics. Use localized data when available	Once
Number of fuel types	*J*	-	Project proponent database	Annually
Number of retrofitted Dwellings	*I*	-	Project proponent database	Annually
Number of	*S*	-	Pre- and Post-	Once

sample Dwellings			retrofit audit reports	
Replaced Appliance of type *k* not properly disposed of in year *y*	$a_{np,k,y}$	-	Disposal documentation and Project proponent database	Annually
Annual working hours of Appliance *k*	h_k	Hours	Sampling, consumer surveys, or common practice based on local, regional or national data	Once, may be updated
Electricity demand of Appliance *k* before replacement	$E_{dem.pre,k}$	kW	Nameplate, or manufacturer's specification sheet, or direct metering of the Appliance	Once pre-replacement
The refrigerant charge capacity of the cooling Appliance not properly disposed of.	*RCCa*	Grams	Manufacturer's specification sheet on the cooling Appliance.	Once
Type of refrigerant used in the cooling Appliance.	*R*	-	Manufacturer's specification sheet on the cooling Appliance.	Once

Table 11. Monitoring parameters for control group approach

Parameter Description	Parameter	Unit	Source	Frequency
Mean electricity consumed by sample group Dwellings in Building Stock b in year *y*	$Elec_{SG,y,b}$	kWh/yr	Electricity bills	Monitored monthly, calculated annually
Mean electricity consumed by control group Dwellings in Building Stock b in year *y*	$Elec_{CG,y,b}$	kWh/yr	Electricity bills	Monitored monthly, calculated annually
Mean fuel type *j* consumed by sample group Dwellings in Building Stock *b* year *y*	$F_{SG,y,j,b}$	Mass or volume, per Dwelling per year	Fuel bills	Monitored monthly, or as fuel is delivered, totaled annually

Mean fuel type *j* consumed by control group Dwellings in Building Stock *b* year *y*	$F_{CG,y,j,b}$	Mass or volume, per Dwelling per year	Fuel bills	Monitored monthly, or as fuel is delivered, totalled annually
Number of fuel types	*J*	-	Project proponent database	Annually
Number of Dwellings in Building Stock b	I_b	-	Project proponent database	Annually
Replaced Appliance of type *k* not properly disposed of in year *y*	$a_{np,k,y}$	-	Disposal documentation and Project proponent database	Annually
Annual working hours of Appliance *k*	h_k	Hours	Sampling, consumer surveys, or common practice based on local, regional or national data	Once, may be updated
Electricity demand of Appliance *k* before replacement	$E_{dem,pre,k}$	kW	Nameplate, manufacturer's specification sheet, or direct metering of the Appliance	Once pre-replacement
The refrigerant charge capacity of the cooling Appliance not properly disposed of.	RCCa	Grams	Manufacturer's specification sheet on the cooling Appliance.	Once
Type of refrigerant used in the cooling Appliance.	R	-	Manufacturer's specification sheet on the cooling Appliance.	Once

Table 12. Monitoring parameters for replacement of Appliances

Parameter Description	Parameter	Unit	Source	Frequency
Electricity demand of Appliance *k* pre-replacement	$E_{dem,pre,k}$	kW	Nameplate, manufacturer's specification sheet, or direct metering of the Appliance	Once, pre-replacement
Electricity demand of Appliance *k* post-replacement	$E_{dem,post,k}$	kW	Nameplate, manufacturer's specification sheet, or direct metering of the	Once, post-replacement

			Appliance	
Annual working hours of Appliance *k*	h_k	Hours	Sampling, consumer surveys, or common practice based on local, regional or national data	Once, may be updated
Correction factor for the failed operation of type of Appliance *k*	$Corr_k$	-	Surveys conducted by Project proponent	Within the first year of installation and in years 1, 4 and 7 thereafter
Replaced Appliance of type *k* not properly disposed of in year *y*	$a_{np,k,y}$	-	Disposal documentation and Project proponent database	Annually
The refrigerant charge capacity of the cooling Appliance not properly disposed of.	*RCCa*	Grams	Manufacturer's specification sheet on the cooling Appliance.	Once
Type of refrigerant used in the cooling Appliance.	*R*	-	Manufacturer's specification sheet on the cooling Appliance.	Once
Number of Appliance type	*K*	-	Project proponent database	Once
Number of Appliances of each Appliance type k	a_k	-	Project proponent database	Once

Table 13. Monitoring parameters for mobile homes approach

Parameter Description	Parameter	Unit	Source	Frequency
Heat load of mobile Dwelling *i* to be replaced	$H_{load,pre,i}$	kWh/m^2/HDD GJoules/m^2/HDD	Calculating the heat load by applying a heat load formula with default values derived from reliable regional	Once

			energy consumption data.	
Heat load of replacement Dwelling *i*	$H_{load,post,i}$	kWh/m²/HDD GJoules/m²/HDD	Calculated using best practice heat load modeling based on the specification sheet provided by the manufacturer.	Once
Heating degree days in year *y*	HDD_y	Degree Days	Regional statistics	Annually
Cooling degree days in year *y*	CDD_y	Degree Days	Regional statistics	Annually
Size of Dwelling *i* to be replaced	$S_{pre,i}$	m^2	Project proponent database	Once for each Dwelling
Size of replacement Dwelling *i*	$S_{post,i}$	m^2	Project proponent database	Once for each Dwelling
Electricity demand of Appliance *k* before replacement	$E_{dem,pre,k}$	kW	Nameplate, or manufacturer's specification sheet, or direct metering of the Appliance	Once pre-replacement
Electricity demand of Appliance *k* post-replacement	$E_{dem,post,k}$	kW	Nameplate, or manufacturer's specification sheet, or direct metering of the Appliance	Once post-replacement
Annual working hours of Appliance *k*	h_k	Hours	Sampling, consumer surveys, or common practice based on local, regional or national data	Once, may be updated
Correction factor for the failed operation of type of Appliance *k*	$Corr_k$	-	Surveys conducted by Project proponent	Within the first year of installation and in three year intervals thereafter
Replaced Appliance of type *k* not properly disposed of in year *y*	$a_{np,k,y}$	-	Disposal documentation and Project proponent database	Annually
The refrigerant charge capacity of the cooling Appliance not properly disposed of.	*RCCa*	Grams	Manufacturer's specification sheet on the cooling Appliance.	Once
Type of refrigerant	*R*	-	Manufacturer's	Once

used in the cooling Appliance.			specification sheet on the cooling Appliance.	
Number of retrofitted Dwellings	*l*	-	Project proponent database	Annually

DOCUMENT HISTORY

Version	Date	Comment
v1.0	7 Dec 2010	Initial version.
v1.1	10 Oct 2012	Revised to conform with VCS requirements for standardized methods.

Approved VCS Methodology
VM0009

Version 3.0, 6 June 2014
Sectoral Scope 14

Methodology for Avoided Ecosystem Conversion

This methodology was developed by Wildlife Works and ecoPartners.

About Wildlife Works

Wildlife Works Carbon LLC, one of the world's leading REDD project development companies, was originally established to help local landowners in the developing world to monetize their forest and biodiversity assets, whether they are governments, communities, ownership groups or private individuals.

Wildlife Works pioneered a novel business model that uses the marketplace to bring innovative economic solutions to wildlife conservation, reduce human/wildlife conflict and protect forests in the developing world.

The company's first project at Rukinga, Kenya has been operating for over a decade protecting wildlife and forests. This history has enabled Wildlife Works to launch the Kasigau Corridor REDD project, through which the company has expanded the area under protection to over 500,000 acres. Wildlife Works continues to bring the benefits of direct carbon financing to Kenyan communities, while simultaneously securing a contiguous wildlife migration corridor between Tsavo East and West National Parks.

Building on this successful model, Wildlife Works plans to leverage its experience in Southeastern Kenya to future REDD projects around the globe, with a goal to protect 5 million hectares from deforestation. Wildlife Works is committed to protecting wildlife, forests and biodiversity, with a direct, hands-on approach to creating alternative livelihoods.

Contributing Authors: Jeremy Freund, Mike Korchinsky, Simon C. Bird, Gordon Smith

About ecoPartners

ecoPartners works with project developers, forest owners and verification bodies to build successful forest carbon offset projects. ecoPartners specializes in the technical aspects of project design, planning and development: remote sensing, biometrics and accounting methodologies, with significant experience validating and verifying projects under the Climate Action Reserve (CAR) Standard, Verified Carbon Standard (VCS), and Climate Community & Biodiversity (CCB) Standard. We help our clients navigate methodologies, mitigate risk, build long-term capacity and generate credits.

Contributing Authors: Kyle Holland, Ben Caldwell, Ryan S. Anderson, Wilson Salls, Melanie Jonas, Zach Barbane, Paz Lozano

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Table of PD Requirements

Also see Appendix I

Table of Monitoring Requirements

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Table of Equations

Equations are in Appendices A-F:

1 SOURCES

This methodology was developed based on the requirements in the following documents:

- VCS Standard, v3.4
- AFOLU Requirements, v3.4
- Program Definitions, v3.5

This methodology uses the latest version of the following tools:

- VT0001 Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities
- CDM tool *Estimation of direct and indirect (eg, leaching and runoff) nitrous oxide emission from nitrogen fertilization*
- CDM tool *Tool for testing significance of GHG emissions in A/R CDM project activities*

2 SUMMARY

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

This methodology provides a means to quantify net GHG emission reductions and removals (NERs) from project activities that prevent conversion of forest to non-forest and of native grassland and shrubland to a non-native state. The methodology accounts for emissions from all allowable pools specified by the VCS *AFOLU Requirements* for the REDD and ACoGS project categories, with the exception of peat soils and litter. This methodology can be applied to account for avoided emissions from planned deforestation and degradation (APD), unplanned deforestation and degradation (AUDD), planned conversion (APC), and unplanned conversion (AUC) baseline scenarios. It uses a project method to determine additionality (see section 7).

This methodology differentiates between eight baseline types based on the proximate agent of conversion, the drivers of conversion, whether the specific agent of conversion can be identified, and the progression of conversion (see Figure 2, Section 6.3). A single project may include one or more baseline types. The addition (in this version 3.0) of ACoGS baseline types for native grassland ecosystems means that the applicability of this methodology has been dramatically expanded, and now can be used to address both planned and unplanned conversion in both forest and native grassland ecosystems. For the five baseline types associated with conversion of forest to non-forest, the agent of conversion can include a primary agent and secondary agents, which contribute to a cascade of degradation ultimately leading to a non-forest state.

Under this methodology, project proponents implement project activities in the project area and surrounding region that address the agents and drivers of conversion. When the agents of conversion are not known, they can be identified using expert knowledge or a participatory rural appraisal, which is a type of community survey. In some cases related to planned conversion, the specific agent of conversion may be known. Identifying the agents and drivers of conversion is essential to designing effective project activities to mitigate conversion of forest and native grassland.

The baseline scenario for a project is defined by at least one baseline type (See Figure 3, Section 6.3). Once the agents and drivers of conversion are known, this information can be used to identify baseline types (section 6.3). Each baseline type is characterized by baseline emissions models that are applied to a project accounting area. All project accounting areas must meet either the definition for *forest project accounting area* or *grassland project accounting area*. Parameters to these models are partially determined using a reference area. Descriptions of parameterization methods are described in section 2.1.1, and vary by baseline type. The intent of these models is to provide simplified and unified accounting with clear and user-friendly implementation. This approach dramatically reduces the number of parameters and equations in the methodology relative to prior versions.

Leakage is quantified using an activity-shifting leakage area(s) and a market leakage area(s), which may or may not overlap with the reference area. Like the reference area, the activity-shifting leakage area is defined by the agents and drivers of conversion for each identified baseline type in the baseline scenario. However, unlike the reference area, the activity-shifting leakage area(s) is also defined by proximity to the project area and anticipated directional shifts in conversion activities. The activity-shifting leakage area is more purposeful than a belt or an arbitrary buffer around the project area. The market leakage area is defined when long-lived wood products or agricultural products exist in the baseline scenario, and is used to estimate leakage resulting from a change in the supply of domestic long-lived wood products or agricultural products as a result of illegal or legal-sanctioned logging or agricultural production.

Residual biomass in the baseline scenario is quantified for each baseline type using a proxy area. The proxy area is distinct from the leakage areas, and may or may not overlap the reference area. For example, the reference area must be similar to the project accounting area in regards to various conditions (see section 6) and must be the same size or greater than the project accounting area, whereas the proxy area may be an area smaller than the project accounting area located inside or outside of the reference area. The proxy area(s) characterizes the carbon stocks associated with the end land uses that are non-forest or converted native grassland in the baseline scenario. Some examples of these end land uses may be pasture, subsistence agriculture or mechanized agriculture. The project proponent measures biomass for selected carbon pools in the proxy area. The proxy area must have the same landscape configuration as the project accounting area before conversion and be large enough to accommodate an adequate (per Appendix B and D) sample of measurement plots, but the proxy area need not be as large as the project area. Because the proxy area allows project proponents to include baseline types with end land uses that have significant biomass, such as swidden agriculture, the accounting is complex.

Compared to approaches taken by other REDD and ACoGS methodologies, the approaches used in this methodology deviate significantly in three regards. First, the baseline emissions models predict cumulative emissions over time rather than an aerial rate of ecosystem conversion in hectares per year. Second, important parameters to the baseline emissions models are fit using simple point observations of land use conversion over a historic reference period rather than requiring a series of complex Land Use Land Cover (LULC) classifications of full-coverage satellite imagery. Third, accounting for the various sources of emissions from biomass is dramatically simplified by rolling all sources of potential emissions into a single model and parameterizing the model based on easily understood baseline types (section 6.3).

These approaches make the baseline emissions models particularly attractive to project proponents for several reasons. First, the time required to build the models is relatively short. Almost any type of historical imagery can be used to build the model, including grey-scale aerial, color aerial, panchromatic, satellite, SAR or even Landsat 7 SLC-OFF imagery (despite its failed sensor). Second, despite the fact that cloud contamination may result in limited coverage of the reference area, all collected imagery can be used to build the models in lieu of cloud cover within individual images. Once the imagery is imported into a geographic information system (GIS), data collection for model fitting is performed using simple, heads-up interpretation of point samples from the imagery. As of the publication of this methodology, Wildlife Works maintains an ArcMap GIS extension to automate point interpretation and compute weights (see section 6.8.6), thus further facilitating the use of the baseline emissions models. For all of these reasons, thematic land cover classifications of complete sets of images for each date in the reference period are not necessarily required.

In addition to the relative simplicity and robustness of the baseline emissions models, this methodology differentiates among carbon pools, and thus project proponents will find it particularly attractive. For example, both standing dead wood and lying dead wood are components of the dead wood pool, but standing dead wood is measured using a plot, while lying dead wood is measured using a line transect. Because the dead wood pool is optional, project proponents may choose to conservatively omit lying dead wood. This avoids the added complexity of sampling line transects while still including the optional standing dead wood pool. Such an approach may be preferable to project proponents as measurements of standing dead wood can easily be made at the same time as measurements of aboveground live trees on the same plot.

This methodology monitors carbon stocks using a sample of fixed area plots in the project accounting area(s) and proxy area(s). Lying dead wood is estimated using a line intersect sample, and soil organic carbon (SOC) is estimated using samples removed from soil cores or pits located within the plots used for biomass estimation. This methodology also differentiates between merchantable trees and non-merchantable trees. In addition to improving sampling techniques, this differentiation allows project proponents to characterize the emissions from biomass as a result of logging in the baseline scenario. Additionally, if any livestock are being grazed within the project area, the emissions from these livestock are quantified and if they are found not to be *de minimis,* they will be included in the calculation of project emissions.

Because this methodology uniquely differentiates among carbon pools, each major accounting section is purposely organized by carbon pool to facilitate ease of use; the baseline scenario, baseline emissions and monitoring sections are subdivided by carbon pool. In this way, project proponents may first select carbon pools to include in the project boundary and then easily trace the accounting sections to find the appropriate methods. This is a departure from other methodologies, which typically attempt to account for all pools simultaneously despite the fact that some pools might not be selected for some projects.

Lastly, project proponents will find that this methodology provides cohesive transitions between the concepts that guide accounting while also providing necessary and important details of the accounting procedures themselves. To unify the text and tone of the methodology, complex equations and variables have been omitted from the body and placed in separate appendices. Equations are placed in Appendix F, and many equations are reused and applied in different sections of the methodology. Project proponents should use these appendices side-by-side with the body of the methodology during project development and reporting.

Background information is provided in Appendix A in order to facilitate understanding of the accounting concepts without affecting usability. Appendix B provides methods for estimating carbon stocks which can be used during monitoring of the project accounting area(s), activity-shifting leakage area(s) and proxy area(s). Appendix C provides methods to account for long-lived wood products under the baseline scenario and from project activities.

Appendix F is a comprehensive list of equations, literature sources, assumptions and comments by equation number, and Appendicies G and H include a list of variables, variable descriptions and units. All equations cited in the body of the methodology are hyperlinked by equation number and all equations are hyperlinked by section number back to the sections where they are used. Many defined terms and abbreviations in the text are hyperlinked to their definitions.

Project proponents considering this methodology for their project are encouraged to contact Wildlife Works for resources and technical assistance.

2.1 Core Concepts in Accounting

Accounting is underpinned by observing specially-defined areas and by specifying the baseline emissions models using time-lag shifts. The baseline emissions models are parameterized for, and applied to, project accounting areas within the project area, each having a unique baseline type. All projects must have at least one project accounting area and therefore at least one set of baseline emissions models. Projects may have more than one project accounting area, and likewise, multiple sets of baseline emissions models.

2.1.1 Emissions Models

The underlying mechanics of this methodology utilize four types of emissions models. The first two relate to the baseline scenario and are referred to as the baseline emissions models. The baseline emissions models include the Biomass Emissions Model (BEM) and Soil Emissions Model (SEM) that characterize the baseline scenario for each accounting area to estimate avoided baseline emissions from forest degradation, land-use conversion and subsequent soil carbon loss. These baseline emissions models may appear complex, but their parameterization and implementation are fairly straightforward. Depending on the baseline type, model parameters are selected from defaults or estimated from data.

The BEM and SEM do not account for carbon stored in long-lived wood products or the decay of carbon in dead wood, below-ground biomass or soil. These emissions are accounted for using Appendix C and the Decay Emissions Model (DEM). The fourth model is the Leakage Emissions Model (LEM) which accounts for emissions from activity-shifting leakage. Project emissions are accounted for separately from the models to determine gross credit generation. Net credit generation is determined by subtracting deductions for contributions to the AFOLU Pooled Buffer Account.

To aid modeling, parameters must match the time scale of the data from which they are derived. For example, if data were collected on a specific day – such as a Landsat image – that specific date must be used. If data is collected on a longer time scale (eg, monthly or annually), that time scale must also be used consistently. See section 6.7.1 for further explanation on how to convert large time scales to a specific day for the purposes of modeling emissions. From a vintage perspective, it is desirable to use a number of days to determine the proportion of emissions reductions or removals that occur in part of a calendar year when monitoring periods are not defined by the first of the year.

2.1.2 Areas

The concept of an area is to specify a location where emissions are characterized or measured. This methodology uses six types of areas (see Table 1). The project area is the area under control of the project proponent and is where the project activities may be implemented to address the agents and drivers of conversion, thus preventing emissions from the project accounting area(s).

The project accounting area is an area within the project area that is subject to conversion under the baseline scenario and is associated with a baseline type. All project accounting areas must meet the definition for either *forest project accounting area* or *grassland project accounting area*. In some cases where there exists multiple baseline types for one project area, there will be multiple project accounting areas within a single project area (see Figure 1). In this methodology, the general term *project accounting area* is used when instructions or requirements cover both forest project accounting areas and grassland project accounting areas. The terms *forest project* *accounting area* or *grassland project accounting area* are used when instructions or requirements specifically apply to only forested or native grassland baseline types.

Associated with each project accounting area is a reference area that is located in the same region as the project area and where historical conversion is observed. The reference area is similar to the project accounting area in most respects, and represents what would have happened to the project accounting area in the baseline scenario over time. The baseline scenario is further characterized using proxy areas, and one proxy area must be defined for each identified baseline type. The proxy area is defined in much the same way as the reference area. Like the project accounting area, the carbon pools in the proxy area are measured through monitoring to establish the residual carbon stocks after conversion.

Finally, emissions from leakage are measured using an activity-shifting leakage area and a market leakage area. A market leakage area is required only when the baseline scenario includes commercial logging. The activity-shifting leakage area is defined similarly to the reference and proxy areas, but also relative to the proximity of agents of conversion. An activity-shifting leakage area is associated with each project accounting area. The definition of the market leakage area is similar, but must be selected based on where baseline logging entities could shift their production. If the baseline scenario includes illegal or legally-sanctioned commercial logging, there will be no more than one market leakage area.

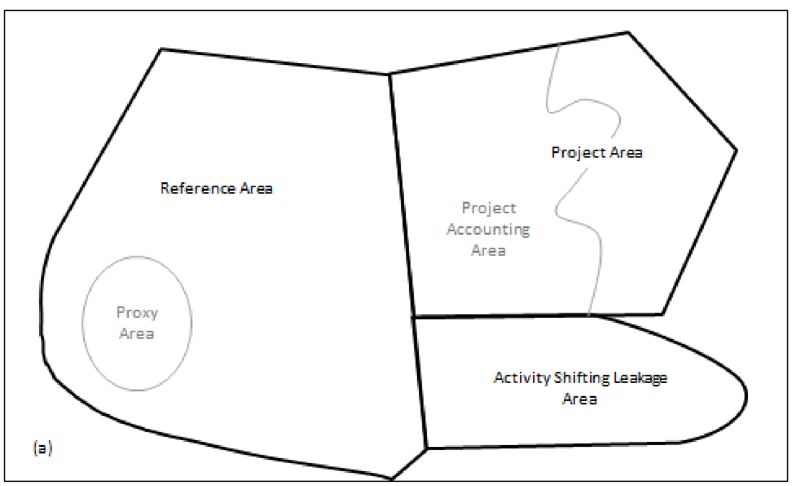
Table 1: Description of carbon accounting areas. For exact definitions, please see section 3.

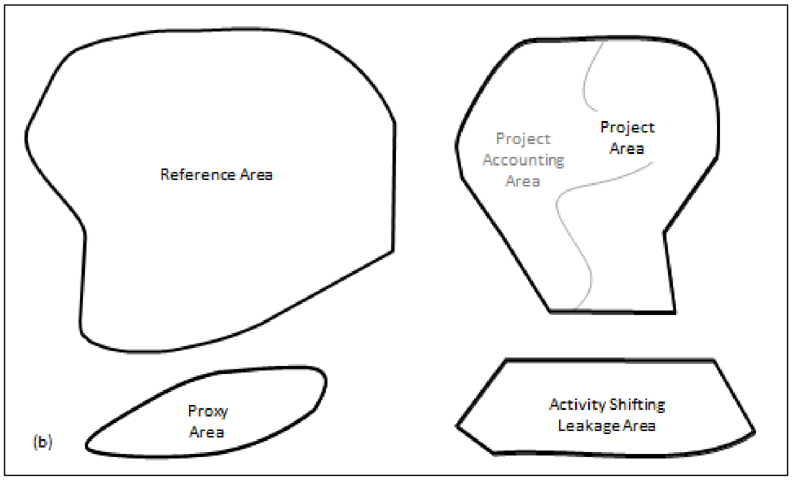
Area	Description	Quantity	Size relative to project area
Project area	The area under control of the project proponent which contains at least one project accounting area.	Only one	Equal
Project accounting area	The area to which the *baseline emissions models* are applied. A forest or native grassland area within the project area that is subject to conversion in the *baseline scenario* as delineated by section 6.2.	One for each identified baseline type	Less than or equal
Reference area	An area in the same region as the project area that is similar to the project area in regards to acting agents of conversion, acting drivers of conversion, socio-economic conditions, cultural	One for each identified baseline type	Greater than or equal

	conditions and landscape configuration.		
Proxy area	The area where residual carbon stocks (after conversion, the end state) are estimated for each baseline type.	One for each identified baseline type	No prescribed size
Activity-shifting leakage area	The area where *leakage* resulting from the activities of the agent of conversion would likely occur due to the *project activity* (ies).	One for each identified baseline type	No prescribed size
Market leakage area	The area where *leakage* would likely occur resulting from a change in the supply of wood products due to the *project activity* (ies).	One if the baseline scenario includes commercial logging	No prescribed size

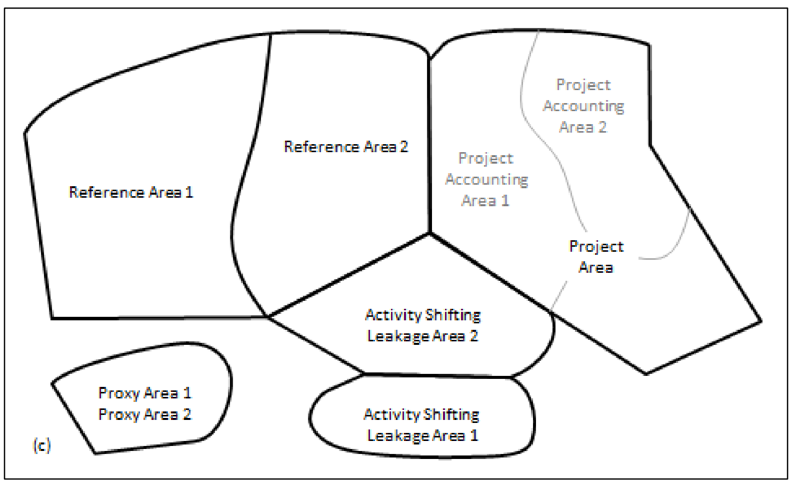
Figure 1: Three example configurations of areas for a single project instance (see section 3.1 for abbreviations).

(a-b) A project area containing one project accounting area, one associated reference area, proxy area and activity-shifting leakage area.





(c) A project area containing two project accounting areas, and an associated reference area, proxy area and activity-shifting leakage area for each project accounting area. The proxy areas happen to be identical.



2.1.3 Shifts

The concept of a shift is to account for temporal differences in the onset of degradation and conversion in the baseline scenario relative to historic observations in the reference area. A shift could also account for the delay between the beginning of degradation and ultimately conversion. Shifts are mathematical expressions or parameters that adjust terms of the baseline emissions models so that the parameterized models reflect a defensible baseline scenario.

Although not always explicitly defined as shifts in the text, several shifts are employed in this methodology depending on the baseline type for a particular project accounting area. For most projects, the baseline emissions models are affected by a shift to apply historic observations made in the reference area to the project accounting area after the project start date. Another shift is associated with emissions from soil relative to degradation because these emissions are assumed to occur after conversion.

2.2 Notation

The notation used in this methodology is intended to clearly communicate the variables and mathematical processes intended for quantifying carbon stock and project greenhouse gas benefits. The notation adopted differs in some ways from that seen in other forest carbon methodologies. These deviations improve the clarity and readability of this document.

2.2.1 Equations

Equations in this methodology are numbered and bracketed (eg, [F.7]). The equations themselves are located in Appendix F and are referenced in the text by number. The intent is that Appendix F will be printed and used as a separate document in conjunction with the text of the methodology. Equations in Appendix F contain additional information including citations, literature sources and comments.

In some instances, similar operations are performed on different variables in multiple places. For example, estimating above-ground carbon stock in the merchantable tree, non-merchantable tree, and non-tree biomass pools involve summing plot level measurements, dividing by plot area, summing across plots in a stratum, and multiplying by stratum area. A generic equation is given to estimate each pool and the relevant variable or equation can be substituted for x as indicated by the methodology.

2.2.2 Variables

Variables in this methodology and their units are enumerated in the list of variables in Appendix G and H. The intent is that Appendix G and H will be printed and used as a separate document in conjunction with the text of the methodology. For most of these variables, their units are in tonnes of carbon dioxide equivalents. The variables x and y (with and without subscripts) are sometimes used as placeholder variables — they may stand in for another variable or the results of an equation as indicated by the methodology text. The variables x and y are also used to indicate geographic coordinates in the development of the conversion and soil carbon loss models in the baseline scenario section (see section 6). The meaning of these variables should be clear based on the context provided in the methodology text.

2.2.3 Summations

Summations use set notation. Sets of variables are indicated using script notation. For example, $\mathcal{S}$ represents the set of all strata in the project area, while $\mathcal{P}_k$ represents the set of all plots in stratum k. Set notation greatly reduces the number of variables used in the methodology as well as the complexity of summations.

2.2.4 Elements

Elements of a set are denoted using subscript notation. A sum over the elements of a set is indicated by the notation $\sum_{k \in \mathcal{S}} A_k$. This particular example sum indicates the sum of the area of all strata, where A_k indicates the area of stratum k. The number of elements in a set is indicated by functional notation $\#(\mathcal{S})$ where the pound sign stands for “count of”.

2.2.5 Standard Deviations and Variances

Standard deviation is indicated by the σ symbol, with subscripts used to indicate the quantity for which it is estimated. Variance is indicated by the σ^2 symbol and is the square of standard deviation. Standard deviations may not be in units tCO2e.

2.2.6 Standard Errors

Estimated standard error is indicated by the U symbol, with additional subscripts used to indicate the quantity for which the uncertainty is estimated. Standard errors are always in units tCO2e.

2.2.7 Theoretical Parameters and Parameterized Models

Parameters to model are denoted by variables, such as the project shift parameter γ. When such parameters have a “hat” on them – such as the parameter $\hat{\gamma}$ – they refer to a value rather than a theoretical, unknown quantity.

2.2.8 Monitoring Periods

Monitoring periods are notated using bracketed superscripts $[m]$. The first monitoring period is denoted by $[m = 1]$, the second monitoring period $[m = 2]$ and so forth. The superscript [m=0] is used to indicate the value of carbon pools at project start. These values remain constant throughout the project crediting period. In the case where project validation and the first verification event fall on the same date, then [*m=0*] parameters will be equal to [*m=1*] parameters. These superscripts should not be confused with references to equation numbers, as equation numbers are never in superscript. Nor should they be confused with powers of numbers which are not enclosed in brackets. Also see the definition for monitoring period. A monitoring event is the reporting and verification of NERs claimed for a monitoring period.

2.2.9 Baseline, Project and Leakage Estimates

Estimates related to emissions, emissions reductions, emissions removals, and carbon stocks for the baseline, project, and leakage are specifically denoted with B, P and L in the subscripts of variables, respectively.

2.2.10 Averages for Carbon Pools

Average carbon (measured by tCO2e/ha) to which accounting is applied is denoted by a lower-case c, with subscripts to differentiate between carbon pools as indicated in the list of variables. For example, $c_{P\ AGMT}^{[m]}$ indicates the average carbon stock in above-ground merchantable trees in the project area in monitoring period $[m]$. Subscripts from carbon pools are acronyms listed in section 3.1.

2.2.11 Totals for Carbon Pools

Total carbon (measured by tCO2e) to which accounting is applied is denoted by a capital C, with subscripts to differentiate between carbon pools as indicated in the list of variables. For example, $C_{AGMT}^{[m]}$ indicates the total carbon stock in above-ground merchantable trees in monitoring period $[m]$. Subscripts from carbon pools are acronyms listed in section 3.1.

2.2.12 Emissions for Carbon Pools and Decay Sources

Total emissions (measured by tCO2e) from accounting are denoted by a capital E, with subscripts to differentiate between carbon pools as indicated in the list of variables. For example, $E_{B\ AGMT}^{[m]}$ indicates the total emissions from above-ground merchantable trees at monitoring period $[m]$ in the baseline scenario. Subscripts from carbon pools are acronyms listed in section 3.1.

2.2.13 Quantified Uncertainties

Uncertainties in major carbon pools are expressed as standard error SE (measured by tCO2e) and are denoted using a capital letter U. For example, $U_{P}^{[m]}$ is used to indicate the uncertainty in estimated total carbon stocks for selected carbon pools in the project accounting area at monitoring period $[m]$.

2.2.14 Vectors

Vectors are indicated using bold face; for example $\boldsymbol{\theta}$ is the vector of covariate parameters to the logistic function of conversion are described in section 6.8. This vector may include numerous elements such as the numeric effects of population density, road density or per-capita household income on predicted conversion.

2.2.15 Matrices

Matrices are intentionally not used in this methodology to avoid complexity and confusion.

2.3 Application Overview

This methodology may be applied in multiple ways and at different stages of project development. For the purposes of project validation, when monitoring data are not yet available, literature estimates for carbon stocks in selected carbon pools may be used (see section 8.4.7). If validation and the first verification occur simultaneously, measurements from monitoring may be used to estimate carbon stocks. During subsequent monitoring events, direct measurements from the various areas must be used to calculate NERs.

Upon the first application of the methodology to a project, project proponents must identify the project area per section 5, and the baseline scenario per section 6. The process will result in at least one project accounting area and one associated reference area. For many project proponents, the project area will be the area to which the project proponent has legal title to the carbon stocks in the selected carbon pools. For REDD and ACoGS projects, the boundaries of the project area may be protected as a project activity.

The baseline scenario may be identified using expert knowledge or a PRA (see Appendix E). Depending on the identified agents and drivers of conversion, the baseline scenario may contain several baseline types. For instance, a portion of the project area may be subject to legally-sanctioned commercial logging which ultimately results in non-forest while a different portion of the project area may be subject to land use conversion caused by charcoal production. Because the agents and drivers are different, the project proponent must define two baseline types in the project's baseline scenario. In this example, one baseline type is F-P1.a and the other may be type F-U1.

For each identified baseline type, project proponents must delineate project accounting areas within the greater project area (see section 6.2). Likewise, the project proponent must delineate a reference area to parameterize the baseline emissions models (see section 6.8.1), a proxy area to estimate residual carbon stocks in the baseline scenario (see section 6.4), and an activity shifting leakage area (see section 8.3.2.1) for each identified baseline type. For most projects, there will be only one baseline type and hence one project accounting area, reference area, proxy area and activity shifting leakage area. For some projects, the project accounting area may encompass the entire project area.

Once baseline types and areas have been defined, the baseline emissions models must be parameterized. For validation purposes, a small sample size of 300 interpretation points in each reference area may be used to estimate the conversion parameters, while for verification purposes a larger sample size should be used (see section 6.8). If a small sample size is selected to estimate the conversion parameters for verification purposes, the calculation of NERs may be reduced as a result of a confidence deduction (see section 8.4.1.1). Likewise, for the estimation of carbon stocks in the project accounting areas and the proxy areas, a small sample size of measurement plots may result in a confidence deduction. The confidence deduction is an incentive for project proponents to invest adequate amount of time and money into model parameterization and carbon stock monitoring without prescribing absolute requirements on sample sizes.

For validation and verification purposes, the project proponent must document the project design and calculated NERs using the Project Description Requirements (PD Requirements) and the Monitoring Requirements. Demonstration of these requirements may be presented in a document(s) referenced from the PD or monitoring reports, or in the PD or monitoring reports themselves. Demonstration of these requirements along with completed, VCS-approved templates must be provided to the Validation/Verification Body (VVB). Project proponents must note that in addition to the Project Description Requirements and the Monitoring Requirements, projects must adhere to all VCS rules when applying this methodology (ie, the PDRs and MRs cover all the requirements of this methodology, but they do not necessarily cover each and every VCS requirements relevant to the project).

Once the baseline emissions models have been validated, the project proponent need only monitor carbon stocks in the project accounting areas and proxy areas, and monitor degradation in the activity shifting leakage areas. The project proponent may choose to monitor log production as a result of project activities in the project area to determine carbon stored in wood products. The project proponent may also choose to monitor the burning of biomass as a result of project activities. However, most project emissions will be captured in the re-measurement of plots in the project accounting areas even if there is a natural disturbance event or logging after the project start date.

3 DEFINITIONS

3.1 Definitions

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions and acronyms apply to this methodology:

Activity-Shifting Leakage Area
The area where leakage resulting from the activities of the agent of conversion would likely occur due to the project activity(ies).

Agent of Conversion
People, groups of people or organizations responsible for degradation and deforestation or native grassland conversion.

Allometric Equation
A statistical model used to predict biomass given the measurement of closely related attributes of a tree or shrub, such as diameter (DBH) or stem count.

Baseline Type
One of five types that address the AFOLU Requirements for planned, unplanned mosaic and unplanned frontier conversion.

Baseline Emissions
For any monitoring period, baseline emissions $E_{B\,\Delta}^{[m]}$ are a sum of estimated emissions over selected carbon pools and time between monitoring events.

Baseline Emissions Models
The Biomass Emissions Model and Soil Emissions Model that characterize the baseline scenario.

Baseline Reevaluation
Revision of the baseline scenario which occurs at least every 10 years (see section 6.20).

Biomass Emissions Model (BEM)
A model that characterizes the emissions from biomass in the baseline scenario.

Carbon Fraction
The proportion of biomass that is carbon, which may vary by species.

Cascade of Degradation
A primary agent and secondary agent(s), and their associated drivers, that eventually degrade the forest to a non-forest state. The secondary agents are ultimately responsible for deforestation.

Class of Agents
A group of agents of conversion that share the same driver of conversion.

Conversion
The removal or replacement of vegetation and/or disturbance of soil.

Conversion Parameters
the parameters of the baseline emissions models that describe the behavior of degradation and conversion over time.

Covariate
A variable possibly predictive of the outcome under study; in this case quantifiable social, economic, or political factors that may improve model fit.

Decay Emissions Model (DEM)
A model that characterizes the exponential decay of certain carbon pools in the baseline scenario or as result of project activity (ies).

Degradation
Please see current VCS definition. In addition, degradation can include any intermediate state of conversion.

Drivers of Conversion
Geographic, climatic or other physical, social and/or economic conditions that cause conversion.

Emissions Model
One of the four emissions models (Biomass Emissions Model, Soil Emissions Model, Decay Emissions Model or Leakage Emissions Model).

End Land Use
The utility of a discrete piece of land that is on average over its area non-forest (eg, pasture land, grazing land, open pit mines, urban living space, subsistence agriculture or mechanized agriculture).

Foreign Agents
Groups originating outside the region in which the project resides (eg, a group of settlers that emigrates a far distance inland from the coast).

Forested Project Accounting Area
A project accounting area that meets the definition of forest as of the project start date and for at least 10 years prior to the project start date.

Forested
Meets the definition of forest on average across the area to which it is applied.

Grassland Conversion
The conversion of grassland in its natural state to one of anthropogenic use (eg, agriculture, development (including housing) or other anthropogenic land-use discernable from remotely sensed imagery). Conversion to grazing lands and/or pasture is excluded from this definition.

Grassland Project Accounting Area
A project accounting area that meets the definition of *native grassland* or *shrubland* as of the project start date and for at least 10 years prior to the project start date.

Imminent Conversion
The risk of land use change in a portion of the project accounting area and within 10 years of the project start date by the agents of conversion.

Leakage Emissions Model
A model that characterizes the emissions from leakage under conditions that would have occurred in the activity-shifting leakage area had the project activity (ies) not been implemented.

Log Production
The carbon in logs removed from a logging unit onto a landing which is subsequently processed and a portion turned into long-lived wood products.

Long-Lived Wood Products
Products derived from the harvested wood of a merchantable tree such as sawn timber and plywood that are assumed to remain or decay during the project crediting period.

Market Leakage Area
The area where leakage would likely occur resulting from a change in the supply of wood products due to the project activity(ies).

Merchantable Tree
A tree containing wood of commercial value, size, and desirable quality.

Monitoring Period
An interval of time following the project start date and project crediting period start date designated for systematically verifying project claims of GHG emissions reductions and/or removals and project additionality. Specifically, an interval of time from $t^{[m-1]}$ to $t^{[m]}$ where

$t^{[m-1]} \geq 0$ (the project crediting period start date) and $t^{[m-1]} < t^{[m]}$. The length of the monitoring period is $t^{[m]} - t^{[m-1]}$ where m denotes the number of any single monitoring period and t the number of days after the project crediting period start date that is the end of the monitoring period. The length of each monitoring period must be less than or equal to five years.

Native Ecosystem

Please see current VCS definition. A native ecosystem must include indigenous species, but does not need to be exclusively indigenous.

Native Grassland

A grassland which includes indigenous grass species, and may include some density of trees too low to be defined as forest (such as a woodland). There may exist some patches of forest which meet the definition of forest, but an area defined as native grassland does not meet the definition of forest, on average, across the area.

Native Shrubland

A shrubland which includes indigenous shrub and woody species, and may include some density of trees too low to be defined as forest. There may exist some patches of forest which meet the definition of forest, but an area defined as native shrubland does not meet the definition of forest, on average, across the area.

Net GHG Emission Reductions and Removals (NERs)

Tonnes of carbon dioxide equivalent (tCO_2e) emissions that are reduced or removed from the atmosphere due to project activities during the project crediting period.

Non-Decay Pool

A carbon pool that does not decay over time.

Non-Forest

Not meeting the country-specific definition of forest.

Non-Merchantable Tree

All other trees that do not meet the definition of a merchantable tree.

Non-Tree Biomass

Biomass that includes grasses, sedges, herbaceous plants and non-tree woody biomass.

Non-Tree Woody Biomass

Biomass that includes woody shrubs and any trees too small for carbon stock estimation using the allometric equation derived or selected for trees.

Participatory Rural Appraisal
A voluntary survey of the populace surrounding the project area that can be used to identify the agents and drivers of conversion, delineate the reference area, and identify strategies to mitigate conversion in the project area.

Peat Soil
See current VCS definition for peatland.

Permanent Plot
A plot with fixed area and location used to repeatedly measure change in carbon stocks over time.

Planned Commercial Deforestation
A deforestation scenario where the immediate agent of deforestation is known and there is commercial harvest in the baseline scenario (baseline type F-P1.a and F-P1.b).

Planned Non-Commercial Conversion
A conversion scenario where the immediate agent of conversion is known and there is no commercial harvest of wood products in the baseline scenario (baseline type F-P2 and G-P2).

Primary Agent
An agent of conversion that initiates cascade of degradation ultimately leading to conversion. Without the primary agent, conversion would not occur.

Project Accounting Area
An area within the project area that meets the definition of forest or native grassland and is subject to conversion in the baseline scenario. All project accounting areas will meet the definition of either a forest project accounting area or grassland project accounting area.

Project Area
The area controlled by the project proponent where project activities may be implemented.

Project End Date
The date of the end of the last monitoring period and the conclusion of the Project Crediting Period.

Project Emissions
Emissions for any monitoring period $[m]$ as estimated by the events of woody biomass consumption.

Project Shift Period
The period of time between conversion observed in the reference area and the project start date, denoted by γ.

Project Performance
A comparison of ex-post credit generation to ex-ante estimates over time.

Proxy Area
The area where residual carbon stocks (after conversion, the end state) are estimated for each baseline type.

Reference Area
An area in the same region as the project area that is similar to the project accounting area in regards to acting agents of conversion, acting drivers of conversion, socio-economic conditions, cultural conditions and landscape configuration. This area is used to estimate the conversion parameters (see section 6.8.1).

Reference Period
A historic period of time in the same region as the project that is similar in acting agents of conversion, acting drivers of , socio-economic conditions, cultural conditions and landscape configuration to the project area.

Secondary Agent
An agent of conversion that follows after the primary agent in the cascade of degradation ultimately leading to conversion. A secondary agent may not be present for conversion to occur.

Shrubland Conversion
The conversion of shrubland in its natural state to one of anthropogenic use (eg, agriculture, development (including housing) or other anthropogenic land-use discernable from remotely sensed imagery). Conversion to grazing lands and/or pasture is excluded from this definition.

Soil Emissions Model (SEM)
A model that characterizes the emissions from SOC in the baseline scenario.

Specific Agent of Conversion
An agent of conversion that can be identified by name and that resides in a known area, and that is directly responsible for conversion or the beginning of cascade of degradation.

Stratification
The process of grouping homogenous subgroups of a given population to reduce sampling measurement error.

Temporal Project Boundary
The period of time when conversion is mitigated in the project area as a result of project activities, the boundaries of which are defined by the project start date and project end date.

Threatened Perimeter
The perimeter of the project area that is vulnerable to conversion by being accessible to the local agents of conversion.

Type of Agent
Either a primary agent or a secondary agent.

Unplanned Conversion
A conversion scenario where the immediate agent of conversion is unknown (baseline type F-U1, G-U1, F-U2, G-U2 and F-U3).

Woody Biomass
Biomass resulting from secondary growth.

3.2 Acronyms

ACoGS	Avoided Conversion of Grasslands and Shrublands
AGMT	Above-ground merchantable tree (see merchantable tree)
AGOT	Above-ground other tree (see non-merchantable tree)
AGNT	Above-ground non-tree
AFOLU	Agriculture, Forestry and Other Land Use
APC	Avoided Planned Conversion
APD	Avoided Planned Deforestation
AS	Activity-shifting
AUC	Avoided Unplanned Conversion
AUDD	Avoided Unplanned Deforestation and Degradation
B	Baseline
BA	Buffer account
BE	Baseline emissions
BEM	Biomass Emissions Model
BGB	Below-ground biomass

BGMT	Below-ground merchantable tree
BGOT	Below-ground other tree
BGNT	Below-ground non-tree
BR	Baseline reevaluation
BRN	Burning of biomass
CF	Carbon fraction
CON	Conversion
D	Decay
DBH	Diameter at breast height
DEG	Degradation
DEM	Decay Emissions Model
DF	Deforestation
DMD	Demand
DOM	Domestic
DNA	Designated National Authority
DW	Dead wood
EM	Emissions models
F	Forest
FAO	Food and Agriculture Organization
G	Grassland
GERs	Gross Emission Reductions
GHG	Greenhouse gas
GIS	Geographic Information System
GLB	Global

IPCC	Intergovernmental Panel on Climate Change
IRLS	Iteratively Reweighted Least Square
ISO	International Organization for Standardization
L	Emissions from leakage
LD	Lying dead wood
LEM	Leakage Emissions Model
LS	Livestock
LTR	Litter
MC	Moisture content
ME	Market leakage
MR	Monitoring requirement
NERs	Net GHG Emission Reductions and/or Removals
P	Project
PA	Primary Agent
PD	Project Description
PDR	Project description requirement
PE	Project emissions
PX	Proxy area
RA	Reference area
REDD	Reduced Emissions from Deforestation and Degradation
RMSE	Root Mean-Squared Error
PA	Project area
PAA	Project accounting area
PAI	Project activity instance

PRA	Participatory Rural Appraisal
RS	Root-to-shoot ratio
SEM	Soil Emissions Model
SA	Secondary agent
SD	Standing dead wood
SE	Standard error
SF	Synthetic fertilizer
SL	Slash
SP	Spatial algorithm
SPC	Species
SOC	Soil organic carbon
SUP	Supply
UNFCCC	United Nations Framework Convention on Climate Change
VVB	Validation/Verification Body
VCS	Verified Carbon Standard
VCSA	Verified Carbon Standard Association
VCU	Verified Carbon Unit
WP	Long-lived wood products

4 APPLICABILITY CONDITIONS

This methodology applies to project activities that prevent conversion of forest to non-forest and of native grassland to a non-native state.

This methodology is applicable under the following conditions:

1. The drivers and agents of conversion in the baseline scenario must be consistent with those described in section 6 of this methodology, and the end land use in the baseline scenario is non-forest (in the case of REDD project activities) or converted native

grassland (in the case of ACoGS project activities). Accordingly, the project activity must be APD or AUDD for forested project accounting areas and APC or AUC for grassland project accounting areas.

2. All project accounting areas must have been in an unconverted state (ie, forest or native grassland) for at least 10 years prior to the project start date, according to the following:
    a. Land in all forested project accounting areas has qualified as forest, on average, across the project accounting areas, as defined by FAO 2010 or by the residing designated national authority (DNA) for the project country for a minimum of 10 years prior to the project start date.
    b. Land in all grassland project accounting areas has qualified as native grassland or shrubland for a minimum of 10 years prior to the project start date.
3. For project accounting areas with an unplanned baseline type, a conversion threat must exist for each project accounting area as demonstrated by one of the following two options:
    a. Imminent conversion (see definition) must be predicted by a survey, where more than 60% of respondents predict the end land use identified in the baseline scenario. The survey must meet the requirements of Appendix E.

       OR
    b. As of the project start date, some point within 2 kilometers of the perimeter of the project accounting area has been converted to the end land use identified in the baseline scenario[1].
4. In the case of baseline type F-U1, at least 25% of the project area boundary is within 120 meters of deforestation and at least 25% of the project area boundary is adjacent to the reference area (see section 6.3).
5. In the case of baseline type G-U1, at least 25% of the project area boundary is adjacent to the reference area (see section 6.3).
6. In the case of baseline type F-U2, at least 25% of the project area boundary is within 120 meters of deforestation (see section 6.3).
7. The project accounting area(s) must not contain peat soil.
8. For each project accounting area, a reference area can be delineated for each baseline type in the baseline scenario that meets the requirements, including the minimum size requirement, of section 6.8.1 of this methodology.
9. As of the project start date, historic imagery of the reference area(s) exists with sufficient coverage to meet the requirements of section 6.8.4 of this methodology.

[1] The appropriateness of the 2 kilometer proximity is described in Broadbent et al., 2008.

10. Project activities are planned or implemented to mitigate ecosystem conversion by addressing the agents and drivers of conversion as described in section 8.3.1 of this methodology.

11. The project proponent has access to the activity-shifting leakage area(s) and proxy area(s) to implement monitoring (see sections 8.3.2.1 and 6.4), or has access to monitoring data from these areas for every monitoring event.

12. If logging is included in the baseline scenario and a market leakage area is required as per section 8.3, then the project proponent has access to (or monitoring data from) the market leakage area if measurement is needed (see section 8.3.3).

13. This methodology is applicable to all geographies. However, if SOC is a selected carbon pool and the default value from section 6.19.2 is selected, then the project must be located in a tropical ecosystem.

14. If livestock are being grazed within the project area in the project scenario, there must be no manure management taking place, as emissions from N_2O as a result of manure management are not quantified or addressed in this methodology.

15. For ACoGS project types, project activities must not result in significant GHG emissions. All GHG emissions from project activities must be shown to be *de minimis* (see section 8.3.1).

PD Requirements: Applicability Conditions
The project description must include the following: **PDR.1** For each applicability condition, a statement of whether it applies to the project. If the applicability condition does not apply to the project, justification for this conclusion. **PDR.2** Where applicability conditions apply, credible evidence in the forms of analysis, documentation or third-party reports to satisfy the condition. **PDR.3** Definition of forest used by the project proponent and its source.

5 PROJECT BOUNDARIES

The physical and temporal constraints of the project as well as the greenhouse gases and carbon pools must be clearly delineated and defined by the project proponent. Bounds must conform to the latest VCS requirements and this methodology, and must be clearly and objectively defined to facilitate monitoring and evaluation per the requirements in this section.

5.1 Delineating the Spatial Boundaries

The project area may be a combination of forest, non-forest, native grassland, or converted native grassland. However the baseline emissions models can only be applied to the forest or native grassland areas subject to conversion in the baseline scenario (see section 6.2). Project accounting areas, on average over their entirety, must meet the definition of forest or native grassland given in section 3 (this means that not every stratum must meet the definition of forest or native grassland). The project area may consist of multiple contiguous or non-contiguous parcels.

The geographic or physical boundaries of the project area must be clearly delineated using, at minimum, the following:

- Name of the project area (compartment or allotment number, local name)
- Digital maps of the area, including geographic coordinates of vertices
- Total land area
- Details of ownership, including user rights and/or land tenure information
- Topography
- Roads
- Major rivers and perennial streams
- Land use/vegetation type classification

The size of the project area cannot increase after the end of the first monitoring period.

PD Requirements: Spatial Project Boundaries
The project description must include the following: **PDR.4** A digital (GIS-based) map of the project area with at least the above minimum requirements for delineation of the geographic boundaries. **PDR.5** Credible documentation demonstrating control of the project area.

Monitoring Requirements: Spatial Project Boundaries
The monitoring report must include the following: **MR.1** A digital (GIS-based) map of the project area with at least the above minimum requirements for delineation of the geographic boundaries.

5.2 Defining the Temporal Boundaries

Temporal boundaries define the period of time when degradation, deforestation and conversion in the project area are mitigated by project activities.

The following temporal boundaries must be defined:

- The project start date.
- The project crediting period (projects may use an historical crediting period under specific circumstances, consistent with current VCS rules).
- The length of the project crediting period.
- The dates and periodicity of baseline reevaluation and monitoring periods. A baseline reevaluation after the project start date and monitoring must conform to the current VCS requirements.

The project crediting period start date may occur after the project start date. If the project crediting period start date is more than 10 years after the project start date, then as of the project crediting period start date, a baseline reevaluation must occur prior to the end of the first monitoring period (see section 6.20).

PD Requirements: Temporal Project Boundaries	
The project description must include the following:	
PDR.6	The project start date.
PDR.7	The project crediting period start date and length.
PDR.8	The dates for mandatory baseline reevaluation after the project start date.
PDR.9	A timeline including the first anticipated monitoring period showing when project activities will be implemented.
PDR.10	A timeline for anticipated subsequent monitoring periods.

Monitoring Requirements: Temporal Project Boundaries	
The monitoring report must include the following:	
MR.2	The project start date.
MR.3	The project crediting period start date, end date and length.

5.3 Gases

Project proponents must account for significant sources of the following included greenhouse gases as specified in Table 2.

Table 2: Included GHG Sources

Gas	Sources	Inclusion	Justification
CO_2 (Carbon Dioxide)	Flux in carbon pools	Yes	Major pool considered in the project scenario
CH_4 (Methane)	Burning of biomass	No	Conservatively excluded
	Livestock	Yes	A required source when emissions from grazing are not *de minimis*
N_2O (Nitrous Oxide)	Burning of biomass	No	Conservatively excluded
	Livestock	No	Excluded on the basis of applicability condition 14.
	Synthetic fertilizer	Yes	Included if not *de minimis*

5.4 Selecting Carbon Pools

Project proponents must account for the required carbon pools and may additionally select from the optional pools listed in Table 3 for forested project accounting areas and Table 4 for grassland project accounting areas.

Table 2: Required and Pptional Carbon Pools for Forested Project Accounting Areas and Justifications.

Pool		Required	Justification
AGMT	Above-ground merchantable tree	Yes, if baseline scenario or project activity (ies) include the harvest of long-lived wood products. Otherwise, accounting for this carbon pool is not required.	Major pool considered when accounting for emissions from long-lived wood products
AGOT	Above-ground other (non-merchantable) tree	Yes	Major pool considered

AGNT	Above-ground non-tree	Yes, if the baseline scenario includes perennial tree crops. Otherwise, accounting for this carbon pool is optional.	May be conservatively excluded, though it is not conservative to exclude if the baseline scenario includes perennial tree crops
BGMT	Below-ground merchantable tree	Optional	May be conservatively excluded
BGOT	Below-ground other (non-merchantable) tree	Optional	May be conservatively excluded
BGNT	Below-ground non-tree	Optional	May be conservatively excluded
LTR	Litter	No	Always conservatively excluded
DW	Dead wood	Yes, if AGMT is selected	May be a significant reservoir from slash under the baseline scenario
SD	Standing dead wood	Optional	May be conservatively excluded
LD	Lying dead wood	Optional	May be conservatively excluded
SOC	Soil organic carbon	Optional	May be conservatively excluded
WP	Long-lived wood products	Yes, if AGMT is selected	May be a significant reservoir under the baseline scenario

Table 3: Required and optional carbon pools for grassland project accounting areas and justifications.

Pool		Required	Justification
AGMT	Above-ground merchantable tree*	Yes, if baseline includes perennial crops. Otherwise, accounting for this carbon pool is optional	May be conservatively excluded
AGOT	Above-ground other (non-merchantable) tree*	Yes, if baseline includes perennial crops. Otherwise,	May be conservatively excluded

		accounting for this carbon pool is optional	
AGNT	Above-ground non-tree*	Yes, if baseline includes perennial crops. Otherwise, accounting for this carbon pool is optional	May be conservatively excluded
BGMT	Below-ground merchantable tree*	Optional	May be conservatively excluded
BGOT	Below-ground other (non-merchantable) tree*	Optional	May be conservatively excluded
BGNT	Below-ground non-tree*	Optional	May be conservatively excluded
LTR	Litter	No	Always conservatively excluded
DW	Dead wood*	Optional	May be conservatively excluded
SD	Standing dead wood*	Optional	May be conservatively excluded
LD	Lying dead wood*	Optional	May be conservatively excluded
SOC	Soil organic carbon	Optional	May be conservatively excluded
WP	Long-lived wood products	No	De minimis

*To avoid confusion, this methodology uses the term "tree" and "non-tree" throughout for both REDD and ACoGS carbon pools. For ACoGS carbon pools, this should be read as "woody" and "non-woody" respectively, as set out in the *AFOLU Requirements*.

Optional pools may be excluded if it can be demonstrated that it is conservative to do so (ie, exclusion of the pool will lead to fewer emission reductions). The project proponent must use *ex-ante* estimates (see section 8.4.7) to demonstrate conservative exclusion of optional pools. Conservative exclusions must always meet current VCS requirements.

Merchantable trees containing biomass in AGMT and BGMT are differentiated from non-merchantable trees containing biomass in AGOT and BGOT. For accounting, the important distinction between these classes of trees is that, under the baseline scenario and as a result of project activities that include logging, carbon stored in long-lived wood products must be considered (see sections 8.1.6 and 8.2.3). Merchantable trees must be defined by expert knowledge, the PRA or third-party publications.

Required and optionally selected carbon pools are referred to as the set of selected carbon pools denoted by $\mathcal{C}$ (see section 2.2 for notation).

PD Requirements: Carbon Pools	
The project description must include the following:	
PDR.11	A list of the greenhouse gases considered.
PDR.12	A list of the selected carbon pools and evidence for the conservative exclusion of any optional pools.
PDR.13	The definition and evidence to support the definition of a merchantable tree if the baseline scenario or project activities include logging.

5.5 Grouped Projects

Grouped projects are allowed, where each project activity instance is treated as a project accounting area in a single project area. All project activity instances that are grouped must be in the same region and must each meet all the applicability conditions of this methodology, including applicability conditions related to the baseline scenario (see sections 4 and 6).

All project activity instances must be exactly the same with regard to common reference areas, baseline scenarios, proxy areas, activity-shifting leakage areas and market leakage areas as described in the project description (see reporting requirements in sections 6, 6.8.1 and 8.3.3). Project documentation may vary with respect to carbon stock estimation, as stratification and plot location will vary by project activity instance (see reporting requirements in section 9), and project emissions (see reporting requirements in section 8.2).

Each project activity instance must have a project activity instance start date and those project activity instances sharing the same project activity instance start date and baseline type must be grouped into a single project accounting area.

PD Requirements: Grouped Projects	
If grouped projects are developed, then the project description must include the following:	
PDR.14	A list and descriptions of all enrolled project activity instances in the group at the time of validation.

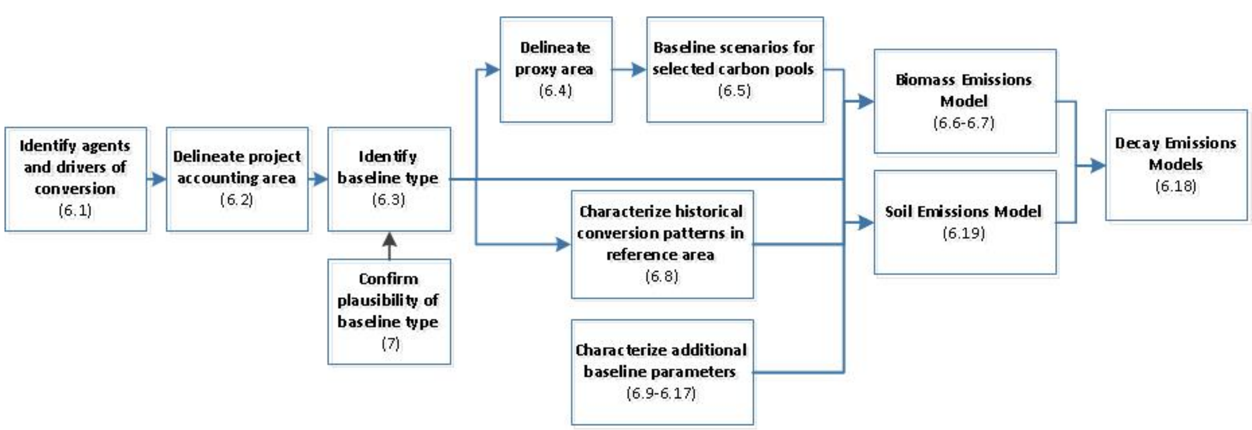
PDR.15	A map of the designated geographic area within which all project activity instances in the group will be located, indicating that all instances are in the same region.
PDR.16	A map of the common reference area, proxy area, activity-shifting leakage area, and market leakage area.

Monitoring Requirements: Grouped Projects
The monitoring report must include the following: **MR.4** A list and descriptions of all instances in the group. **MR.5** A map of the locations or boundaries of all instances in the group indicating that all instances are in the same region.

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

The baseline scenario in this methodology hinges on the identification of the agents and drivers of conversion and an understanding of how, when and where they might have acted in the project area. Upon determining the baseline type (Section 6.3), the end land use in the baseline scenario (Sections 6.4 and 6.5), and historical patterns of conversion (Section 6.8), the proponent develops a BEM (Sections 6.6 and 6.7) and SEM (Section 6.19) in order to calculate the emissions predicted to occur in the absence of the project. The selected baseline type is confirmed to represent the most plausible baseline scenario by considering alternative scenarios in section 7.

Figure 2: Determination of the Baseline Scenario



Section 6 provides detailed guidance for how to determine the baseline scenario and the emissions predicted to occur in the absence of the project.

Since there may be multiple groups of agents acting differently in the baseline scenario, more than one project accounting area may be required within a given project area. A project accounting area is the area for which a unique set of baseline emissions models are parameterized and applied to determine baseline emissions.

If the agents are sequential, they contribute to a cascade of degradation. In the cascade of degradation, the first agent is the primary agent and the subsequent agents are the secondary agents. Often the primary agent creates new roads or infrastructure, providing new access points to secondary agents that ultimately convert degraded forest to non-forest. Each agent may be associated with different drivers. It is important to identify the agents and drivers of conversion in order to design project activities that will successfully mitigate conversion and in order to characterize the baseline scenario.

The baseline scenario for each baseline type is characterized by baseline emissions models that predicts what would have happened in each project accounting area had the project not been initiated. The baseline emissions models incorporate all the necessary accounting for emissions from degradation, deforestation, conversion and loss of SOC. The baseline scenario for each selected carbon pool is described in section 6.5.

The baseline emissions models are a function of time and some external, quantifiable drivers of conversion such as population density, length of road in the region or median household income. These external, quantifiable drivers of conversion are called covariates due to their correlation with observed conversion in the region. The fundamental basis for these models are three parameters (α, β, and θ) estimated by observing conversion in a reference area over a historical reference period. The reference area may surround the project area, may be near to the project area or be in the same geographic region as the project area.

The baseline scenario may include legally-sanctioned commercial logging if the project proponent can demonstrate that as a result of legally-sanctioned commercial logging, the project area would have been ultimately deforested in the baseline scenario resulting from a cascade of degradation. This may be the case if during the course of commercial logging, the primary agent creates new roads or infrastructure which provides new access points to secondary agents that ultimately degrade the forest to non-forest.

The baseline scenario may incorporate project accounting areas with baseline types that involve:

- Planned or unplanned avoided conversion and degradation in addition to deforestation.
- Spatially explicit accounting for conversion.

The baseline emissions models for each project accounting area are parameterized differently depending on the associated baseline type. The project proponent should first identify the baseline type for each project accounting area in section 6.3 and then select the necessary parameters as indicated in Figure 3 in section 6.7. If more than one project accounting area is identified, then apply these sections independently to each project accounting area.

Finally, a proxy area is used to characterize the end carbon stocks in the baseline scenario for each identified baseline type (see section 6.4).

If a jurisdictional baseline has been established and is applicable to the project activity, it may be used per VCS requirements.

PD Requirements: Determining the Baseline Scenario
The project description must include the following with respect to the baseline scenario: **PDR.17** Show that the identified baseline type is the most plausible baseline scenario identified in section 7.

6.1 Identifying the Agents and Drivers

This section is to be applied to identify the agents and drivers of conversion and subsequently define project accounting areas.

The baseline scenario must include at least one agent of conversion, but may include more. These agents may act sequentially to cause conversion in the baseline scenario. The PRA can be used to identify these agents (see Appendix E). The project proponent must provide the information in the below PD requirements regardless of whether a PRA is used.

Where the agents (or class of agents) and drivers of conversion are not cleary identifiable, statistics about the agents and drivers obtained from published or unpublished sources may be used to demonstrate their prevalence. If, during validation, the agents (or class of agents) and drivers of conversion are found to be not clearly identifiable and published or unpublished sources are not available to show their prevalence, a participatory rural appraisal (PRA) must be conducted per the guidance in Appendix E. The PRA is a tool that suffices to identify the agents (or class of agents) and drivers of conversion in the event that the agents and drivers are not clearly identifiable.

PD Requirements: Agents and Drivers of Conversion
The project description must include the following: **PDR.18** A list of the agents and drivers of conversion, including quantitative descriptions of agent mobilities. **PDR.19** A narrative describing the agents and drivers of conversion.

PDR.20 Descriptions of agents and drivers including any useful statistics and their sources.

PDR.21 A list of external drivers (covariates) of conversion used in the model, if any, that may be identified as part of a PRA, expert knowledge or literature (eg, median household income, road density, rainfall).

6.1.1 Primary Agents and Drivers

Distinguishing between the primary and secondary agents and drivers is important for Type F-P1.a and F-P1.b, in which legally-sanctioned commercial logging or agriculture precedes deforestation. For grassland baseline types G-P2, G-U1 and G-U2, it is assumed that there is no grassland degradation before conversion. Therefore, only a single agent or class of agents and drivers can result in the conversion of native grassland. In type F-P1.a and F-P1.b baselines, the agent carrying out the legally-sanctioned conversion is the primary agent. The primary agent provides the access and infrastructure to the secondary agents of conversion. As a result, the emissions from biomass in the early years of the baseline scenario are not logistic over time, but rather linear as a result of a regulated harvest schedule.

Other baseline types may also have primary and secondary agents acting in a cascade of degradation. However, the emissions from biomass resulting from primary and secondary agents are assumed to be logistic over time as demonstrated by observing historical conversion in the reference area.

6.1.2 Secondary Agents and Drivers

Baseline emissions resulting from the secondary class of agents are assumed to be logistic over time as demonstrated by observing conversion in the reference area. For the secondary agents in baseline type F-P1.a (APD), if a specific agent is identified in the baseline scenario, the reference area must be determined based on the activities of the most-likely agent who would have acquired control of and cleared the project area. If not, the reference area will be based on the most-likely class of agents to have acted in the project area. The reference area must be appropriate for the agents and drivers of deforestation that the project proponent identifies, and be in conformance with the criteria in Appendix D.

Under the F-P1.b scenario, the frontier configuration is assumed for the baseline, a consequence of the road network created by the primary agents of deforestation. The reference area must be appropriate for the agents and drivers of deforestation that the project proponent identifies, and be in conformance with the criteria in Appendix D.

6.2 Delineating Project Accounting Areas

This section is to be applied to delineate each project accounting area based on constraints to conversion. Project accounting areas must be defined based on the constraints associated with the identified agents and drivers of conversion. Agents may be constrained by areas that are too remote, steep, infertile or rocky to be accessed and converted.

Project accounting areas must not overlap and per current VCS requirements, forested project accounting areas must be forested and grassland project accounting areas must meet the definition of native grasslands as of the project start date and for at least 10 years prior to the project start date. Each project accounting area must be subject to conversion in the baseline scenario. For example, if the agent of conversion is constrained by steep slopes, the project accounting area would not contain these inaccessible slopes. Each project accounting area must be measured to determine its area in hectares.

The project accounting area may be optionally delineated based on the results of a participatory rural appraisal or expert knowledge (see Appendix E).

The geographic or physical boundaries of the project accounting areas must be clearly delineated by considering, at minimum, the following:

- Topography
- Roads
- Major rivers and perennial streams
- Land use/vegetation type classification
- Total area

For AUC baseline types (G-U1 and G-U2), the project proponent must take into account the patch size at which land conversion typically occurs (eg, areas unsuitable for crops may still be plowed if they are a small part of a larger suitable parcel). The minimum patch size must be 250m x 250m.

The set of all delineated project accounting areas in the project area is denoted $\mathcal{A}$. The sum of these areas must be less than or equal to the project area.

PD Requirements: Project Accounting Areas
The project description must include the following:
PDR.22 A digital (GIS-based) map of the project accounting areas, including aerial or satellite imagery showing that they are comprised of forest or native grassland as of the project start date and 10 years prior to the project start date.
PDR.23 Justify the project accounting areas using the identified agents and drivers of conversion, constraints to conversion, and attributes listed above in section 6.2.
For Avoided Unplanned Conversion (AUC) baseline types G-U1 and G-U2 (see section 6.3), the project description must include the following:
PDR.24 Selection of patch size at which land conversion typically occurs.
PDR.25 Justification of selection of patch size for delineation of project accounting area.

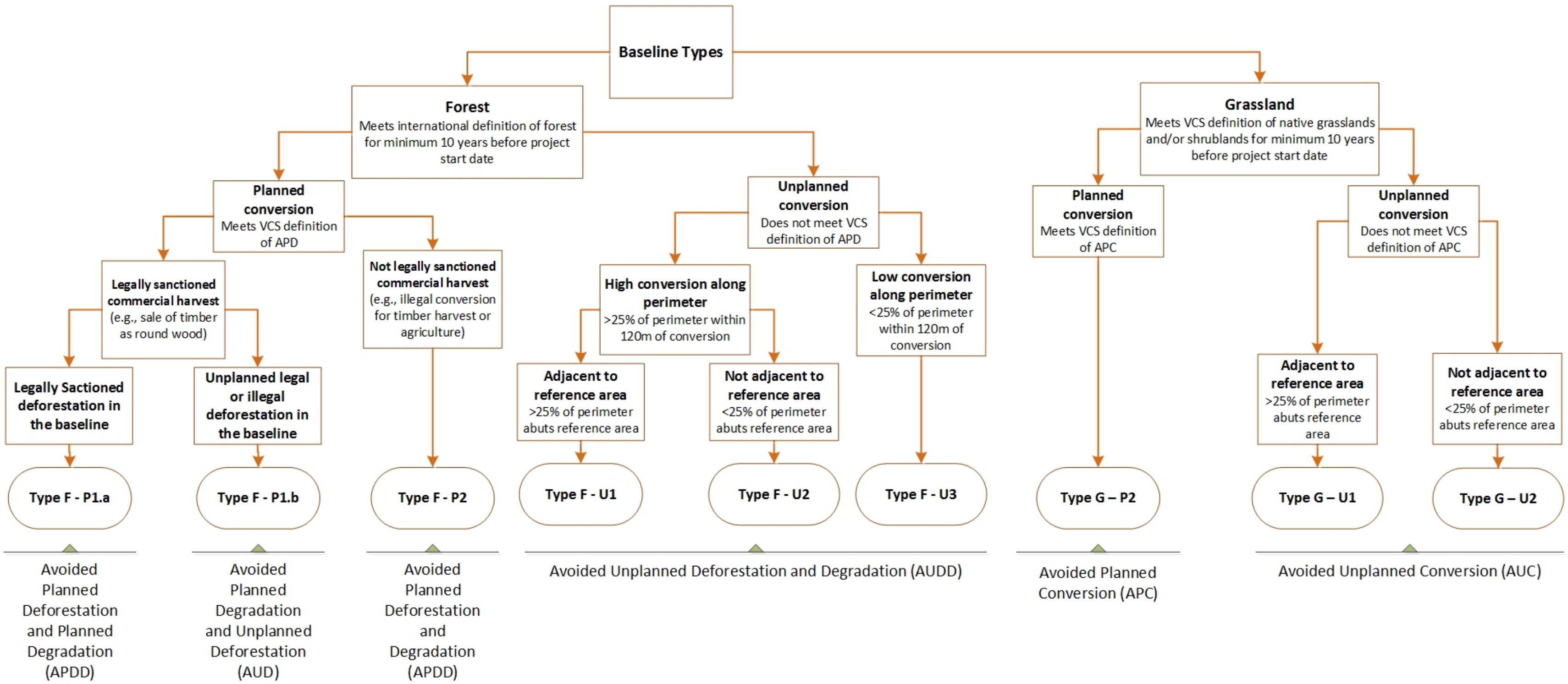
Monitoring Requirements: Project Accounting Areas
The monitoring report must include the following:
MR.6 A digital (GIS-based) map of the project accounting areas with at least the above minimum requirements for delineation of the geographic boundaries.

6.3 Identifying Baseline Types

This section is to be applied separately to each project accounting area to identify its baseline type.

The baseline emissions models account for emissions differently depending on the baseline type. A decision tree is presented in Figure 3. To determine the baseline type for a project accounting area, first determine whether the area qualifies as forest or native grassland. The baseline scenario for each baseline type is given in section 6.5, which must match most plausible baseline scenario identified in section 7.

Figure 3: Decision Tree to Determine Baseline Type



6.3.1 Forest Baseline Types

Where deforestation is initiated by the primary agent through legally-sanctioned commercial harvest (eg, sale of timber as round wood) and the area is ultimately converted to non-forest by the secondary agent through planned deforestation (eg, conversion to agriculture), the baseline type is F-P1.a.

Where deforestation is initiated by the primary agent through legally-sanctioned commcercial harvest and the area is ultimately converted to non-forest by the secondary agent through unplanned deforestation (eg, subsistance agriculture), the baseline type is F-P1.b.

Where deforestation occurs in a planned fashion but does not take place as a result of legally-sanctioned activities (eg, clearing for a plantation), it is planned non-commercial conversion and the baseline type is F-P2 (eg, the land is illegally logged or cleared for agriculture).

The baseline for the legally-sanctioned commercial harvest component of baseline types F-P1.a and F-P1.b is established using management plans from the primary agent. The secondary agents of conversion of F-P1.a and F-P1.b being carried out by the secondary agents of conversion are assumed to follow a frontier pattern of deforestation stemming from the roads. The project proponent must demonstrate that infrastructure that leads to deforestation would have existed in the baseline. To do this, projects may produce permits, construction plans, contracts or tenders, budgets, or other evidence of the intent to construct roads. Alternatively, the proponent must demonstrate that it is in fact common practice for comparable commercial logging outfits to build roads and other access infrastructure in order to legally degrade under a logging concession and that the primary agent has sufficient access to the project area to build infrastructure in the forest project accounting area. This can include the demonstration of a major road(s) leading to the project area, granting large machinery access to the project area and/ or definitive plans to build such infrastructure in the near future. The combination of demonstrating the construction of logging infrastructure in the reference area and roads having either been already built or plans for such roads showing clear access up to (but not necessarily within) the forest project accounting area will satisfy the requirement to show that such infrastructure would have been built in the baseline. For baseline type F-P1.b, a spatial algorithm of the baseline emissions models is required to conservatively determine baseline emissions over time (see sections 8.1.1.5.1 and 8.1.2.4.1).

If the baseline scenario does not meet the definition of APD, then determine the length of perimeter along the boundaries of the project area that is within 120 meters of deforestation that occurred within 10 years prior to the project start date. If this length is less than 25% of the entire perimeter of the project area, then the baseline type is F-U3. If 25% or more of the project area perimeter is 120 meters or less from deforestation, and if 25% or more of the project area perimeter also abuts the reference area, then the baseline type is F-U1. If 25% or more of the project area perimeter is 120 meters or less from deforestation but does not abut the reference area then the baseline type is F-U2.

Per the VCS *AFOLU Requirements*, the configuration of Type F-U1 and F-U2 must be mosaic while Type F-U3 may be mosaic or frontier. Type F-U3 requires a spatial algorithm of the baseline emissions models to conservatively determine baseline emissions over time (see section 8.1.1.5.1).

If the baseline type is F-U1, also see the requirements in section 8.4.1.2.

The selected baseline type must not change after validation and remains in effect for the entire project lifetime.

PD Requirements: Identifying the Baseline Type - Forest
The project description must include the following: **PDR.26** If Types F-P1.a, F-P1.b or F-P2 are selected, justification for meeting the definition of APD in the current VCS-approved AFOLU Requirements. **PDR.27** If Type F-P1.a or F-P1.b is selected, evidence of legally-sanctioned commercial harvest in the baseline scenario. **PDR.28** If Type F-P1.a is selected, evidence of legally-sanctioned deforestation in the baseline scenario. **PDR.29** If Type F-P1.b is selected, evidence of frontier configuration: Projects must demonstrate that the agent of degradation had access to the project area AND that comparable agents create roads for extraction of timber AND/OR Projects may produce permits, construction plans, contracts or tenders, budgets, or other evidence of the intent to construct roads. **PDR.30** If Type F-U1 is selected, a spatial analysis of the project area showing that at least 25% of the perimeter is within 120 meters of deforestation that occurred within 10 years prior to the project start date and showing that the reference area is adjacent to at least 25% of the project area. **PDR.31** If Type F-U2 is selected, a spatial analysis of the project area showing that at least 25% of the perimeter is within 120 meters of deforestation that occurred within 10 years prior to the project start date. **PDR.32** If Types F-U1, F-U2 or F-U3 is selected, a spatial analysis of the project area showing that it is within 120 meters of deforestation that occurred within 10 years prior to the project start date.

6.3.2 Grassland Baseline Types

For each grassland project accounting area, determine whether the baseline scenario meets the current definition of avoided planned conversion in the VCS *AFOLU Requirements*. The project proponent must provide evidence that the project area was intended to be converted in the absence of the project, and must meet the definition of anthropogenic land-use conversion. Native grassland and shrubland conversion shall be defined as, and limited to, the conversion of native grassland or shrubland from its natural state to one of anthropogenic use. This includes the land-use categories of agriculture, development (including housing) or other anthropogenic land-use discernable from remotely sensed imagery. Conversion to grazing lands and/or pasture shall not be included in the grassland/shrubland converted category, for the following reasons:

- In some cases, cattle or other grazing actually results in increased carbon stocks, and therefore may not represent a net carbon reduction.
- It is conservative to exclude pasture/grazing lands from the converted category.

Pasture/grazing lands are highly difficult to identify using nominal remote sensing techniques, and would thus prove impossible to recognize using the BEM model.
The conversion of native grassland / shrubland should be discernable using the same techniques as used for REDD type baseline models. Pixel pattern, texture and context should be employed to delineate anthropogenically converted native grassland / shrubland from its natural state, just as deforested areas are delineated from natural forest within the BEM. In cases where the agent of conversion is not the landowner, the project proponent may determine the baseline scenario using historical and current conversion activities of the most likely agent who would have acquired the project area in the absence of the project. If the baseline scenario meets the definition of APC, then the baseline type is planned conversion (G-P2).

If the baseline scenario does not meet the definition of APC, but still meets the definition of native grassland / shrubland conversion, determine the portion of the project area perimeter that abuts the reference area. If 25% or more of the project area perimeter abuts the reference area, then the baseline type is G-U1. Conversely, if less than 25% of the project area perimeter abuts the reference area, then the baseline type is G-U2.

If the baseline type is G-U1, also see the requirements in section 8.4.1.2.

PD Requirements: Identifying the Baseline Type - Grassland
The project description must include the following: **PDR.33** If Type G-P2 is selected, justification for meeting the definition of APC in the current VCS-approved AFOLU Requirements. Justification must include evidence of intent to convert the project area and that the converted land-use category would meet the definition of native grassland / shrubland conversion.

PDR.34	If Type G-U1 is selected, a spatial analysis of the project area showing that the reference area is adjacent to at least 25% of the project area.

6.4 Delineating Proxy Areas

This section is to be applied separately for each identified project accounting area, however proxy areas for each project accounting area may partially or entirely overlap. Therefore, an individual proxy area must be identified for each project accounting area, but two or more proxy areas may share identical boundaries.

The proxy area is used to estimate residual carbon stocks of the end land use in the baseline scenario associated with a particular project accounting area. It must be located in the same general region as the project area, but not necessarily adjacent to the project area. The proxy area must also be physically accessible to the project proponent, as ongoing ground-based measurement will be necessary. For each project accounting area, the proxy area must be similar to the corresponding project accounting area with respect to vegetation, landscape configuration and climatic conditions.

The proxy area must represent areas already converted to the end land use (eg, non-forest or converted native grassland) in the baseline scenario as of the project start date. There is no minimum or maximum size for the proxy area, however it must have a similar landscape configuration to the project accounting area. The proxy area must not include the project area but may overlap with the reference area. The proxy area must not be altered after the first monitoring period unless there is a baseline reevaluation (see section 6.20).

The proxy area must be delineated per the requirements of Appendix D.

PD Requirements: Delineation of the Proxy Areas
The project description must include the following information with respect to the proxy area:
PDR.35 A map of the delineated boundaries.
PDR.36 Maps or other evidence that the proxy area's site characteristics and landscape configuration is similar to its respective project accounting area, including: • Vegetation; • Climatic conditions (eg, mean temperature, rainfall, etc.); • Topographic constraints to conversion (slope, aspect, elevation); • Land use and/or land cover; • Soil map (if available) or other soil information;

- Applicable infrastructure (eg, water ways, roads, railroad, airports, provision of electricity, and other access points); and
- Ownership/tenure boundaries that influence conversion (eg, government holdings, private holdings and reserves).

PDR.37 A narrative describing the rationale for selection of proxy area boundaries, including the proxy area's similarity to the corresponding project accounting area with respect to vegetation, soil and climatic conditions.

PDR.38 Results of a spatial analysis to demonstrate the proxy area is converted, on average, as of the project start date.

6.5 Baseline Scenarios for Selected Carbon Pools

The following sections describe how the baseline emissions models are applied to each pool and any additional assumptions used in determining baseline emissions. The BGB pool is described in section 6.5.4, and the DW pool is described in section 6.5.2. Accounting for emissions from decay relative to source of emissions is outlined in Table 5 below.

Table 4: Decay Emissions by Carbon Pool

Carbon Pool	Soil	Below-Ground	Dead Wood	Wood Products
AGMT			Decay in DW (from slash)	Decay in WP (from log export by wood product type)
AGOT			Decay not Considered (not applicable)	
AGNT				
BGMT		Decay from BGB		
BGOT				
BGNT				
SOC	Decay in SOC (as a result of land-use conversion)			
SD		Decay not Considered (not applicable)		
LD				

The categories shown across the top of the table (columns) are decay pools per AFOLU requirements. The left side of the table (rows) shows carbon pools defined by this methodology. Table 5 shows the intersection of these two categories. Where there are blank spaces, the carbon pools are not applicable to the decay pools. For example, the AGMT (Above-Ground Merchantable Tree) carbon pool does not apply to the Below-Ground decay pool, thus the cell where they intersect is left blank.

The residual carbon stocks associated with the end land use in the baseline scenario are characterized by the proxy area for all baseline types (see section 6.4).

6.5.1 Baseline Scenario for Livestock

Livestock grazing may occur in the baseline scenario, but any emissions from this activity are conservatively assumed to be zero and are not credited. Livestock grazing or conversion to pasture must not be the primary driver of conversion, as decribed in section 6.3.2. Any emissions from livestock grazing in the project area, however, must be quantified as described in section 8.2.4.

PD Requirements: Describing the Baseline Scenarios for Selected Carbon Pools
The project description must include the following: **PDR.39** A qualitative description of the baseline scenario for each selected carbon pool.

6.5.2 Baseline Scenario for AGMT

In baseline types F-P1.a and F-P1.b, above-ground commercial portions of commercially viable trees are assumed to be removed (see section 8.1.6.1), and then converted to long-lived wood products (see section 8.1.6), accounted for as in Appendix C. The non-merchantable portion of merchantable trees (ie, the slash) is decayed linearly over ten years (see section 8.1.3). Primary agents are presumed to initiate the removal of merchantable trees; this initial degradation by primary agents is followed by secondary agents of conversion who remove remaining merchantable trees. It is conservative to account for the emissions from logging slash as a decay source, even if in reality these materials would have been burned or used for fuel.

Similarly in baseline types F-P2, F-U1, F-U2, F-U3, G-P2, G-U1 and G-U2, above-ground commercial portions of commercially viable trees are assumed to be removed (see sections 8.1.6.2, 8.1.6.3 and 8.1.6.4), and then converted to long-lived wood products by the agents of conversion (see section 8.1.6). The portions of merchantable trees that do not have commercial value are likewise decayed linearly over ten years (see section 8.1.3). The same process that occurs in F-P2, F-U1, F-U2, G-U1 and G-U2 is assumed to occur in baseline type F-U3, but merchantable trees are conservatively assumed to be removed first in the stratum with the lowest carbon stocks and last in the stratum with the highest carbon stocks (see section 8.1.1.5).

The baseline scenario for above-ground merchantable trees is directly related to the BEM (see section 8.1.1), which predicts the emissions from conversion and degradation over time, the decay of wood products over time (see section 8.1.6), and decay of slash (see section 8.1.3). In all cases, it is possible that above-ground merchantable tree biomass will exist after the agents of conversion have acted upon the forest or native grassland. This residual biomass must be determined using permanent plot measurements in the proxy area (see section 6.4), as prescribed in Appendix B. The proportion of above-ground merchantable trees that is converted to long-lived wood products is addressed under the scenario for wood products (see section 6.5.8).

6.5.3 Baseline Scenario for AGOT and AGNT

In baseline types F-P1.a, F-P1.b, F-P2, F-U1, F-U2, F-U3, G-P2, G-U1 and G-U2, above-ground portions of trees that are not commercially viable (ie, other trees that are not merchantable) and above-ground non-tree biomass are assumed to be immediately burned during clearing of the land or converted to fuel wood and burned (see section 8.1.1). The same process is assumed to occur in baseline type F-U3 where AGOT and AGNT are conservatively assumed to be converted to an emission first in the stratum with the lowest carbon stocks and last in the stratum with the highest carbon stocks (see section 8.1.1.5).

The baseline scenario for above-ground other trees and non-trees is characterized by the BEM. In all cases, it is possible that AGOT and AGNT biomass will exist after the agents of conversion have acted upon the forest. This residual biomass must be determined using permanent plot measurements in the proxy area (see section 6.4), as prescribed in Appendix B.

6.5.4 Baseline Scenario for BGMT, BGOT, and BGNT

The only below-ground portions of trees and other below-ground biomass affected in during commercial activity in F-P1.a and F-P1.b are conservatively assumed to be that of merchantable trees killed by logging. This below-ground biomass is decayed over ten years (see section 8.1.4). After the completion of commercial activity, below-ground biomass is assumed to be removed or to decay over time in the soil as land is deforested and converted to its end land use.

In baseline types F-P2, F-U1, F-U2, F-U3, G-P2, G-U1 and G-U2, below-ground biomass is assumed to be partially removed or to begin decay at the time of conversion (see section 8.1.4). Below-ground biomass in Type F-U3 is conservatively assumed to be partially removed first in the stratum with the lowest carbon stocks and last in the stratum with the highest carbon stocks (see section 6.4).

The baseline scenario for below-ground biomass is directly related to the baseline emissions model. It is assumed that below-ground biomass is not converted to long-lived wood products.

6.5.5 Baseline Scenario for SD

Prior to deforestation, standing dead wood is assumed to be insignificantly impacted by commercial agents in baseline types F-P1.a and F-P1.b. Following completion of commercial activity, the mass of standing dead wood not observed in the proxy area (see section 6.4), as compared to the project, is assumed to be removed, burned or converted to fuel wood by secondary agents.

Likewise in baseline types F-P2, F-U1, F-U2, F-U3, G-P2, G-U1 and G-U2, the difference between standing dead wood stocks in the project and the proxy area is assumed to be immediately removed, burned or converted to fuel wood. The same process is assumed to occur in baseline type F-U3, though standing dead wood is conservatively assumed to be removed first in the stratum with the lowest carbon stocks and last in the stratum with the highest carbon stocks (see section 8.1.1.5).

The baseline scenario for standing dead wood is directly related to the BEM, which predicts emissions from degradation and deforestation over time. In all cases, it is possible that standing dead wood will exist after the agents of conversion have acted upon the forest. This residual biomass must be determined using permanent plot measurements in the proxy area (see section 6.4), as prescribed in Appendix B. It is assumed that standing dead wood is not converted to long-lived wood products.

6.5.6 Baseline Scenario for LD

Lying dead wood is assumed to be impacted only slightly by commercial agents in baseline types F-P1.a and F-P1.b. Following completion of commercial activity, the difference in lying dead wood stocks between the project and proxy area is assumed to be removed (see section 6.4), burned or converted to fuel wood by secondary agents.

In baseline types F-P2, F-U1, F-U2, F-U3, G-P2, G-U1 and G-U2, the difference in lying dead wood stocks between the project and proxy area is assumed to be removed, burned or converted to fuel wood beginning immediately. In baseline type U3, lying dead wood is conservatively assumed to be removed first in the stratum with the lowest carbon stocks and last in the stratum with the highest carbon stocks.

The baseline scenario for lying dead wood is directly related to the baseline emissions model, which predicts emissions from degradation, deforestation and conversion over time. In all cases, it is possible that lying dead wood will exist after the agents of conversion have acted upon the forest. This residual biomass must be determined using permanent plot measurements in the proxy area (see section 6.4), as prescribed in Appendix B. It is assumed that lying dead wood is not converted to long-lived wood products.

6.5.7 Baseline Scenario for SOC

Soil is assumed to lose its organic carbon over time as a result of land conversion to agriculture (E. Davidson & Ackerman, 1993). This loss is assumed to follow not only conversion to agriculture, but any non-forest end state with lower soil carbon stocks than the project area. The total loss is established by measurements in the proxy area (see section 6.4), while the rate is determined using one of three options given in section 6.15.

Commercial agents in baseline types F-P1.a and F-P1.b account for only slight soil carbon loss because they degrade the area but do not deforest it. As secondary agents subsequently act on and ultimately deforest the area soil carbon is assumed to eventually reach equilibrium as determined by measurements within the proxy area.

In baseline types F-P2, F-U1, F-U2, F-U3, G-P2, G-U1 and G-U2 it is assumed that soil carbon will deplete to the SOC measured in the proxy area after a long period of time (see sections 6.4 and 8.1.2.1).

The baseline scenario for soil carbon is characterized by the SEM (see sections 8.1.2.1, 8.1.2.2 and 8.1.2.3), which predicts the SOC emissions from conversion over time (see section A.2 for a description of the model). Residual soil carbon must be determined using permanent plot measurements in the proxy area (see section 6.4), as prescribed in Appendix B.

6.5.8 Baseline Scenario for WP

Biomass remaining in wood products is assumed to be restricted to AGMT biomass (see sections 8.1.6.2, 8.1.6.3 and 8.1.6.4). The proportion of biomass remaining in wood products follows the procedure in section 8.1.6 and Appendix C.

6.6 The Baseline Emissions Models

This section must be applied separately for each identified project accounting area.

The baseline emissions models characterize the baseline scenario and include the BEM and the SEM for a particular project accounting area. The BEM predicts cumulative emissions from biomass as a result of degradation, deforestation and conversion while the SEM predicts cumulative emissions from SOC as a result of conversion.

The BEM for baseline types F-P1.a and F-P1.b is given by [F.2] and includes a linear component for emissions from planned commercial harvest and a logistic component for emissions from degradation. The BEMs for the other baseline types are given by [F.3], [F.4] and [F.5]. Theoretical background on the logistic nature of degradation, deforestation and conversion are presented in Appendix A. The logistic nature of ecosystem conversion is justified using established resource economic theory.

The SEM is given by [F.6], [F.7] and [F.8]; it is also based on a logistic model of ecosystem conversion. It assumes that SOC begins to decay in the project accounting area when it is cleared from forest or native grassland.

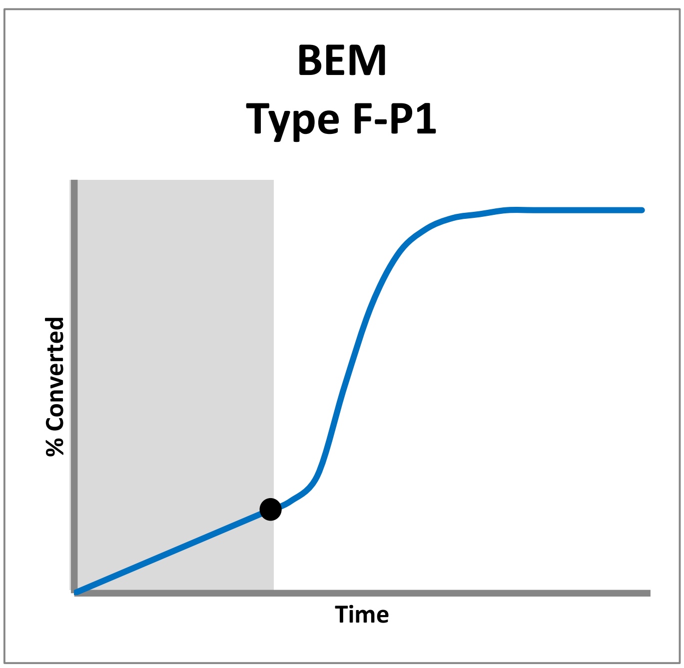
The baseline emissions models must be parameterized in terms of days relative to the project start date (see section 6.7.1 for discussion of data resolution). The models predict baseline emissions as tCO2e. These unified models dramatically simplify baseline accounting relative to other approaches, as all that is required is to determine the baseline type and select parameters based on Table 6 in section 6.7.

6.7 Parameterizing the Baseline Emissions Models

This section must be applied separately for each identified project accounting area.

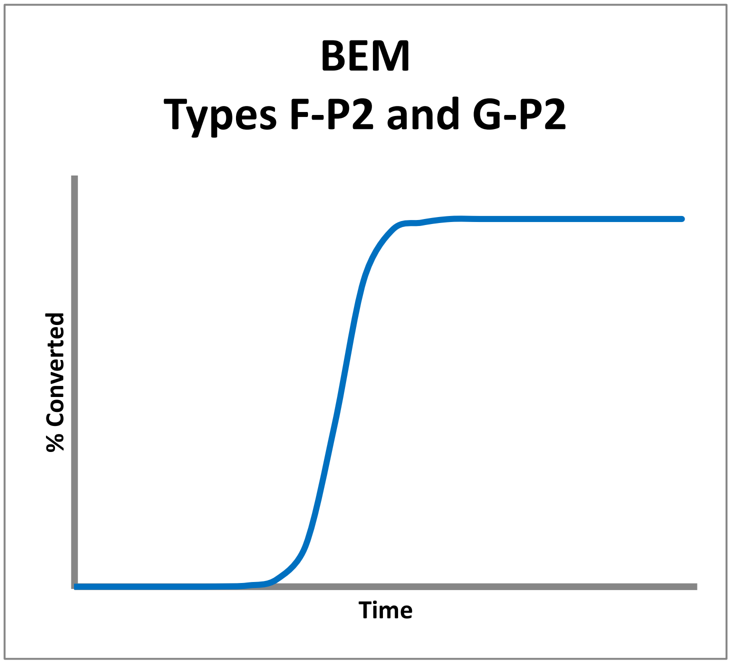
Use Table 6 to identify parameters to the baseline emissions models. Project proponents should first determine the baseline type per section 6.3. All parameters are set at the time of project validation or baseline reevaluation. Note that parameters with superscript $[m]$ are determined for each monitoring period and are specified in section 9.

Figure 4A: Example of BEM for Baseline Types F-P1.a and F-P1.b



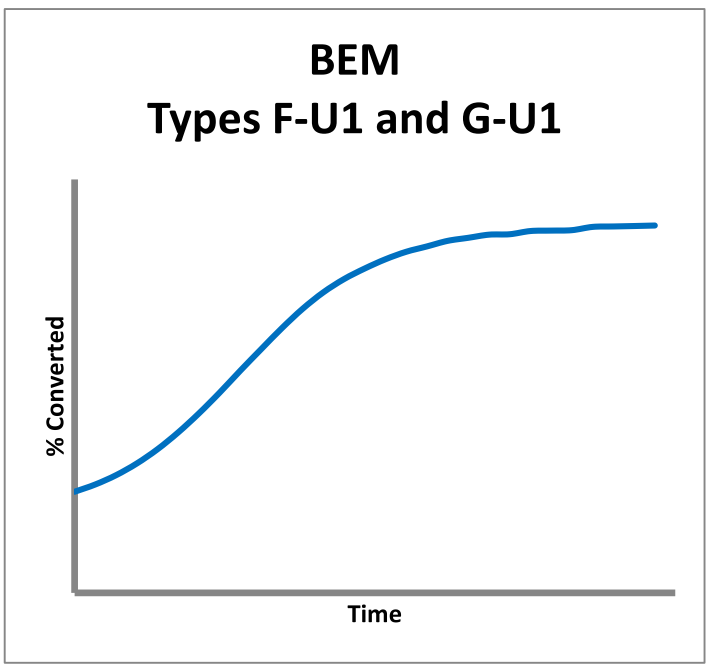
Conversion occurs at a linear rate from the time of arrival of the primary agents (t_{PA}) until the time of arrival of the secondary agents (t_{SA}), after which conversion follows a logistic curve. Actual curves for each project may vary.

Figure 4B: Example of Biomass Eissions Model for Baseline types F-P2 and G-P2.



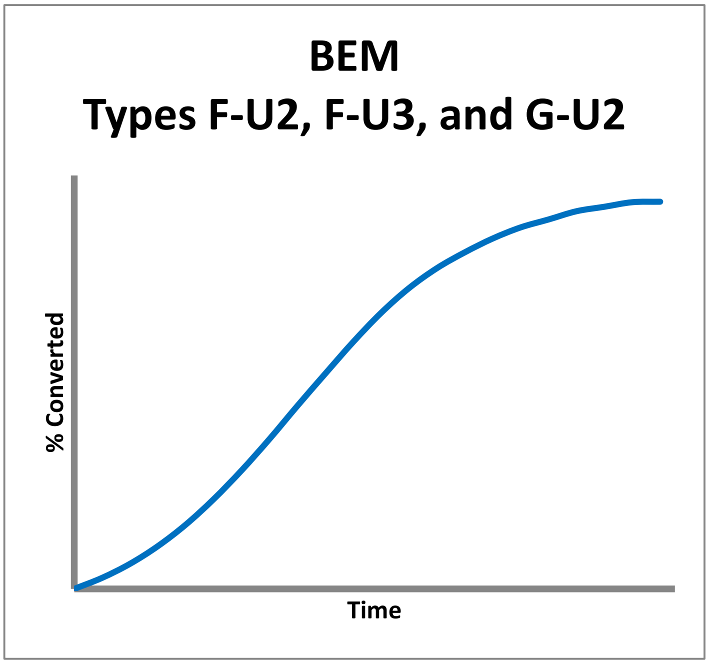
Conversion follows a steep logistic curve, reflecting the rapid conversion rates of baseline types F-P2 and G-P2. Actual curves for each project may vary.

Figure 4C: Example of BEM for Baseline Types F-U1 and G-U1



Conversion follows a logistic curve. Note that the BEM for F-U1 and G-U1 are rescaled in [F.5] so estimated baseline emissions start at zero as of the project start date. Actual curves for each project may vary.

Figure 4D: Example of BEM for Baseline Types F-U2, F-U3, and G-U2



Conversion follows a logistic curve. Actual curves for each project may vary.

Table 5: Selection of Conversion Parameters by Baseline Type

Parameter	Explanation	Section	F-P1*	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
α	Average effects of time and other covariates on degradation, deforestation and conversion (conversion parameters)	6.8	✓	✓	✓	✓	✓	✓	✓	✓
β	Effect of time on degradation, deforestation and conversion (conversion parameters)	6.8	✓	✓	✓	✓	✓	✓	✓	✓
θ	Effect of covariates on degradation, deforestation and conversion (conversion parameters)	6.8	✓	✓	✓	✓	✓	✓	✓	✓
t_{PAI}	Time of project activity instance start date relative to project start date for a project activity instance in a grouped project (days)	6.9	✓	✓	✓	✓	✓	✓	✓	✓
t_{SA}	Arrival time of secondary agents after start of commercial logging (days)	6.10	✓							
t_{PA}	Time prior to the project start date when the primary agent began commercial logging in the project accounting area (days relative to the project start date, negative)	6.11	✓							
x_0	Covariates as of the project start date.	6.12	✓	✓	✓	✓	✓	✓	✓	✓
x_{PAI}	Covariates as of the project activity instance start date for a project activity instance in a grouped project (days)	6.13	✓	✓	✓	✓	✓	✓	✓	✓
m	Commercial degradation per year (tCO2e/yr)	6.14	✓							
γ	Time shift from beginning of historic reference period to project start date (days relative to project start date)	6.15	✓ (if incl. soil)	✓				✓ (if incl. soil)		
q	Time shift between start of degradation and conversion (days)	6.16		✓	✓	✓	✓		✓	✓

r_U	Converted area or threatened perimeter in the project area at the project start date (hectares)	6.17				✓	✓			✓

+ indicates that value must be conservatively set to zero unless justified; * indicates both F-P1.a and F-P1.b)

6.7.1 Resolution of Parameter Values

In order to aid modeling, whenever possible, time is parameterized in terms of days in this methodology. Monitoring and measurement need not have that precision. For example, if the precision of the data available for m is on a monthly basis, the conversion should simply be made from months to days. It is always conservative to use a larger number for time (eg, to round up when converting units of time).

6.8 Determining Historical Conversion (α, β and θ)

This section is to be applied separately for each identified project accounting area.

A reference area and historic reference period are used to find α, β and θ, the parameters that are used to depict the historic pattern of ecosystem conversion to be applied to the project accounting area in the baseline scenario. The reference area is used to determine the landscape pattern of conversion while the reference period is used to determine the change in the cumulative proportion of conversion over time.

The parameter β is the effect of time on the cumulative proportion while θ, a vector, is the effect of certain covariates on the cumulative proportion. The parameter α is related to the combined effects of the other parameters at the start of the historic reference period.

This methodology does not specify a fixed length for the historic reference period. Instead, the reference period is defined by the availability of historic images of the reference area and the occurrence of important past events related.

Specific requirements for the reference area and historic reference period are given in sections 6.8.1 and 6.8.2.

6.8.1 Delineating Reference Areas

The reference area is defined differently for baseline types F-P1.a, F-P1.b, F-P2, F-U1, F-U2, F-U3, G-P2, G-U1 and G-U2. While the reference area is defined differently for the baseline types mentioned, the reference area selection criteria outlined below must be applied to all baseline types. A reference area must be delineated for each project accounting area. Reference areas may overlap.

6.8.1.1 Reference Area Selection Requirements

The reference area must address the following criteria in order to ensure that the agents and drivers of conversion are similar to those of the project accounting area, as well as to prove that those agents performed similarly in the reference area to the way they would have performed in the project accounting area under the baseline scenario.

1. The location and size of the reference area relative to the project accounting area:

    a. A pair of maps showing the boundaries and size of the reference area and the project accounting area, including an indication of their locations relative to each other.

    b. Written justification for the selection of the location of the reference area.

2. A description of the drivers of conversion, including the following, relative to the project area:

    a. Written description of the socio-economic conditions in the reference area and project accounting area including the following data where available:

        i. Census data depicting relevant demographics and socioeconomic conditions

        ii. PRA data

        iii. Economic studies

        iv. Maps depicting demographic data and socio-economic conditions

    b. Written description of the cultural conditions, such as historical events, cultural shifts, migration patterns, tribal traits and characteristics, and current cultural patterns including the following data where available:

        i. PRA data

        ii. Publications relevant to the cultural conditions in the area

        iii. Maps depicting cultural data

3. The location(s) of the agents of conversion relative to the project accounting area and surrounding region including the following:

    a. A paired comparison of maps of the reference area and project accounting area, including locations of settlements or other population centers. For subsequent use in determining the mobilities of the agents of conversion.

4. The mobilities of the agents of conversion relative to the project accounting area, including the following:

    a. Written description of the mobility of all primary and secondary agents in the project accounting area and reference area. Acceptable data sources should be used to demonstrate mobility, including geographic and/or anthropogenic factors that may influence their movement or access.

5. Landscape configuration of the reference area and the project accounting area, including all of the following factors:

    a. A paired comparison of maps of the reference area and project accounting area, which must include the following criteria:

        i. Topographic constraints to conversion (slope, aspect, elevation);

ii. Land use and/or land cover;

iii. Soil map (if available) or other soil information;

iv. Applicable infrastructure (eg, water ways, roads, railroad, airports, provision of electricity, and other access points);

v. Distance to important markets;and

vi. Ownership/tenure boundaries that influence conversion (eg, government holdings, private holdings and reserves).

b. Written justification of similarities between the project and reference area using acceptable data sources.

For each reference area selection criteria set out above, acceptable data sources may include any of following verifiable forms of evidence:

- Maps with underlying data from official or commonly accepted sources (eg, UN/FAO, National or Jurisdictional government, WRI, IPCC, etc.);
- A participatory rural appraisal (PRA) or other such locally applicable survey;
- Published and/or refereed literature sources; or
- Expert knowledge originating from local or generally accepted sources.
- Documented observations from the reference area not included in other surveys.

PD Requirements: Delineation of the Reference Area for Planned and Unplanned Types
The project description must include the following information with respect to each reference area: **PDR.40** A map of the delineated boundaries, demonstrating that the reference area was held by the identified baseline agent or agents and does not include the project area. **PDR.41** Results of a spatial analysis to demonstrate the reference area had as much forest or native grassland as the project accounting area at some point in time during the historic reference period. **PDR.42** Evidence that the management practices of the baseline agent in the reference area are similar to those that would have been applied to the project accounting area or areas in the baseline. **PDR.43** A description of the rationale for selection of reference area boundaries relative to the respective project accounting area.

PDR.44	The documentation required in the reference area selection requirements that the selected reference area meets the Reference Area Selection Requirements.

6.8.1.2 Baseline Types F-P1.a, F-P1.b, F-P2 and G-P2

The reference area is defined by what would have happened in the project accounting area in a planned deforestation scenario (for forest) or planned conversion scenario (for native grassland).

Where the specific primary agent of conversion can be identified for baseline types F-P2 and G-P2, the reference area is defined by an area and for a period of time controlled by that same specific primary agent of conversion. Where the specific primary agent of conversion cannot be identified, the reference area is defined by an area and for a period of time controlled by the class of agents that contains the primary agent. For example, if there is logging in or around the project area and the company doing this logging is identifiable, this company would be considered the specific primary agent of conversion. However, if the identity of this logging company is unknown, then the primary agent of conversion would be considered a part of a class of agents carrying out logging operations. All agents in a class share the same drivers of conversion. The reference area may be landholdings of the agent or areas directly affected by the agent. The reference period may begin when the agent acquired access to the reference area or when the land management objectives for the reference area changed.

As opposed to baseline types F-P2 andf G-P2 (for which there exists only a single agent of conversion), where baseline types F-P1.a or F-P1.b are selected, the reference area must be appropriate for the specific primary agent (or class of primary agent where the specific primary agent cannot be identified) *and* the specific secondary agent (or class of secondary agents where the specific secondary agent cannot be identified) of deforestation. The project proponent must identify the reference area as landholdings of the specific agents of conversion or of an agent in the class of agents.

The reference area must have as much forest as the forest project accounting area at some point in time during the historic reference period if the baseline cover type is forest. Or, the reference area must have as much native grassland as the grassland project accounting area at some point in time during the historic reference period if the baseline cover type is native grassland. If a reference area based on a single agent cannot be located to meet this requirement, landholdings from multiple agents in the class of agents may be combined to meet this requirement.

The forest or native grassland management practices used by the agent in reference area must be similar to that of the likely forest or native grassland management practices applied to the project accounting area in the baseline scenario. The reference area must not include the project area and must not be altered during the historic reference period.

PD Requirements: Defining the Reference Area for Planned Baseline Types
The project description must include the following with respect to the reference area: **PDR.45** Evidence that secondary agents have been considered in the delineation of the reference area for baseline types F-P1.a, F-P1.b.

6.8.1.3 Baseline Types F-U1, F-U2, F-U3, G-U1 and G-U2

The reference area must be in the same general region as the project area, but not necessarily adjacent to the project area. At some point in time during the historic reference period, the reference area must contain as much forested area (for F-U1, F-U2 and F-U3) or native grassland (for G-U1 and G-U2) as the project accounting area. The reference area must not include the project area and must not be altered during the historic reference period. The boundaries of the reference area must include one or more of the following:

- Environmental, natural or political boundaries.
- Major transportation infrastructure such as highways or railroads.
- Land ownership/tenure boundaries.
- Latitudinal or longitudinal degree boundaries.

The reference area must be delineated per the Reference Area Selection Requirements (section 6.8.1.1).

6.8.2 Defining the Historic Reference Period

The reference period is defined differently for baseline types F-P1.a, F-P1.b, F-P2, F-U1, F-U2, F-U3, G-P2, G-U1 and G-U2. A reference period must be delineated for each project accounting area. Reference periods must not overlap where reference areas overlap.

6.8.2.1 Baseline Types F-P1.a, F-P1.b, F-P2 and G-P2

If the specific agent of conversion can be identified, the reference period must be established when the agent acquired control of the reference area or when the land management practices employed in the reference area changed. Where landholdings from more than one agent in a class of agents are used to define the reference area, the reference period must be established by the agent that first acquired control of the landholding or when the land management practices employed in the landholding changed. Control can be obtained by the establishment of title while land management can change as a result of a change in laws, access to markets for wood products or access to new technologies, for example.

PD Requirements: Defining the Reference Period for Planned Types	
The project description must include the following with respect to the reference period:	
PDR.46	Established reference period boundaries.
PDR.47	The date when the agent acquired control of the reference area or when the land management practices employed in the reference area changed.

6.8.2.2 Baseline Types F-U1, F-U2, F-U3, G-U1 and G-U2

If the specific agent of conversion cannot be identified, the reference period must be established by important historic events as identified by the information obtained from expert knowledge or the participatory rural appraisal and corresponding analysis of agents and drivers of conversion. These events include the following:

- The arrival time of specific foreign agents of conversion, if any;
- The times when the drivers of conversion became apparent, if any; and
- The times of significant economic growth or decline.

Historic imagery of the reference area must be acquired for times before and after these events and this imagery must be used to parameterize the baseline emissions models per section 6.8.3. If no important events are identified, then the reference period should be established by the times of available historic images of the reference area.

PD Requirements: Defining the Reference Period for Unplanned Types	
The project description must include the following with respect to the reference period:	
PDR.48	Established reference period boundaries.
PDR.49	A list of available historic imagery for the reference area.
PDR.50	A timeline of important events as they relate to the agents and drivers of conversion.
PDR.51	Narrative rationale for the selection of the reference period.

6.8.3 Analyzing Ecosystem Conversion in the Reference Area

The baseline scenario is characterized by observing ecosystem conversion in the reference area assuming the same would occur in the project accounting area in the absence of the project activity. The parameters α, β and $\boldsymbol{\theta}$ are estimated from observations of land cover change in the reference area over the reference period based on a logistic function (see Appendix A). Once estimated, these parameters depict the shape of the logistic function and the cumulative emissions that would have occurred at any point in time after the project start date.

To analyze ecosystem conversion and estimate α, β and $\boldsymbol{\theta}$, historical imagery must be acquired and interpreted for land cover (see section 6.8.4). Interpretation is accomplished using a set of points distributed across the reference area (see sections 6.8.5 through 6.8.7). Weights are computed from interpretation points to account for cloud contamination, coverage and time differences in image acquisition dates (see section 6.8.6). Measures must be taken to minimize uncertainty and uncertainty must be estimated (see sections 6.8.9 and 6.8.10).

Sections 6.8.4 through 6.8.8 illustrate this approach using a fictitious example, assuming a reference area of 10km by 10km in dimension (100km^2) and a project start date of January 1 2011.

To facilitate this approach to analyzing ecosystem conversion, Wildlife Works maintains a free ArcMap GIS extension to generate and automate point interpretation and weighting.

6.8.4 Selecting Historical Imagery

Ecosystem conversion is sampled from available historical imagery of the reference area over the reference period. The project proponent must have “double coverage” for at least 90% of the reference area over the entire reference period (see Appendix A).

Fulfillment of this requirement can be demonstrated by aligning a dot grid of points over the reference area using a GIS. Then, for each co-registered image in the system, those grid points that fall over the cloud-free, visible portion of each image are copied to a new file. This is done for all images and produces the same number of shapefiles as number of images. All derived shapefiles are then merged to form a single file. One of the attributes for each point in the merged file should contain a count of corresponding time periods on which it falls. For example, if one particular grid point was observed to fall onto the cloud-free portions of six images, then the attribute count of that point in the merged shapefile would be six. In the merged file, those points with a count less than two should be discarded (hence the remaining points in the merged file representing "double-coverage"). The number of remaining points should comprise at least 90% of the total number of points within the reference area.

The minimum spatial resolution of the imagery must be 30 m. Where possible, multi-spectral imagery should be enhanced using a Tasseled-Cap transformation, Principal Components Analysis (PCA) or other similar transformation to facilitate the differentiation of forest vegetation from other land covers. To ensure that the selected imagery is of adequate spatial resolution to allow for the identification and discernment between natural, unconverted status and converted status, the project proponent must provide evidence, by providing one of the following to the VVB:

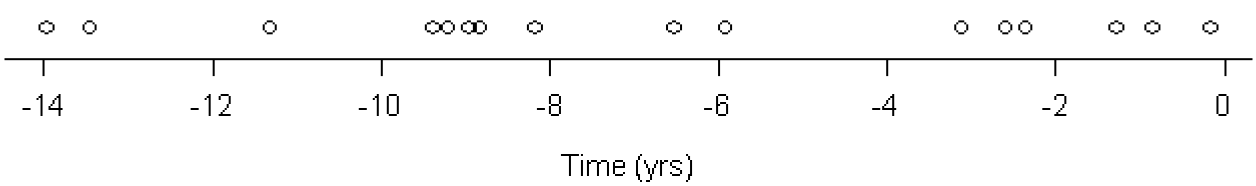
1. A set of geo-referenced photos taken on the ground in areas that represent both unconverted and converted land cover. The auditor should check that these photos

satisfy the burden of proof that adequate shape, texture and context is discernable in order to identify land cover state change between unconverted and converted status.

2. High-resolution imagery coinciding with both unconverted and converted areas within the reference area(s). This imagery should be of significantly higher spatial resolution in comparison to the imagery used for the collection of data for the BEM, and should only be used to determine the adequacy of the spatial resolution of the data to be interpreted. Accuracy and resolution of the validation imagery should be at the discretion of the auditor.

The dates of historic imagery should be plotted on a line plot and this plot should be interpreted for stationarity in the time series of imagery (see Figure 4). This is necessary to ensure the estimated time components of the image weights per equation [A.3] are unbiased. The time series is stationary if the image dates are distributed, on average, across the entire historic reference period.

Figure 4: Line Plot to Demonstrate Approximate Stationarity of Historical Imagery.



A line plot of the time series of historic images to visually confirm stationarity. The time series is stationary if the images are well distributed throughout the reference period.

All imagery must be spatially registered to the same coordinate system with accuracy less than 10% Root Mean-Squared Error (RMSE) as measured by the error relative to the pixel diagonal of the image being evaluated or relative to the absolute difference between the greatest error and the smallest error, on average across all images (Congalton, 1991). The accuracy of spatial registration is assessed empirically; each image is relative to other collocated images or a ground control point. Oblique imagery should be avoided to maintain accurate spatial registration.

PD Requirements: Historic Imagery to Parameterize α, β and θ
The project description must include the following: **PDR.52** A map of the reference area showing the area of "double-coverage". **PDR.53** Quantification of "double coverage"(greater than 90%).

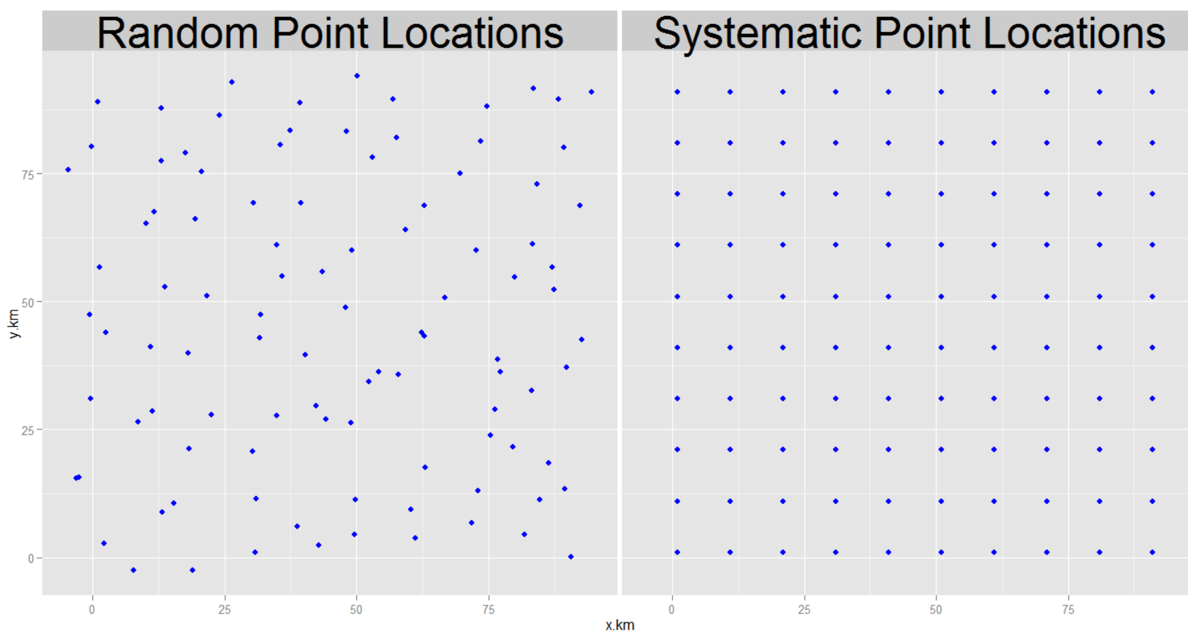
PDR.54	A line plot of the historic image dates to confirm stationarity.
PDR.55	Evidence that all image pixels are not more than 30m x 30m.
PDR.56	Empirical evidence that imagery is registered to within 10% RMSE, on average.

6.8.5 Determining Sample Size

Sample size determination is optional, but a minimum sample size may be estimated within +/- 15% of the estimated proportion of conversion in the reference area during the historic reference period.

To optionally determine sample size, a pilot sample of interpretation points may be distributed across the reference area either randomly or systematically on a grid to estimate the ultimate sample size used to estimate α, β and $\boldsymbol{\theta}$ (for an example, see Figure 5). The pilot sample should be large enough to obtain a rough estimate of the population variance. Depending on the size of the reference area and the prevalence of conversion during the reference period, a good minimum sample size is approximately 300 points in the reference area. If a grid is used, then it must feature a random origin.

Figure 5: Systematic Versus Random Sampling



Types of sample points distributed across the example reference area: random (left) and systematic (right).

Forest or native grassland state (forest/non-forest or native grassland/anthropogenic conversion) is observed at each interpretation point that falls on the cloud-free portion of each image. Visually interpret all images at each point and record forest or native grassland state (0 for forest/native grassland or 1 for non-forest/ anthropogenic conversion) and the image date in a table, one table for each point, for all points in the pilot sample and all images.

When interpreting a point, use its context to determine the presence of forest/native grassland. For example, if the point falls onto a pixel and it is unclear whether the pixel is forested, but it is clear that all surrounding pixels are agriculture, its context implies that forest is absent at the point.

For each image, record the number of points that fall on the cloud-free portion in a list.

Next, for each point, sort its table by image date from oldest to most-recent (for example see Figure 6). Discard those points for which the first conversion entry in the table is 1 (forest or native grassland absent); conversion cannot be observed without initially observing forest or native grassland. Each row in each table for each non-discarded point is now an observation as defined by equation [F.11]. For each row, calculate an observation weight using equation [A.6] for each state observation where $\#(observations\ at\ x_i, y_i)$ is the number of rows in the table and $\#(observations\ at\ t_i)$ is the number of points recorded in the list for the image with its image date.

Figure 6: Table of State Observations for a Sample Point in the Reference Area

Image	Date	State Observation	Weight
1	9/6/1992	0	0.34045
2	3/10/1994	0	0.2236
3	3/13/1995	0	0.54361
4	6/1/1998	0	0.64526
5	9/22/1998	1	0.4363
6	7/15/2001	1	0.62354
7	1/30/2003	1	0.11469
8	3/9/2003	1	0.1233
9	1/29/2005	1	0.63760
10	4/11/2007	1	0.3548

Table for a non-discarded x_i, y_i sample points sorted by image date.

Next, for each remaining table – one for each non-discarded point – aggregate its rows into a single master table. For each row in the master table, normalize its weight by dividing each weight by the sum of all weights, so that all the weights add to one. The master table may still include locations in the reference area that do not experience conversion during the reference period.

The master table, constructed from the pilot sample, contains rows that correspond to observations of forest state, observation times and weights. If the exact date of the image is known, the exact date should be included in the master table (if not known exactly, see guidance in section 6.7.1). A Horvitz-Thompson estimator of the standard deviation of conversion state σ_{EM} in the reference area is given in equation [F.13] where o_i corresponds to an observed state, w_i corresponds to a normalized weight for the i^{th} row and $\mathcal{I}$ is the set of all rows in the master table.

The minimum sample size m_{DF} in the space of the reference area required for parameterizing α, β and $\boldsymbol{\theta}$ to within +/- 15% on average is estimated by [F.12]. This is the number of sample points to be placed in the reference area to parameterize α, β and $\boldsymbol{\theta}$. This number differs from n_{DF} which represents the total number of state observations across both time and space.

6.8.6 Sampling Conversion

The BEM is designed around the concept that natural and converted land-use categories are difficult, and in some cases impossible, to distinguish using traditional wall-to-wall, pixel-based remote sensing techniques. This is because such techniques use pixel-by-pixel analysis of spectral reflectance properties alone, and often fail to delineate the land-use categories required to accurately calculate ecosystem conversion rates (eg, native grassland from anthropogenically converted grassland, etc.). That said, the BEM requires manual, “heads-up” image interpretation of the sample set described below, which is overlaid on the remotely sensed imagery collected as described in Section 6.8.4. This allows for the identification of land-use categories using shape, texture and context attributes, which typically can only be completed by human analysts engaged in manual image interpretation. It should be noted that the BEM does not support automated, pixel-by-pixel classification techniques, and project proponents should not attempt to replace or sidestep manual image interpretation with an automated process such as a maximum likelihood or nearest neighbor classifier, as this tends to introduce significant errors into the model.

Sampling conversion to parameterize α, β and $\boldsymbol{\theta}$ is similar to the procedure for estimating sample size using a pilot sample in section 6.8.5, except that the sample size must be at least $\hat{m}_{DF}$ to achieve +/- 15% average precision in estimated parameters. The observed state vector $\boldsymbol{o}$, time vector $\boldsymbol{t}$ and the weight vector $\boldsymbol{w}$ used to fit the model comprise columns of the master table.

PD Requirements: Sampling Conversion to Parameterize α, β and θ
The project description must include the following: **PDR.57** The sample size. **PDR.58** A map of the reference area showing the sample point locations.

6.8.7 Discarded Sample Points

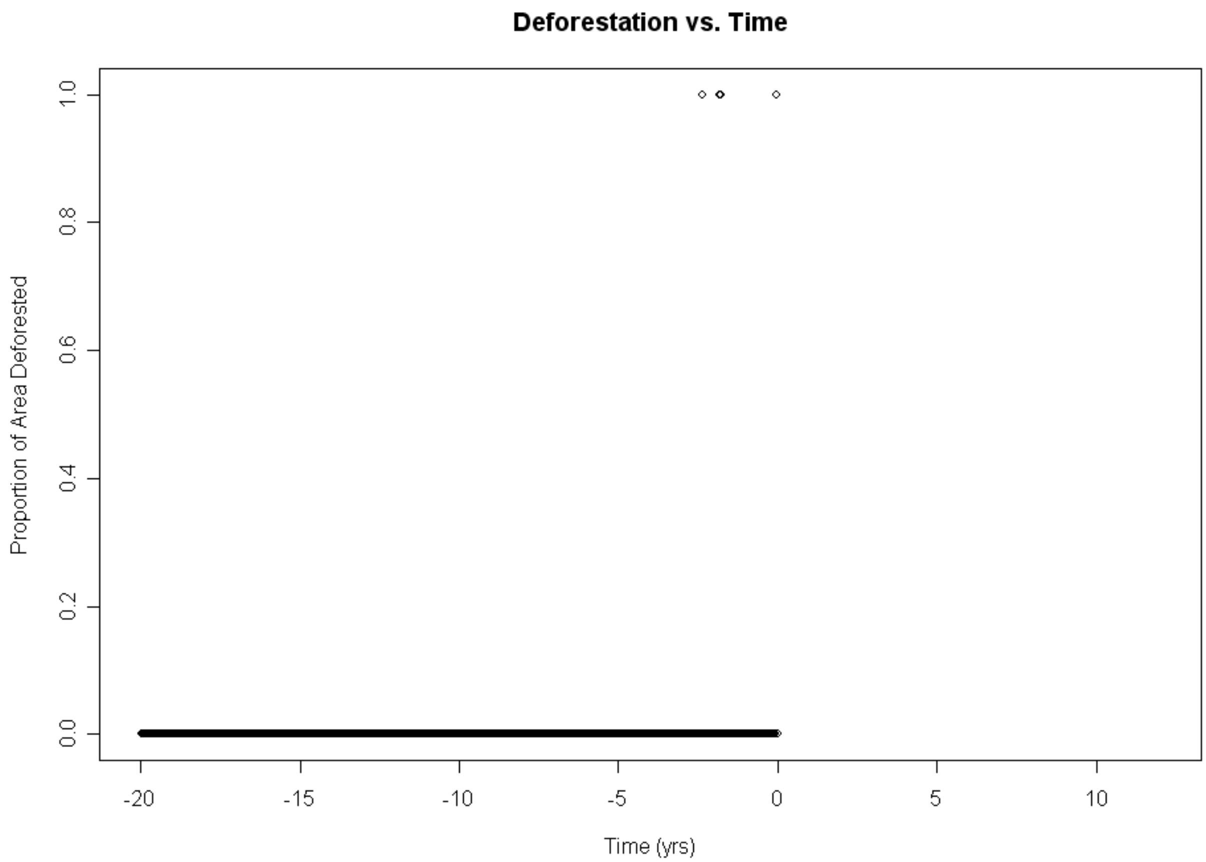
When sampling ecosystem conversion in the reference area, some sample points must be discarded because in their initial observations they were already in a state of conversion or agriculture. Conversion cannot be observed without initially observing forest or native grassland. As such, these points must not be considered when estimating the minimum sample size.

In the master table, an attribute should be retained for all non-discarded sample points so that these sample points can be mapped back to locations in the reference area. The Wildlife Works export to text file tool automatically discards sample points whose initial observations were converted, as they are of no use to the BEM model.

6.8.8 Parameterizing $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$ and $\boldsymbol{\theta}$

The logistic function defined by equation [A.4] is fit using the sample data depicting patterns of conversion in the reference area as well as conversion data for the historic reference period. The sample conversion data include the state observation vector $\boldsymbol{o}$ and the time vector $\boldsymbol{t}$ (see Appendix A). A plot of these vectors shows that land cover states are zeros and ones (for an example, see Figure 6). The time vector is expressed as the numbers of days relative to the project start date. If the historic reference period occurs before the project start date, the values of the time vector will be negative. Upon baseline reevaluation, some values will be positive because land cover state is observed after the project start date up to the time of baseline reevaluation.

Figure 7: Plot of Example State Observations Over Time



A graph of the state vector over time for the example reference area showing ones and zeros.

Covariate data are collected for interpretation point in the reference area. As such, covariate data may need to be interpolated from their sources (eg, census data that may only be collected once every 10 years). These data are used to estimate the linear predictor of the logistic function where $\boldsymbol{\theta}$ is the parameter vector (see Appendix A).

In order to avoid the possibility of perverse incentive in model fitting, covariate data must originate from the following sources:

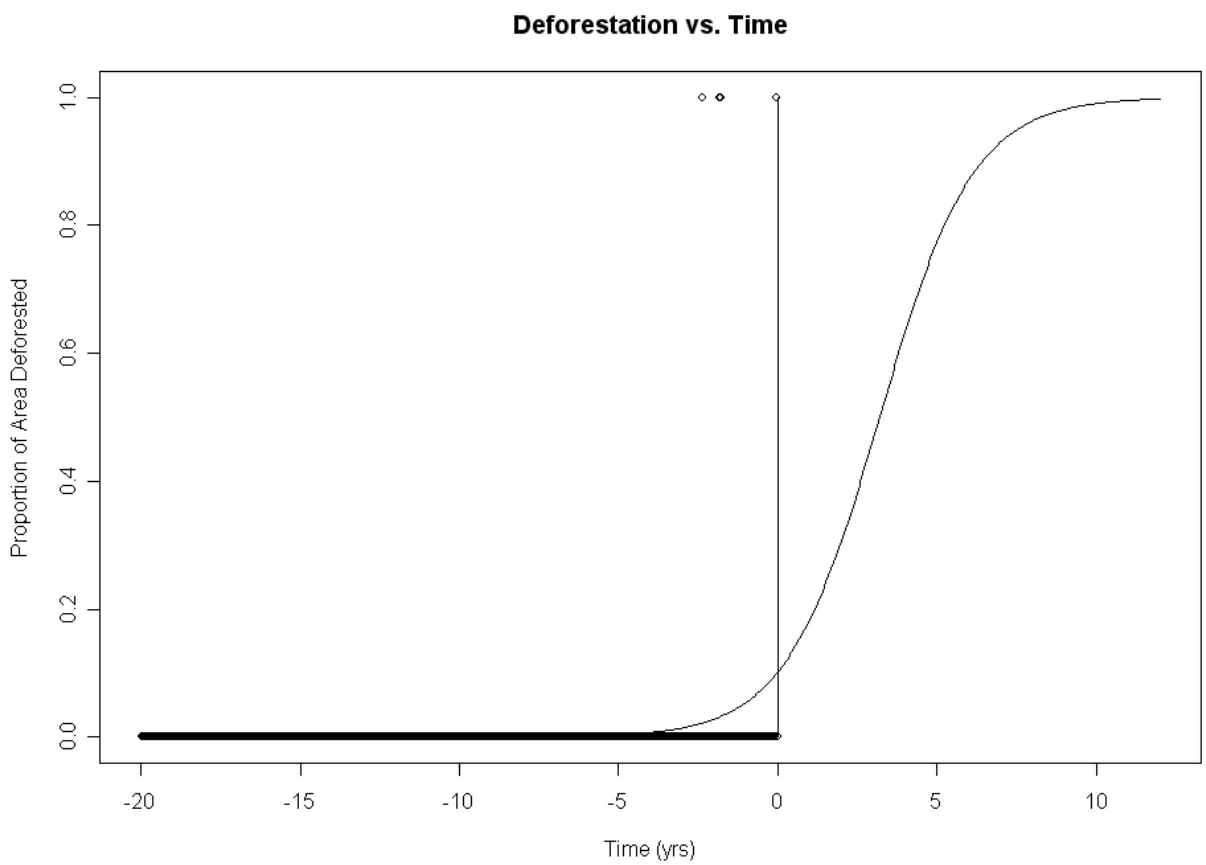
- Government publications.
- Publications by an independent third party.
- Peer reviewed literature.

These sources must be publicly available per current VCS requirements.

The parameters are found using IRLS with an initial weight vector $\boldsymbol{w}$ that corrects for spatial and temporal artifacts from sampling historic imagery (see Venables & Ripley, 2002 for information on model fitting with IRLS).

Given all possible covariate parameters $\boldsymbol{\theta}$, select the best subset of covariate parameters $\widehat{\boldsymbol{\theta}}$ using AIC as a measure of fit. For information on model selection see Davidson (2003) and Freedman (2009). The fit model must be plotted with conversion state over time and the project start date (for an example see Figure 8).

Figure 8: Graph of an Example Logistic Function Determined by α, β and θ.



A graph of the estimated logistic function over time for the example reference area relative to the project state at time zero for a forested baseline type.

PD Requirements: Parameterizing α, β and θ	
The project description must include the following:	
PDR.59	The covariates that were considered and their data sources.
PDR.60	The parameters in θ that were evaluated during model selection.
PDR.61	The parameters in $\hat{\theta}$ of the selected model.

PDR.62	The rationale used for selecting $\hat{\theta}$ including comparisons of AIC.

6.8.9 Minimizing Uncertainty

Observation error must be mitigated as much as possible by developing a protocol for the interpretation of land cover state from remotely-sensed imagery. Training should ideally be provided to the interpreter(s).

Observation data must be checked for inconsistencies. For example, observations of forest state over time at any one point in space probably do not transition from forest to non-forest, and then back to forest during the reference period (for an example, see Figure 9). A list of "impossible" or "unlikely" forest or native grassland state transitions must be developed, and each point that matches the criteria should be reexamined.

Figure 9: Table of State Observations to Identify Possible Errors.

Image	Date	State Observation
1	9/6/1992	0
2	3/10/1994	0
3	3/13/1995	0
4	6/1/1998	0
5	9/22/1998	1
6	7/15/2001	1
7	1/30/2003	0
8	3/9/2003	1
9	1/29/2005	1
10	4/11/2007	1

Table for an x_i, y_i sample point featuring a potential interpretive error at image date 1/2003.

A random subset of sampled points must be interpreted by a different person than the first point interpreter, and these observations must be checked against the observations made by the interpreter or interpretive team members to identify any systematic misinterpretation. If it is not possible to determine the correct state for a point, it is conservative to mark the transition to a converted state to a later date in the historic reference period when that transition is apparent. If desirable, the conversion date of a point or set of points may be determined by asking persons with first-hand knowledge of that conversion date. All systematic errors must be corrected.

PD Requirements: Minimizing Uncertainty in Parameters $\hat{\alpha}$, $\hat{\beta}$ and $\hat{\theta}$
The project description must include the following: **PDR.63** A protocol for interpreting land cover state from imagery, which must include guidance for interpreting the following: • Discerning conversion features using shape, texture and context in the reference area landscape • Addressing seasonal variation of vegetation (phenology) within imagery • Identifying and addressing the characteristics of specific landscape configurations (ie, mosaic forest, grassland, etc.) **PDR.64** The results of an independent check of the interpretation. **PDR.65** Evidence that systematic errors, if any, from the independent check of the interpretation were corrected.

6.8.10 Estimating Uncertainty

Uncertainty in estimated parameters $\hat{\alpha}$, $\hat{\beta}$ and $\hat{\boldsymbol{\theta}}$ is estimated using [F.13]. This is the standard error of weighted point observations where the i^{th} observation of forest state is o_i, multiplied by the current estimated baseline emissions in the project accounting area across all selected carbon pools (see section 8.1).

PD Requirements: Estimating Uncertainty in Parameters $\hat{\alpha}$, $\hat{\beta}$ and $\hat{\theta}$
The project description must include the following: **PDR.66** The estimated uncertainty $\hat{\sigma}_{EM}$ from [F.13] and statistical summaries from model fitting software, if available. **PDR.67** Reference to uncertainty calculations.

6.9 Determining t_{PAI}

This section is to be applied separately for each identified project accounting area when the project is a grouped project.

The parameter t_{PAI} is the number of days after the project start until the project activity instance start date for the project activity instance associated with a particular project accounting area.

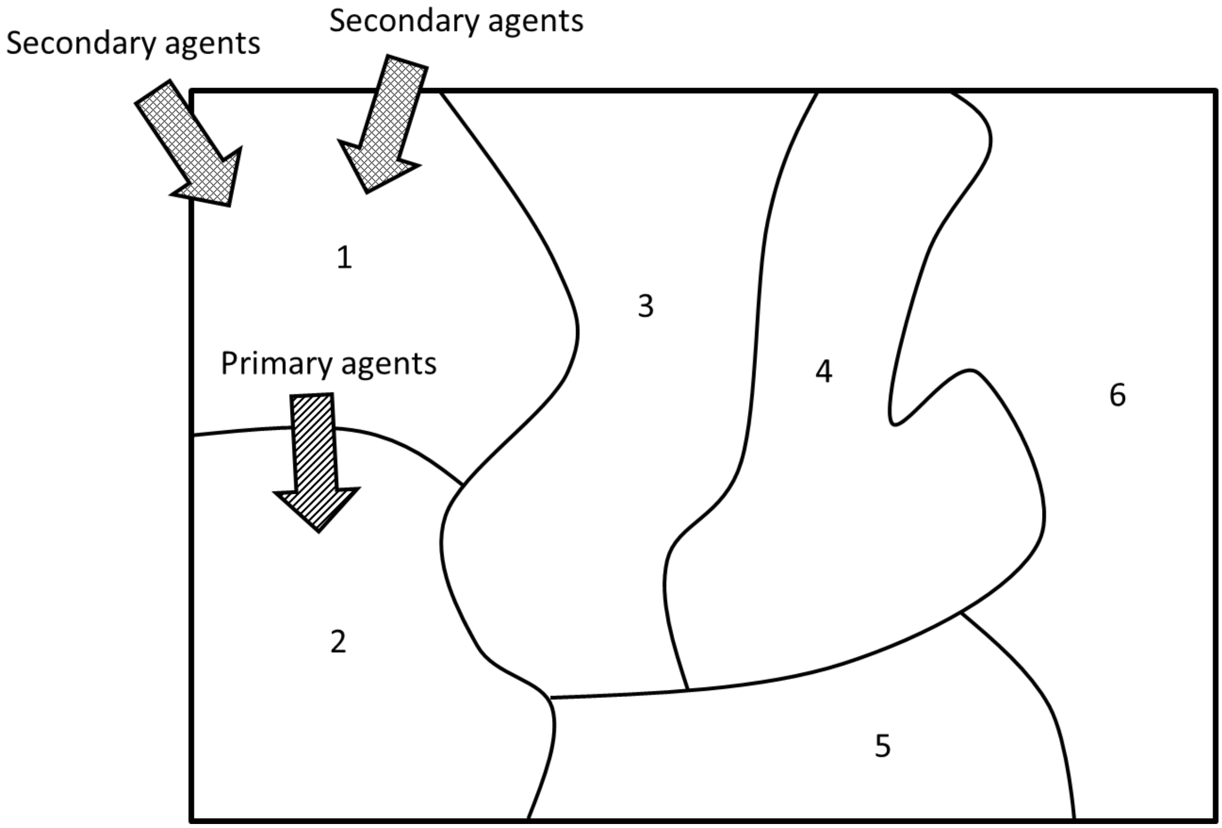
Monitoring Requirements: Determining t_{PAI}
The monitoring report must include the following if the project is a grouped project: **MR.7** For each project activity instance in the group, its project activity instance start date. **MR.8** For each project accounting area, the value of $\hat{t}_{PAI}$.

6.10 Determining t_{SA}

This section is to be applied separately for each identified forest project accounting area having a baseline type F-P1.a or F-P1.b.

The parameter t_{SA} is the number of days after the primary agent begins commercial logging until when the secondary agent of deforestation is likely to begin degrading the forest project accounting area under the baseline scenario. This parameter can be determined from the results of the PRA or expert knowledge. In many cases of legally-sanctioned commercial logging, it is the length of the logging period to harvest the first regulated harvest unit. Often, due to unsustainable harvest plans, corruption, or indifference, the logging infrastructure may be exploited by secondary agents in the cascade of degradation. Often, after the commercially viable timber has been removed from the primary agent's first harvest unit, the primary agent will abandon that area and secondary agents will enter to further degrade and ultimately deforest the area.

Figure 10: Cutting Cycle Under a Type F-P1.a Project Scenario.



When unsustainable harvest occurs, after the primary agents abandon a timber harvest area to move to another area (1 to 2 in the figure above), secondary agents will move in and continue to degrade and deforest that area. The length of time between the entry of primary agents to a harvest area and the arrival of secondary agents is t_{SA}.

In the case when the parameter is the length of the first cutting cycle and the primary agent's harvest plans for the forest project accounting area cannot be obtained, the first observed instance of deforestation apparently caused by secondary agents can be used as a conservative value for the parameter (parameterized in terms of days after the start of the historic reference period). When evaluating possible values for this parameter, a larger number is always more conservative than a smaller number. This parameter must be greater than or equal to zero.

PD Requirements: Parameterizing t_{SA}
The project description must include the following: **PDR.68** The parameter $\hat{t}_{SA}$ as the number of days after the primary agent begins commercial logging until when the secondary agent of deforestation is likely to begin degrading the forest project accounting area.

PDR.69	A description of how $\hat{t}_{SA}$ was obtained.
PDR.70	Harvest plans for the forest project accounting area under the baseline scenario, results from the PRA or analysis of the reference area to determine the parameter.

6.11 Determining t_{PA}

This section is to be applied separately for each identified forest project accounting area having a baseline type F-P1.a or F-P1.b.

The parameter t_{PA} is the number of days relative to the project start date when the primary agent began or would have begun legally-sanctioned commercial logging in the forest project accounting area. This can only be established by harvest plans prepared for the forest project accounting area or by public record. In most cases, the primary agent would have started commercial logging in the forest project accounting area at the project start date and in these cases, the parameter should be set to zero. (For baseline type F-P2 and G-P2, the parameter is always zero.) In other cases when the primary agent has already started logging as of the project start date, the parameter will be negative (days relative to the project start date at time zero). In other cases when the primary agent would have started logging after the project start date, the parameter will be positive.

PD Requirements: Parameterizing t_{PA}	
The project description must include the following:	
PDR.71	The parameter $\hat{t}_{PA}$ as the number of days relative to the project start date when the primary agent began or would have begun legally-sanctioned commercial logging in the forest project accounting area.
PDR.72	A description of how $\hat{t}_{PA}$ was obtained.
PDR.73	Harvest plans for the forest project accounting area under the baseline scenario or public records to support the determination of the parameter.

6.12 Determining x_0

This section is to be applied separately for each identified project accounting area.

The parameter $\boldsymbol{x}_0$ is a vector of covariate data as of the project start date. See section 6.8.8 and Appendix A for more information on covariates.

If covariate values are used to predict a rate of conversion higher than the rate observed in the reference area during the historic reference period, the project proponent must provide clear evidence to substantiate the use of the covariate data.

PD Requirements: Determining x_0
If covariates to conversion are used, the project description must include the following: **PDR.74** A table of covariate values as of the project start date and a description of how the values were determined including any interpolation or extrapolation methods. If covariates are used to predict a rate of conversion higher than the rate of observed in the reference area during the historic reference period, the project description must include the following: **PDR.75** Justification for why the rate of conversion predicted by covariates exceeds the rate indicated from historical conversion patterns.

6.13 Determining x_{PAI}

This section is to be applied separately for each identified project accounting area when the uped project.

The parameter x_{PAI} is a vector of covariate data as of the project activity instance start date for the project activity instance associated with a particular project accounting area. See section 6.8.8 and Appendix A for more information on covariates.

Monitoring Requirements: Determining x_{PAI}
The monitoring report must include the following if the project is a grouped project: **MR.9** A table of covariate values as of the project activity instance start dates and a description of how the values were determined including any interpolation or extrapolation methods.

6.14 Determining m

This section is to be applied separately for each identified forest project accounting area having a baseline type F-P1.a or F-P1.b.

The parameter m is the average carbon in merchantable trees cut each year as a result of legally-sanctioned commercial logging. It is not the volume of harvested wood. If AGMT and

BGMT are selected carbon pools then it must include carbon in both the above-ground and below-ground portions of merchantable trees cut each year. If only AGMT is selected then it need only include the above-ground portion.

The project proponent must estimate m using timber harvest plans, if available, which apply to the forest project accounting area and were developed by the specific agent of deforestation under the baseline scenario. In the absence of timber harvest plans, m may be conservatively determined from the measurement of carbon stocks in merchantable trees in the forest project accounting area using equation [F.1] where $C_{AGMT}^{[m=0]}$ and $C_{BGMT}^{[m=0]}$ are determined prior to the first monitoring event or at the first monitoring event, and t_m is the number of days in the project lifetime or the length of time the primary agent would have harvested the entire merchantable trees in the baseline scenario. If BGMT is not a selected pool, then $C_{BGMT}^{[m=0]}$ can be set to zero. If t_m is the project lifetime, this method can only be used if the project end date is after the date on which the primary agent would have concluded legally-sanctioned commercial logging in the forest project accounting area under the baseline scenario. Regardless of which method is used to estimate m, timber harvests in the baseline scenario must comply with the legal maximum allowable cut as published by the relevant national authority of the country where the project is located.

This parameter must be greater than zero.

This methodology deliberately omits prescribing accounting for re-growth and residual damage in order to conservatively simplify accounting. In commercial logging, the emissions from residual damage will exceed carbon sequestration from re-growth.

PD Requirements: Parameterizing m	
The project description must include the following:	
PDR.76	The parameter $\hat{m}$ as the average carbon in merchantable trees cut each year as a result of legally-sanctioned commercial logging.
PDR.77	Documentation of how m was determined. This may include an analysis of carbon stocks in merchantable trees in the forest project accounting area, timber harvest plans for the project accounting area or reference to a publication containing the maximum allowable cut applicable to the project area. The parameter must be greater than zero.

6.15 Determining γ

This section is to be applied separately for each identified project accounting area having a planned baseline type (F-P1.a, F-P1.b, F-P2 or G-P2). The parameter γ is the number of days between the beginning of the historical reference period and the project start date.

PD Requirements: Determining γ
The project description must include the following: **PDR.78** The project shift parameter γ as the number of days between the beginning of the historical reference period and the project start date.

6.16 Determining q

This section is to be applied separately for each identified project accounting area.

The parameter q is the number of days between the onset of degradation and the beginning of conversion. This parameter can be determined by expert knowledge, results from the PRA or reports from peer-reviewed literature. It is always conservative to set this parameter equal to zero and any other value must be justified. When evaluating possible values for this parameter, it is always conservative to select a lower number. This parameter must be greater than or equal to zero.

PD Requirements: Parameterizing q
The project description must include the following: **PDR.79** The parameter q as the number of days between the onset of degradation and the beginning of conversion. **PDR.80** If the default of zero is not selected for q, then a justification for the determination of q.

6.17 Determining r_U

This section is to be applied separately for each identified project accounting area having a baseline type of Type F-U2, F-U3, or G-U2.

The parameter r_U is set to position the baseline emissions models relative to the onset rate of conversion immediately adjacent to the project area at the project start date. There are two permissible methods by which this parameter can be determined:

1. In the first method, the ratio of converted perimeter to the total threatened perimeter along the boundaries of the project area must be measured as of the project start date. Converted perimeter is defined as the total perimeter that has been converted prior to the project start date within 120 meters inside or outside the project area boundary, which can be measured from any point in time up until the project start date. Threatened

perimeter is defined as that which is vulnerable as of the project start date to conversion by being accessible to the local agents of conversion and has not yet been converted. Threatened perimeter does not include converted perimeter. Examples of non-threatened perimeter include perimeter that abuts a national park, is surrounded by steep slopes that prohibit access to the project area boundary (as defined by project proponent), or is adjacent to water. For forest baseline types, non-threatened perimeter also may include naturally-occurring non-forest within 120 m of the project area boundary.

$$r_U = \frac{converted\ perimeter}{threatened\ perimeter}$$

For example, consider the situation in which the project area has a total perimeter of 500 km. If 200 km of this perimeter is adjacent to a national park, and 30 km is naturally-occurring non-forest within 120 m on either side of the perimeter, then the total threatened perimeter is 270 km. If 150 km of this perimeter becomes converted, then r_U will be (150/270, or 0.556).

2. Alternatively, r_U can be quantified using the ratio of converted area within the project area to the sum of all project accounting areas less the area that is converted. Conversion is defined as area that has been converted prior to the project start date from forest to non-forest or from native grassland to anthropogenic conversion.

$$r_U = \frac{converted\ area}{sum\ of\ all\ project\ accounting\ areas - converted\ area}$$

Both of these methods rely on the identification of conversion relative to the project area boundary or in the project area. Images or data used to determine conversion must not be older than ten years prior to the project start date. Both of these methods require images or data from two points in time be analyzed. Measurement units for the denominator and the numerator must be the same. Depending on the state of conversion at the project start date, the ratio may be greater than one.

PD Requirements: Parameterizing r_U
The project description must include the following: **PDR.81** The parameter $\hat{r}_U$ as the ratio of converted perimeter to total threatened perimeter, or the ratio of converted area to total project accounting area(s), as of the project start date. **PDR.82** Description of how $\hat{r}_U$ was obtained. **PDR.83** Results of GIS analysis to determine or measure $\hat{r}_U$ in the project area including the dates of images used to identify conversion.

6.18 The Decay Emissions Model

This section is to be applied separately for each identified project accounting area.

The Decay Emissions Model accounts for decay from biomass and dead wood from all pools considered. It uses the same parameters from section 6.7 as the BEM. No additional parameters are required. The Decay Emissions Model is given by [F.10], and predicts linear decay over a ten-year period. The Decay Emissions Model for dead wood and below-ground biomass are based on the VCS default decay models for these pools.

6.19 The Soil Emissions Model

This section must be applied separately for each identified project accounting area if SOC is an included carbon pool.

The SEM is given by [F.6], [F.7] and [F.8]; it predicts the exponential decay of SOC over time. The Decay Emissions Model for carbon in soil, given by [F.9], contains λ_{SOC}, a parameter that characterizes the decay of SOC over time. The parameter λ_{SOC} should be determined using a default value or empirical estimation per section 6.19.1.

6.19.1 Determining λ_{SOC}

If SOC is included as a carbon pool the parameter λ_{SOC} must be determined with the use of one of the three methods as outlined in sections 6.19.2, 6.19.3 and 6.19.4.

6.19.2 Default Values for λ_{SOC}

The default value for λ_{SOC} is 0.2 and is derived from E. Davidson & Ackerman (1993). Projects located in tropical climates may apply this default value. This is a default that may become out of date and is subject to periodic re-assessment. All other projects must empirically estimate λ_{SOC} or use appropriate decay rates from peer-reviewed literature.

6.19.3 Empirically Estimating λ_{SOC}

In order for the project proponent to estimate λ_{SOC} from empirically measured data, the project proponent must perform a “space for time” substitution, as it is impractical to repeatedly sample the same recently-converted forest or native grassland patch over the project crediting period (required to generate enough measurements to derive a soil decay curve). The space for time substitution allows the project proponent to make many measurements at the same point in time, over a range of agricultural fields, distributed spatially within the reference area, that were converted at *known times*.

Given expert knowledge of the reference area, including knowledge of farming practices and culture, the project proponent may apply empirically measured soil carbon results to mathematically derive a value for λ_{SOC}. This should involve a statistically sound method such as temporal regression or trend analysis, and must be accepted by the validator at project validation.

If the project proponent opts to measure λ_{SOC} empirically, measurements must be taken within the same reference area that meets the requirements listed in section 6.8.1. This serves to ensure that parameterization of the Decay Emissions Model is representative of common farming practices in the region.

PD Requirements: Empirically Estimating λ_{SOC}	
If $\boldsymbol{\lambda_{soc}}$ is estimated using data, the project description must include the following:	
PDR.84	Description of how samples from the reference area were selected including stratification, if any.
PDR.85	A map of sample locations in the reference area.
PDR.86	A table showing the conversion time for each area (farm or otherwise) from which samples were taken.
PDR.87	Description of and statistics for the method applied to estimate $\hat{\lambda}_{SOC}$.
PDR.88	Graph of projected decay model over project lifetime.

6.19.4 Literature Estimates for $\boldsymbol{\lambda_{SOC}}$

Literature estimates may be taken from peer-reviewed scientific or government publications rather than using the default value or empirically estimating λ_{soc}. Publications must come from the same ecotype and soil type as the project, include the same soil profile considered, have an adequate sample size and published measures of precision (per Appendix B) , and be generally representative of the project area. The field experiments performed by the authors of the peer-reviewed literature must be based on data from replicated field experiments whose management treatments with a duration of at least five years.

PD Requirements: Literature Estimates for λ_{SOC}	
If an alternate $\boldsymbol{\lambda_{soc}}$ is used, the project description must include the following:	
PDR.89	Inclusion of decay model on which parameter is based.

PDR.90	Explicit description of referenced literature, including project location, sampling methodology, included species, sample size, duration of field experiments, and decay parameter upon which decay is based.
PDR.91	Graph of projected decay model over project lifetime.
PDR.92	If decay model is based on any other element besides carbon, defense of ability to predict carbon decay must be provided.

6.20 Baseline Reevaluation

The baseline scenario must be reevaluated per current VCS requirements. Prior to baseline reevaluation, the project proponent may choose to conduct a new PRA and subsequent analyses to re-appraise the baseline scenario (see section 6.1). The project proponent must reassess certain elements of the baseline scenario per sections 6.20.1 and 6.20.2.

PD Requirements: Baseline Reevaluation	
Upon a baseline revision, the project description must include the following as of the current monitoring period:	
PDR.93	All required documentation as specified in section 6 for the project prior to the baseline reevaluation.
PDR.94	All required documentation as specified in section 6 for the project after the baseline reevaluation including the reevaluation period.
PDR.95	A narrative of the reevaluation including any obstacles and how they were overcome.

6.20.1 Reevaluation of the Reference Area and Period

This section is to be applied separately for each identified project accounting area.

The reference area may be resized to be larger or smaller than prior to baseline reevaluation to reflect the following changes:

- Refine the boundaries of the reference area and delineate new boundaries to exclude any new REDD projects or additions to the project area, based on the results of the new PRA or expert knowledge.
- Extend the reference period – the new period should reflect the time since the start of the original reference period up to the time of the most recent baseline reevaluation.

The new reference area must meet all requirements specified in section 6.8.1. If the new reference area does not meet these requirements, then the project is not eligible for additional crediting for monitoring periods subsequent to the baseline reevaluation until a new reference area can be defined that meets the requirements specified in section 6.8.1.

Projects that share the same reference area are eligible for crediting for all monitoring periods.

PD Requirements: Reevaluation of the Reference Area and Period
Upon a baseline revision, the project description must include the following as of the current monitoring period: **PDR.96** A map of the new reference area.

6.20.2 Re-parameterization of α, β and θ

This section is to be applied separately for each identified project accounting area.

The baseline emissions models must be re-parameterized by adding new observations of land cover state per section 6.7 and the values for α, β and θ must be re-estimated per section 6.8. The data from observations of prior reference areas should remain unchanged even though the boundaries of the prior reference areas may be different than those of the current reference area. The re-parameterized values must be used for all monitoring periods subsequent to baseline reevaluation.

PD Requirements: Re-parameterization of α, β and θ
Upon a baseline revision, the project description must include the following as of the current monitoring period: **PDR.97** Summary of new data observed in the new reference area. **PDR.98** The re-parameterized values $\hat{\alpha}$, $\hat{\beta}$ and $\hat{\theta}$.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

This methodology uses a project method for determining additionality.

Project proponents must demonstrate additionality using the latest version of the VCS *Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities*.

The common practice test must demonstrate that project activities will address at least one driver of conversion in such a way that the driver would not have been addressed had the project not been undertaken.

PD Requirements: Demonstration of Project Additionality	
The project description must include the following:	
PDR.99	A list of alternative land use scenarios to the project.
PDR.100	Justification for the selected baseline scenario. This justification can include expert knowledge, results from the participatory rural appraisal and ex-ante estimates of avoided emissions (see sections 6.1 and 8.4.7).
PDR.101	An investment or barriers analysis proving that the project is not the most economical option.
PDR.102	A common practice analysis including a list of project activities and the drivers of conversion that they address.
PDR.103	Evident compliance with the minimum requirements of the aforementioned VCS tool. This evidence may be the same as the evidence provided to meet reporting requirements listed in section 4.

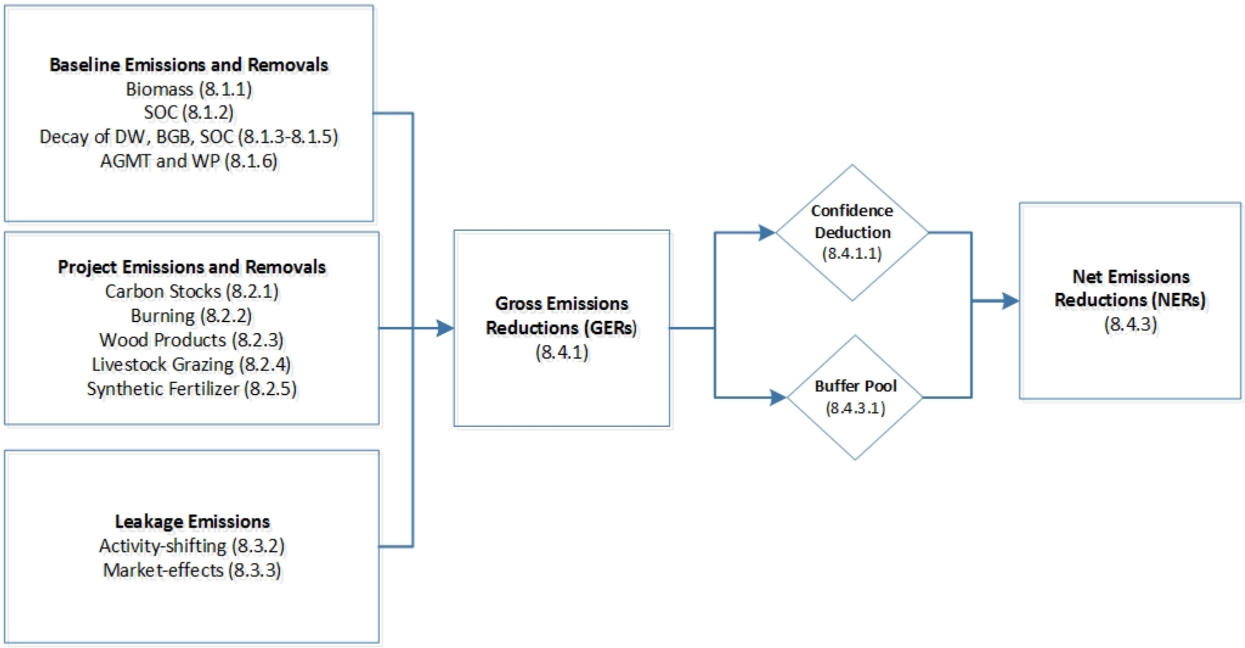
8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND/OR REMOVALS

Cumulative emissions reductions and/or removals are quantified as those since the project crediting period start date up to the end of the current monitoring period. Current gross emissions reductions and/or removals (GERs) are quantified as the difference between cumulative emissions up to the end of the current monitoring period and cumulative emissions up to the end of the previous monitoring period, minus any project emissions that have occurred during the current monitoring period, emissions from leakage and carbon not decayed in certain decay pools (see section 8.4.1 and Figure 11).

Net emissions reductions and/or removals (NERs) are GERs minus a confidence deduction (if any) and buffer pool allocation (see section 8.4.3). NERs are determined for each project accounting area and if the project area contains multiple project accounting areas, summed across project accounting areas (see sections 8.4.3 and 8.4.5).

For each project accounting area, apply sections 8.1, 8.2, 8.3.2, and 8.4.1. If the baseline scenario includes legally-sanctioned or illegal logging, use section 8.3.3 to determine market leakage, if any. Use section 8.4.1 to determine GERs for each project accounting area. If the baseline type for a project accounting area is F-U1 or G-U1 see the special requirements in section 8.4.1.2.

Figure 11: Flow Diagram for the Quantification of GHG Emissions Reductions and/or Removals



8.1 Baseline Emissions

This section is to be applied separately for each identified project accounting area. The baseline emissions $E_{B\,\Delta}^{[m]}$ for the current monitoring period are given by [F.15]. This is a function of the cumulative baseline emissions at the beginning and end of the current monitoring period as given by [F.16]. After this quantity is verified, it becomes fixed when determining emissions at subsequent monitoring events. It is possible that $E_{B\,\Delta}^{[m]}$ could be less than zero due to conditions in the proxy area and parameter effects in the baseline emissions models over time. However, for most projects, this value will be positive indicating baseline emissions would have occurred in the absence of the project.

If any of the following pools are not selected, their corresponding values in [F.15] are zero: SOC, BGB, DW or WP.

Monitoring Requirements: Baseline Emissions
The monitoring report must include the following: **MR.10** Calculations of current baseline emissions $E_{\mathrm{B}\,\Delta}^{[m]}$ as of the current monitoring period.

MR.11	Calculations of baseline emissions $E_{B\,\Delta}^{[m-1]}$ from prior monitoring periods.
MR.12	Calculations of cumulative baseline emissions for each selected pool ($E_{B\,BM}^{[m]}$ and $E_{B\,SOC}^{[m]}$) and undecayed carbon ($C_{B\,BGB}^{[m]}$, $C_{B\,DW}^{[m]}$, $C_{B\,SOC}^{[m]}$ and $C_{B\,WP}^{[m]}$), as of the current monitoring period.

8.1.1 Calculating Baseline Emissions from Biomass

Baseline emissions from biomass are determined based on the baseline type and selected carbon pools. For each selected carbon pool in biomass (BM), the appropriate BEM is applied to calculate baseline emissions per the following sections. Baseline emissions from biomass for the current monitoring period are based on the average carbon stock in selected carbon pools from AGMT, AGOT, AGNT, BGMT, BGOT and BGNT given by [F.17] for the project accounting area and [F.18] for the proxy area. This set of selected carbon pools in biomass $\mathcal{B}$ is a subset of all selected carbon pools $\mathcal{C}$ (see section 5.4).

The cumulative baseline emissions from biomass $E_{B\,BM}^{[m]}$ as of monitoring period $[\boldsymbol{m}]$ are calculated by equations [F.19], [F.20], [F.21], and [F.22] discussed in sections 8.1.1.1, 8.1.1.2, 8.1.1.3 and 8.1.1.4. Once verified, these quantities do not change when calculating baseline emissions for subsequent monitoring periods.

Monitoring Requirements: Baseline Emissions from Biomass	
The monitoring report must include the following:	
MR.13	Calculations of cumulative baseline emissions from biomass $E_{B\,BM}^{[m]}$ for the current monitoring period.
MR.14	Calculations of cumulative baseline emissions from biomass $E_{B\,BM}^{[m]}$ for all prior monitoring periods.

8.1.1.1 Calculating Cumulative Baseline Emissions from Biomass for Type F-P1.a

The cumulative baseline emissions from biomass $E_{B\,BM}^{[m]}$ as of monitoring period $[m]$ are calculated by [F.19]. The variables $c_{P\,BM}^{[m=0]}$ is the average carbon stocks in biomass as measured in the project accounting area prior to the first monitoring event for F-P1.a. $c_{B\,BM}^{[m]}$ is the average carbon stocks in biomass as measured in the proxy area, $t^{[m]}$ is the time of the monitoring event and $x^{[m]}$ is the monitored covariates as of the time of the monitoring event. These variables are monitored per section 9.

8.1.1.2 Calculating Cumulative Baseline Emissions from Biomass for Types F-P2 and G-P2

The cumulative baseline emissions from biomass $E_{B\,BM}^{[m]}$ as of monitoring period $[m]$ are calculated by [F.20]. The variable $c_{P\,BM}^{[m=0]}$ is the average carbon stocks in biomass as measured in the project account area prior to the first monitoring event, $c_{B\,BM}^{[m]}$ is the average carbon stocks in biomass as measured in the proxy area, $t^{[m]}$ is the time of the monitoring event and $x^{[m]}$ is the monitored covariates as of the time of the monitoring event. These variables are monitored per section 9.

8.1.1.3 Calculating Cumulative Baseline Emissions from Biomass for Types F-U1 and G-U1

The cumulative baseline emissions from biomass $E_{B\,BM}^{[m]}$ as of monitoring period $[m]$ are calculated by [F.22]. The variable $c_{P\,BM}^{[m=0]}$ is the average carbon stocks in biomass as measured in the project account area prior to the first monitoring event, $c_{B\,BM}^{[m]}$ is the average carbon stocks in biomass as measured in the proxy area, $t^{[m]}$ is the time of the monitoring event and $x^{[m]}$ is the monitored covariates as of the time of the monitoring event. These variables are monitored per section 9.

8.1.1.4 Calculating Cumulative Baseline Emissions from Biomass for Types F-U2 and G-U2

The cumulative baseline emissions from biomass $E_{B\,BM}^{[m]}$ as of monitoring period $[m]$ are calculated by [F.21]. The variable $c_{P\,BM}^{[m=0]}$ is the average carbon stocks in biomass as measured in the project account area prior to the first monitoring event, $c_{B\,BM}^{[m]}$ is the average carbon stocks in biomass as measured in the proxy area, $t^{[m]}$ is the time of the monitoring event and $x^{[m]}$ is the monitored covariates as of the time of the monitoring event. These variables are monitored per section 9.

8.1.1.5 Calculating Cumulative Baseline Emissions from Biomass for Type F-U3 and F-P1.b

When the baseline type is Type F-U3 or F-P1.b, a spatial model called the spatial algorithm is used to conservatively estimate baseline emissions from biomass by carbon pool per AFOLU requirements (see section 8.1.1.5.1). The cumulative baseline emissions from biomass $E_{B\,BM}^{[m]}$ as of monitoring period $[m]$ are calculated by [F.24] using the spatial algorithm (see section 8.1.1.5.1). Once verified, this quantity does not change when calculating baseline emissions for subsequent monitoring periods.

8.1.1.5.1 The Spatial Algorithm for Biomass

Of all possible spatial models, the spatial algorithm is the most conservative possible for depleting carbon stocks in the baseline scenario.

To implement the spatial algorithm, first order the estimates of average carbon stocks across all selected carbon pools in biomass from lowest to highest, $1,2 \dots n$ by stratum for all strata in the project accounting area. Use [F.23] to estimate the average carbon in biomass for each stratum s.

This ordering should be conducted at the first monitoring period and then the order should be fixed for subsequent monitoring periods. Every monitoring period, apply the spatial algorithm given by [F.24] to determine cumulative emissions for each selected carbon pool in biomass. The spatial algorithm uses the weighted average carbon stocks across all strata currently being depleted in the baseline. Weighted average carbon stocks are calculated as in [B.35]. The spatial algorithm is denoted as $BEM_{SP}\left(wc_{P\ i\ BM}^{[m=0]}, c_{B\ BM}^{[m]}, t^{[m]}, x^{[m]}\right)$. The average carbon in biomass in the proxy area $c_{B\ BM}^{[m]}$ is given by [F.18].

Monitoring Requirements: Applying the Spatial Algorithm
The monitoring report must include the following: **MR.15** The order of strata from lowest carbon stocks to highest carbon stocks based on the average across all pools. **MR.16** Calculations for each step which are carried through from monitoring period to monitoring period. **MR.17** Calculations of cumulative baseline emissions from biomass $E_{B\ BM}^{[m]}$ for prior monitoring periods.

8.1.2 Calculating Baseline Emissions from SOC

Baseline emissions from SOC are determined based on the baseline type if the SOC pool is selected. The appropriate SEM is applied to calculate baseline emissions per the following sections. Baseline emissions from SOC for the current monitoring period are based on the average carbon stock in SOC in the project accounting area and in the proxy area.

The current baseline emissions from SOC $E_{\mathrm{B}\ \Delta SOC}^{[m]}$ are estimated as [F.26] from all types other than F-P1.b and F-U3, which is the difference in cumulative baseline emissions for the current monitoring period $E_{B\ SOC}^{[m]}$ and the cumulative baseline emissions for the prior monitoring $E_{B\ SOC}^{[m-1]}$ (fixed at prior monitoring event). Current baseline emissions from SOC $E_{\mathrm{B}\ \Delta\ SOC}^{[m]}$ are used to calculate carbon not decayed in soil (see section 8.1.5).

For baseline types F-P1.b and F-U3, current baseline emissions from SOC $E_{\mathrm{B}\ \Delta SOC}^{[m]}$ are calculated as in [F.29], using the spatial algorithm in 8.1.2.4.1.

Monitoring Requirements: Baseline Emissions from SOC for Types F-P1.a, F-P1.b, F-P2, and G-P2
The monitoring report must include the following: **MR.18** An estimate of current baseline emissions from SOC $E_{\mathrm{B}\,\Delta\,SOC}^{[m]}$ as of the current monitoring period. **MR.19** An estimate of cumulative baseline emissions from SOC $E_{B\,SOC}^{[m]}$ for the current monitoring period. **MR.20** Calculations of cumulative baseline emissions from SOC $E_{B\,SOC}^{[m]}$ for all prior monitoring periods.

8.1.2.1 Calculating Baseline Emissions from SOC for Types F-P1.a, F-P2, and G-P2

Baseline emissions from SOC for Types F-P1.a, F-P2, and G-P2 are calculated using the SEM. The cumulative baseline emissions from SOC $E_{B\,SOC}^{[m]}$ as of monitoring period $[m]$ are estimated by [F.25]. Once verified, this quantity does not change when calculating baseline emissions for subsequent monitoring periods.

8.1.2.2 Calculating Baseline Emissions from SOC for Type F-U1 and G-U1

baseline emissions from SOC for Types F-U1 and G-U1 are estimated using the SEM. The cumulative baseline emissions from SOC $E_{B\,SOC}^{[m]}$ as of monitoring period $[m]$ are estimated by [F.27]. Once verified, this quantity does not change when calculating baseline emissions for subsequent monitoring periods.

8.1.2.3 Calculating Baseline Emissions from SOC for Types F-U2 and G-U2

Baseline emissions from SOC for Types F-U2 and G-U2 are estimated using the SEM. The cumulative baseline emissions from SOC $E_{B\,SOC}^{[m]}$ as of monitoring period $[m]$ are estimated by [F.28]. Once verified, this quantity does not change when calculating baseline emissions for subsequent monitoring periods.

8.1.2.4 Calculating Baseline Emissions from SOC for Types F-U3 and F-P1.b

Baseline emissions from SOC for Types F-U3, and F-P1.b are estimated using the SEM. The cumulative baseline emissions from SOC $E_{B\,SOC}^{[m]}$ as of monitoring period $[m]$ are estimated by [F.29]. Once verified, this quantity does not change when calculating baseline emissions for subsequent monitoring periods.

8.1.2.4.1 The Spatial Algorithm for SOC

Of all possible spatial models, the spatial algorithm is the most conservative possible for depleting carbon stocks in the baseline scenario.

To implement the spatial algorithm, first order the estimates of average carbon stocks in SOC from lowest to highest, $1,2 \ldots n$ by stratum for all strata in the project accounting area.

This ordering should be conducted at the first monitoring period and then the order should be fixed for subsequent monitoring periods. Every monitoring period, apply the spatial algorithm given by [F.29] to determine cumulative emissions for SOC. The spatial algorithm uses the weighted average carbon stocks across all strata currently being depleted in the baseline. Weighted average carbon stocks are calculated as in [B.35]. The spatial algorithm is denoted as $SEM_{sp}\left(c_{P\ i\ SOC}^{[m=0]}, c_{B\ SOC}^{[m]}, t^{[m]}, x^{[m]}\right)$.

8.1.3 Calculating Carbon Not Decayed in DW

Calculate carbon in non-decayed DW using [F.36] where $\mathcal{M}$ is the set of all monitoring periods including the current and past monitoring periods. The cumulative emissions from DW $E_{B\ DW}^{[m]}$ are calculated by [F.34] where cumulative emissions from AGMT $E_{B\ AGMT}^{[m]}$ are calculated in sections 8.1.6.1, 8.1.6.2 and 8.1.6.3 and the slash portion of total above-ground carbon stock $p_{SL}^{[m]}$ is estimated in B.2.7 as part of monitoring (see section 9). Once verified, this quantity does not change when calculating baseline emissions for subsequent monitoring periods. For the first monitoring period, the cumulative emissions from the prior monitoring period, DW $E_{B\ DW}^{[i-1]}$ are zero

Monitoring Requirements: Carbon Not Decayed in DW
The monitoring report must include the following:
MR.21 An estimate of carbon stored in non-decayed DW $C_{B\ DW}^{[m]}$ for the current monitoring period.
MR.22 An estimate of cumulative baseline emissions from DW $E_{B\ DW}^{[m]}$ for the current monitoring period.
MR.23 An estimate of cumulative baseline emissions from AGMT $E_{B\ AGMT}^{[m]}$ for the current monitoring period.
MR.24 Calculations of cumulative baseline emissions from DW $E_{B\ DW}^{[m]}$ for all prior monitoring periods.

MR.25	Calculations of cumulative baseline emissions from AGMT $E_{B\ AGMT}^{[m]}$ for all prior monitoring periods.

8.1.4 Calculating Carbon Not Decayed in BGB

Calculate carbon in non-decayed BGB using [F.32] where $\mathcal{M}$ is the set of all monitoring periods including the current and past monitoring periods. The cumulative emissions from BGB $E_{B\ BGB}^{[m]}$ are calculated by [F.30] where cumulative emissions from biomass $E_{B\ BM}^{[m]}$ are calculated in section 8.1.1 or 8.1.1.5. Once verified, this quantity does not change when calculating baseline emissions for subsequent monitoring periods. For the first monitoring period, the cumulative emissions from the prior monitoring period, BGB $E_{B\ BGB}^{[i-1]}$ are zero.

Monitoring Requirements: Carbon Not Decayed in BGB	
The monitoring report must include the following:	
MR.26	An estimate of carbon stored in non-decayed BGB $C_{\mathrm{B}\ BGB}^{[m]}$ for the current monitoring period.
MR.27	An estimate of cumulative baseline emissions from BGB $E_{B\ BGB}^{[m]}$ for the current monitoring period.
MR.28	Calculations of cumulative baseline emissions from BGB $E_{B\ BGB}^{[m]}$ for all prior monitoring periods.

8.1.5 Calculating Carbon Not Decayed in SOC

Calculate carbon in non-decayed SOC using [F.33], where $\boldsymbol{\lambda_{SOC}}$ is determined in section 6.19.1 and $\boldsymbol{\mathcal{M}}$ is the set of all monitoring periods including the current and past monitoring periods. The cumulative emissions from SOC $\boldsymbol{E_{B\ SOC}^{[m]}}$ are calculated in section 8.1.2.1, 8.1.2.2 or 8.1.2.3. Once verified, this quantity does not change when calculating baseline emissions for subsequent monitoring periods. For the first monitoring period, the cumulative emissions from the prior monitoring period, SOC $E_{B\ SOC}^{[i-1]}$ are zero.

Monitoring Requirements: Carbon Not Decayed in SOC	
The monitoring report must include the following:	
MR.29	An estimate of carbon stored in non-decayed SOC $C_{\mathrm{B}\ SOC}^{[m]}$ for the current monitoring period.

8.1.6 Determining Carbon Stored in WP

If logging is included in the baseline scenario, carbon stored in long-lived wood products must be accounted for using Appendix C. To use Appendix C, certain measurements of carbon stocks in the project accounting area are required from monitoring (see section 9), determined using Appendix B.

Use the following sections to estimate cumulative emissions from AGMT, $E_{B\ AGMT}^{[m]}$ in [C.1] by baseline type.

Monitoring Requirements: Carbon Stored in Wood Products
The monitoring report must include the following: **MR.30** Carbon stored in long-lived wood products $C_{B\ WP}^{[m]}$ after 100 years. **MR.31** Calculations to determine $C_{B\ WP}^{[m]}$.

8.1.6.1 Calculating Cumulative Emissions from AGMT for Types F-P1.a and F-P1.b

Calculate cumulative emissions from AGMT $E_{B\ AGMT}^{[m]}$ using [F.37]. If the BGMT pool is not selected then set $c_{P\ BGMT}^{[m=0]}$, $c_{B\ BGMT}^{[m=0]}$ and r_{RS} to zero. This quantity is used in sections 8.1.3 and 8.1.6, but not directly in the calculation of cumulative baseline emissions.

The variable $c_{P\ AGMT}^{[m=0]}$ is the average carbon stocks in above-ground merchantable trees as measured in the project accounting area prior to the first monitoring event, $c_{B\ AGMT}^{[m]}$ is the average carbon stocks in above-ground merchantable trees as measured in the proxy area, $t^{[m]}$ is the time of the monitoring event and $x^{[m]}$ is the monitored covariates as of the time of the monitoring event. These variables are monitored per section 9.

8.1.6.2 Calculating Cumulative Emissions from AGMT for Types F-P2 and G-P2

For Type F-P2, calculate cumulative emissions from AGMT $E_{B\ AGMT}^{[m]}$ using [F.38]. If the BGMT pool is not selected then set $c_{P\ BGMT}^{[m=0]}$, $c_{B\ BGMT}^{[m=0]}$ and r_{RS} to zero. This quantity is used in sections 8.1.3 and 8.1.6, but not directly in the calculation of cumulative baseline emissions.

The variable $c_{P\ AGMT}^{[m=0]}$ is the average carbon stocks in above-ground merchantable trees as measured in the project accounting area prior to the first monitoring event, $c_{B\ AGMT}^{[m]}$ is the average carbon stocks in above-ground merchantable trees as measured in the proxy area, $t^{[m]}$ is the time of the monitoring event and $x^{[m]}$ is the monitored covariates as of the time of the monitoring event. These variables are monitored per section 9.

8.1.6.3 Calculating Cumulative Emissions from AGMT for Types F-U1 and G-U1

For Types F-U1, and G-U1 calculate cumulative emissions from AGMT $E_{B\ AGMT}^{[m]}$ using [F.39]. If the BGMT pool is not selected then set $c_{P\ BGMT}^{[m=0]}$, $c_{B\ BGMT}^{[m=0]}$ and r_{RS} to zero. This quantity is used in sections 8.1.3 and 8.1.6, but not directly in the calculation of cumulative baseline emissions.

The variable $c_{P\ AGMT}^{[m=0]}$ is the average carbon stocks in above-ground merchantable trees as measured in the project accounting area prior to the first monitoring event, $c_{B\ AGMT}^{[m]}$ is the average carbon stocks in above-ground merchantable trees as measured in the proxy area, $t^{[m]}$ is the time of the monitoring event and $x^{[m]}$ is the monitored covariates as of the time of the monitoring event. These variables are monitored per section 9.

8.1.6.4 Calculating Cumulative Emissions from AGMT for Types F-U2, F-U3, and G-U2

For Types F-U2 and F-U3, calculate cumulative emissions from AGMT $E_{B\ AGMT}^{[m]}$ using [F.40]. If the BGMT pool is not selected then set $c_{P\ BGMT}^{[m=0]}$, $c_{B\ BGMT}^{[m=0]}$ and r_{RS} to zero. This quantity is used in sections 8.1.3 and 8.1.6, but not directly in the calculation of cumulative baseline emissions.

The variable $c_{P\ AGMT}^{[m=0]}$ is the average carbon stocks in above-ground merchantable trees as measured in the project accounting area prior to the first monitoring event, $c_{B\ AGMT}^{[m]}$ is the average carbon stocks in above-ground merchantable trees as measured in the proxy area, $t^{[m]}$ is the time of the monitoring event and $x^{[m]}$ is the monitored covariates as of the time of the monitoring event. These variables are monitored per section 9.

8.2 Project Emissions

Project emissions for any monitoring period $[m]$ are calculated from the events of biomass consumption through fire, burning, logging or other disturbance. Current project emissions for the current monitoring period $E_{P\ \Delta}^{[m]}$ are estimated as [F.41]. Emissions from forest fire, grass fire, natural disturbances and logging are inherently captured by the monitoring of carbon stocks in the project area. Total project emissions for the current monitoring period can be negative if some major disturbance event occurs. The project proponent must have sufficient ongoing observation of the project lands such that disturbance that is likely to be greater than *de minimis* will be detected. These observations may consist of staff on the ground, aerial observation, remote sensing, or some other method that captures conversion in a timely manner.

This section is to be applied to each project accounting area.

8.2.1 Calculating Emissions from Changes in Project Stocks

Emissions from forest fires, grass fires, natural disturbance, logging and other events within the project accounting areas are inherently captured by the monitoring of forest carbon stocks. Nevertheless, maps of significant events are necessary to aid verification of carbon stock estimates. Current emissions from changes in project carbon stocks are calculated in [F.41] as the last term on the left-hand side, the difference between carbon stocks from the prior monitoring period and the current monitoring period. In order to estimate these carbon stocks, the project accounting areas may need to be re-stratified per Appendix B as part of monitoring (see section 9).

Monitoring Requirements: Emissions Events in Project Area
The monitoring report must include the following:
MR.32 A map of the boundaries of any significant disturbance in the project accounting areas during the monitoring period.
MR.33 Evidence that plots were installed into these disturbed areas and were measured per section 9.

8.2.2 Calculating Emissions from Burning

Current emissions from the burning of woody or herbaceous biomass as a result of project activities in the project area must be recorded as the weight (in tonnes) of woody or herbaceous biomass consumed during each burning event. If the production of sustainable charcoal occurs within the project accounting areas, then it must be accounted for under emissions from burning. Emissions from the controlled burning of woody or herbaceous biomass are equivalent to the sum of all burning events $\mathcal{E}^{[m]}$ during the monitoring period as defined by [F.42].

Monitoring Requirements: Emissions from Burning from Project Activities
The monitoring report must include the following:
MR.34 A table of events when woody or herbaceous biomass was burned during the monitoring period, showing the weight of woody or herbaceous biomass in tonnes and the date consumed.

8.2.3 Determining Carbon Stored in WP

If logging is a project activity, the project proponent can choose to measure the mass of logs exported from the project accounting areas and then apply an equation to account for milling inefficiencies, wastage and decay at the mill using procedures in Appendix C.

Wood lost due to wastage and milling inefficiencies over time is calculated and decayed per Appendix C.

Monitoring Requirements: Carbon Stored in Wood Products from Project Activities	
The monitoring report must include the following:	
MR.35	Carbon stored in long-lived wood products $C_{P\,\Delta\,WP}^{[m]}$ after 100 years.
MR.36	Scale reports or records of carbon in log production by wood products type $C_{P\,ty}^{[m]}$.
MR.37	Calculations to determine $C_{P\,\Delta\,WP}^{[m]}$.

8.2.4 Calculating GHG Emissions from Livestock Grazing

If grazing of livestock occurs within the project area during the current monitoring period, the project proponent must calculate greenhouse emissions as a result of grazing. Current greenhouse gas emissions from livestock $E_{P\,\Delta\,LS}^{[m]}$ is given by equation [F.43] , based on IPCC Good Practice Guidelines and IPCC Guidelines for National Greenhouse Gas Inventories. This procedure involves the identification of livestock species, their IPCC default emissions factors (see Table 14), and the number of head per species. The number of head per species of livestock grazing within the project area is monitored per the requirements in section 9.3.2.

In some projects, emissions from grazing may be deemed *de minimis* as per VCS requirements.

Monitoring Requirements: Livestock Grazed in the Project Area	
The monitoring report must include the following:	
MR.38	A report or record of the number of livestock per species of livestock $n_{LS\,i}$ being grazed within the project area $\mathrm{n}_{\mathrm{LS\,i}}$.
MR.39	Emissions released due to livestock grazing $\mathrm{E}_{\mathrm{P\,\Delta\,LS}}^{[\mathrm{m}]}$.
MR.40	Calculations to determine $\mathrm{E}_{\mathrm{P\,\Delta\,LS}}^{[\mathrm{m}]}$.

Table 14: IPCC Default Emission Factors for Livestock in Developed and Developing Countries

IPCC Default Emission Factors (kg CH4 head^{-1} yr^{-1})		
Livestock	**Developed countries**	**Developing countries**
Buffalo	55	55
Sheep	8	5
Goats	5	5

Camels	46	46
Horses	18	18
Mules and Donkeys	10	10
Deer	20	20
Alpacas	8	8
Swine	1.5	1

8.2.5 Calcuating N_2O Emissions from the Use of Synthetic Fertilizers

If project activities includes the use of synthecitc nitrogen fertilzers to improve agricultural yields, then N_2O emissions must be quantified. Use the CDM tool *Estimation of direct and indirect (eg, leaching and runoff) nitrous oxide emission from nitrogen fertilization* to calculate emissions released due to use of synthetic fertilizer $\mathrm{E}_{\mathrm{P}\,\Delta\,\mathrm{SF}}^{[\mathrm{m}]}$.

Monitoring Requirements: Synthetic Fertilizer in the Project Area
The monitoring report must include the following: **MR.41** A report or record of the quantity of synthetic fertilizer applied in the project area. **MR.42** Emissions released due to use of synthetic fertilizer $\mathrm{E}_{\mathrm{P}\,\Delta\,\mathrm{SF}}^{[\mathrm{m}]}$. **MR.43** Calculations to determine $\mathrm{E}_{\mathrm{P}\,\Delta\,\mathrm{SF}}^{[\mathrm{m}]}$.

8.3 Leakage

This section is to be applied separately for each identified project accounting area. Activity-shifting leakage results from the activities of the agent of conversion due to the project activities and applies to all projects. Market leakage applies to projects that cause a reduction in the supply of commodities (either legally sanctioned, illegal or both) in the baseline scenario. The applicability of these types of leakage depends upon the baseline type.

Emissions from activity-shifting leakage are calculated using the Leakage Emissions Model and an activity-shifting leakage area, while emissions from market leakage are estimated using a market leakage area and default values specified in the AFOLU Requirements. To calculate market leakage, the project proponent must use either the production approach (section 8.3.3.4) or discount approach (section 8.3.3.3) as deemed appropriate through the flowchart in figure 13.

Total emissions from leakage for the current monitoring period $E_{L\,\Delta}^{[m]}$ are calculated by [F.44]. The cumulative emissions from leakage for the current monitoring period are given by [F.45], the sum of cumulative emissions from activity-shifting leakage in forest strata $E_{L\ ASF}^{[m]}$, the activity-shifting leakage in grassland strata $E_{L\ ASG}^{[m]}$ and market leakage $E_{L\ ME}^{[m]}$ for the current monitoring period. Once estimated for the current monitoring period, these cumulative emissions from leakage $E_{L}^{[m]}$ are fixed for subsequent monitoring periods.

If market leakage is not considered, then cumulative emissions from market leakage $E_{L\ ME}^{[m]}$ should be set to zero (see section 8.3.3). If the emissions from activity-shifting leakage in forest strata $E_{L\ ASF}^{[m]}$, in grassland strata $E_{L\ ASG}^{[m]}$ or market leakage $E_{L\ ME}^{[m]}$ are negative (indicating "negative leakage"), then their value must be set to zero. If the total emissions from leakage for the current monitoring period are negative (indicating "negative leakage") then the value of $E_{L\ \Delta}^{[m]}$ should be set to zero.

8.3.1 Leakage Mitigation Strategies

Projects must include activities designed to reduce ecosystem conversion resulting from at least one of the drivers identified in section 6.1. The types of activities most appropriate vary based on the specific drivers identified, as well as local socio-economic conditions. Project activities must not result in a significant increase in project GHG emissions. Emissions from project activities must be shown to be *de minimis* using either peer reviewed literature or the use of the CDM A/R methodological *Tool for testing significance of GHG emissions in A/R CDM project activities*. Examples of these activities may include, but are not limited to:

- Developing economic opportunities for local communities that encourage protection, such as employment as protected-area guards or ecotourism guides.
- Developing alternative incomes not derived from conversion.
- Introducing improved agricultural practices that result in a decreased demand for newly cleared land.
- Developing sustainable means of producing fuel wood.
- Developing sustainably-produced timber to replace supply eliminated by conservation of project lands.
- Secure land tenure to enable ongoing sustainable management of lands or investment in productive capacity of lands.

Project activities must be monitored to demonstrate their effect on leakage mitigation. Possible monitoring approaches vary by project and may include:

- The number of people that directly benefit from the activity.
- The number of units distributed as a result of an activity (such as number of trees, foodstuffs, vaccines or dollars).
- The time devoted to implementing an activity.

- Community surveys about the effectiveness of an activity.

PD Requirements: Leakage Mitigation Strategies	
The project description must include the following:	
PDR.104	A list of project activities designed to mitigate leakage.

Monitoring Requirements: Leakage Mitigation Strategies	
The monitoring report must include the following:	
MR.44	A description of project activities that have been implemented since the project start date and the estimated effects of these activities on leakage mitigation.

8.3.1.1 Commodity Production for Leakage Mitigation

Mitigation activities can avoid leakage by increasing production elsewhere, to replace production forgone by the project (see section 8.3.3.4). Also, mitigation activities can reduce demand for the forgone goods and services. An example of replacing forgone supply would be a project that helps farmers increase crop productivity, increasing the total amount of crops produced without increasing the area farmed. An example of reducing demand would be converting local people from inefficient three-stone hearths for cooking to efficient wood stoves, allowing the same amount of food to be cooked with substantially less consumption of fuel wood. For each type of commodity that is being reduced or replaced, amounts must be monitored and verified. Amounts are production increased or consumption decreased, not effort or activity. For example, where fuel consumption decreased as a result of a program that gets families to switch from open-hearth cooking fires to efficient stoves, the project proponent would have to monitor usage of stoves and fuel, and calculate the reduction in the amount of wood fuel consumed. It would not be sufficient to merely report the number of stoves distributed.

There are two alternative approaches to quantifying mitigation. One approach is to implement specific activities and monitor those activities. For example, a project could provide technical assistance to farmers or access to high yielding seeds and measure increases in crop yields on farms that are assisted.

Alternatively, total production in the country can be monitored. If, across the entire country, total production of a category of goods remains constant or increases, then there was 100% replacement of the predicted amount of forgone production of that category of goods.

Monitoring Requirements: Commodity Production for Leakage Mitigation
The monitoring report must include the following: **MR.45** A list of mitigation activities reduce demand for forgone goods and services. **MR.46** Quantities for the reduction or replacement of goods and services if they are used in section 8.3.3.4. **MR.47** Methods for measuring the reduction or replacement of goods and services.

8.3.2 Estimating Emissions from Activity-Shifting Leakage

Activity-shifting leakage is estimated by directly observing conversion (and, in the case of forest baseline types, degradation) in the activity-shifting leakage area (see section 8.3.2.1). The project proponent must establish leakage plots per the requirements in this section and in Appendix B. The activity-shifting leakage area is identified by the project proponent as an area to which activity-shifting leakage is most likely to be displaced, and must be monitored throughout the project lifetime for leakage that may be caused to the project activity.

In the instance where there is no accessible forest or native grassland for the agents of conversion other than the project, then activity-shifting leakage from the project cannot occur. In this instance, there need not be an activity shifting leakage area. This can be demonstrated using the PRA and/or expert knowledge, coupled to analysis of forested, native grassland or native shrubland areas accessible to the agents of conversion, those nearest to the project. In all other cases, there must be one activity shifting leakage area for each project accounting area.

Cumulative emissions from activity-shifting leakage for the current monitoring period $E_{L\ AS}^{[m]}$ are estimated by [F.46] and [F.47] using the Leakage Emissions Model. Once verified, this quantity becomes fixed for subsequent monitoring periods. For the first monitoring period, cumulative emissions from activity-shifting leakage $E_{L\ ASF}^{[m]}$ and $E_{L\ ASG}^{[m]}$ are zero. Carbon stocks in the project accounting area and the proxy area, $c_P^{[m]}$ and $c_B^{[m]}$ are the sum of all selected carbon pools for the current monitoring period (tCO2e/ha).

Monitoring Requirements: Estimating Emissions from Activity-Shifting Leakage
The monitoring report must include the following: **MR.48** Calculated cumulative emissions from activity-shifting leakage for the current monitoring period $E_{L\ ASF}^{[m]}$, $E_{L\ ASG}^{[m]}$ and supporting calculations.

MR.49	Calculated cumulative emissions from activity-shifting leakage for the prior monitoring periods $E_{L\ AS}^{[m]}$ and $E_{L\ ASG}^{[m]}$. If an activity-shifting leakage area is not installed, then include results from the participatory rural appraisal and/or expert knowledge, with an analysis of the nearest suitable forest cover for activity shifting leakage.

8.3.2.1 Delineating the Activity-Shifting Leakage Area

The activity-shifting leakage area must be in the same general region as the project area, but not necessarily adjacent to the project area. As of the project start date, the activity-shifting leakage area must be entirely unconverted (ie, in a forest or native grassland state), and no larger than the project accounting area, or no larger than the geographic area in the case of grouped projects. The activity-shifting leakage area must not include the project area but can overlap with the reference area. In many cases, the reference area will contain the activity-shifting leakage area. The activity-shifting leakage area may not be altered after the first monitoring period unless a baseline reevaluation is triggered per section 6.20.

The activity-shifting leakage area must be delineated per the requirements of Appendix D.

If, upon application of Appendix D, the resultant activity-shifting leakage area is smaller than the project accounting area or cannot be defined (has zero size), the project proponent must provide clear justification for the size of the area. This may be the case if the project proponent is protecting the last remaining forest, native grassland or native shrubland in the region as a project activity. In this case, there may be few or no areas to which the agents can shift their activity.

For foreign agents whose activities may not be restricted to the general region of the project area, the project proponent must show that the foreign agents are unlikely to shift their activities outside the activity-shifting leakage area.

The boundaries of the activity-shifting leakage area may be revised without requiring a baseline reevaluation if one of the following criteria is met:

1. Conservation activity is established in the activity-shifting leakage area such that the agents of conversion no longer have access to the activity-shifting leakage area or a portion thereof.
2. In the case of a grouped project where a new project activity instance(s) is added such that a new activity-shifting leakage area must be created for its associated project accounting area.

The monitoring report must reflect all changes to the activity-shifting leakage area. In the case of forests refer to section 8.3.2.3 and for native grasslands refer to section 8.3.2.4 for requirements for each.

PD Requirements: Delineation of the Activity-Shifting Leakage Area
The project description must include the following information with respect to the activity-shifting leakage area: **PDR.105** A map of the delineated boundaries. **PDR.106** Maps of the landscape configuration, including: Topography (elevation, slope, aspect); Recent land use and land cover (either a thematic map created by the project proponent or publicly available map); Access points; Soil class maps (if available); Locations of important markets; Locations of important resources like waterways or roads; and Land ownership/tenure boundaries. **PDR.107** A narrative describing the rationale for selection of activity-shifting leakage area boundaries. If the activity-shifting leakage area is smaller than the project accounting area or cannot be defined, justification for the size of the area. If foreign agents have been identified as an agent of conversion, justification that they are unlikely to shift their activities outside the activity-shifting leakage area. **PDR.108** Results of a spatial analysis to demonstrate the activity-shifting leakage area is entirely in a non-converted state (eg, forested or native grassland) as of the project start date. **PDR.109** Results of a spatial analysis to demonstrate the activity-shifting leakage area is no larger than the project accounting area.

Monitoring Requirements: Change to the Activity-Shifting Leakage Area
The monitoring report must include the following if there is a change to the activity-shifting leakage area: **MR.50** A description and justification of the change to the activity-shifting leakage area. **MR.51** A map of the delineated boundaries. **MR.52** Maps of the landscape configuration, including:

Topography (elevation, slope, aspect);

Recent land use and land cover (either a thematic map created by the project proponent or publicly available map);

Access points;

Soil class maps (if available);

Locations of important markets;

Locations of important resources like waterways or roads; and

Land ownership/tenure boundaries.

MR.53 A narrative describing the rationale for selection of activity-shifting leakage area boundaries. If the activity-shifting leakage area is smaller than the project accounting area or cannot be defined, justification for the size of the area.

MR.54 Results of a spatial analysis to demonstrate the activity-shifting leakage area is entirely in a non-converted state (eg, forested or native grassland) as of the project start date.

MR.55 Results of a spatial analysis to demonstrate the activity-shifting leakage area is no larger than the project accounting area.

8.3.2.2 The Leakage Emissions Model

The Leakage Emissions Model given by [F.48] and [F.49] estimates cumulative emissions from activity-shifting leakage and is based on the parameterization of α, β and θ and others from section 6.7. Equation [F.48] is for forested project accounting areas while [F.49] is for grassland project accounting areas.

Upon baseline reevaluation, the leakage model is updated to reflect the re-parameterization of α, β and θ (see section 6.20) and other parameters remain unchanged per section 6.20.

8.3.2.3 Estimating $p_{L\,DEG}^{[m]}$ for Forest

The parameter $p_{L\,DEG}^{[m]}$ is estimated at least every five years using Appendix B and monitoring requirements (see Appendix B.2.8 and section 9). This parameter must be applied at each monitoring event, including for the first monitoring period despite zero leakage. Although Appendix B does not prescribe sample sizes to estimate this parameter, it is in the project proponent's best interest to choose a large enough sample size in order to minimize sampling variation that may result in sudden leakage events. Conversion of a single plot in the fifth monitoring period, for example, would have a significant effect on this parameter if the project proponent only monitored 15 leakage plots.

Monitoring Requirements: Estimating $p_{L\ DEG}$
The monitoring report must include the following: **MR.56** The estimated value $\hat{p}_{L\ DEG}^{[m]}$ for the current monitoring period and supporting calculations. **MR.57** The calculated value $\hat{p}_{L\ DEG}^{[m=0]}$ calculated for the first monitoring period.

8.3.2.4 Estimating $p_{L\ CON\ G}^{[m]}$ for Grasslands

The parameter $p_{L\ CON\ G}^{[m]}$ is estimated at least every five years using Appendix B and monitoring requirements (see Appendix B.2.11 and section 9). This parameter must be applied each monitoring event including for the first monitoring period despite zero leakage. Although Appendix B does not prescribe sample sizes to estimate this parameter, it is in the project proponent's best interest to choose a large enough sample size in order to minimize sampling variation that may result in sudden leakage events. Conversion of a single plot in the fifth monitoring period, for example, would have a significant effect on this parameter if the project proponent only monitored 15 leakage plots.

Monitoring Requirements: Estimating $p_{L\ CON\ G}$
The monitoring report must include the following: **MR.58** The estimated value $\hat{p}_{L\ CON\ G}^{[m]}$ for the current monitoring period and supporting calculations. **MR.59** The calculated value $\hat{p}_{L\ CON\ G}^{[m=0]}$ calculated for the first monitoring period.

8.3.3 Determining Emissions from Market Leakage

Market leakage occurs when production of commodities – most likely timber or agricultural products – shifts elsewhere to make up for the lost supply resulting from project activities. Market leakage is that which is not directly caused by the agents of conversion, but is the consequence of supply and demand effects in the national commodity market. For example, a reduction in supply of wood products may result in increased logging elsewhere within national boundaries. The project proponent must account for this shift in production per current AFOLU Requirements and the flowchart provided in Figure 12. Apply sections 8.3.3.2, 8.3.3.3 and 8.3.3.4 of this methodology according to the flowchart.

When the agents and drivers of conversion only use land converted in the baseline for subsistence, no market leakage will occur as a result of the project, and potential leakage, if any, is restricted to the activity-shifting type (see section 8.3.2). If emissions from market leakage do not need to be accounted for, the cumulative emissions from market leakage $E_{L\,ME}^{[m]}$ for every monitoring period will be zero.

Commodities produced for export outside the country of origin do not need to be considered, per AFOLU Requirements. If there is no change in market commodities due to the project, market leakage does not occur and need not be accounted for.

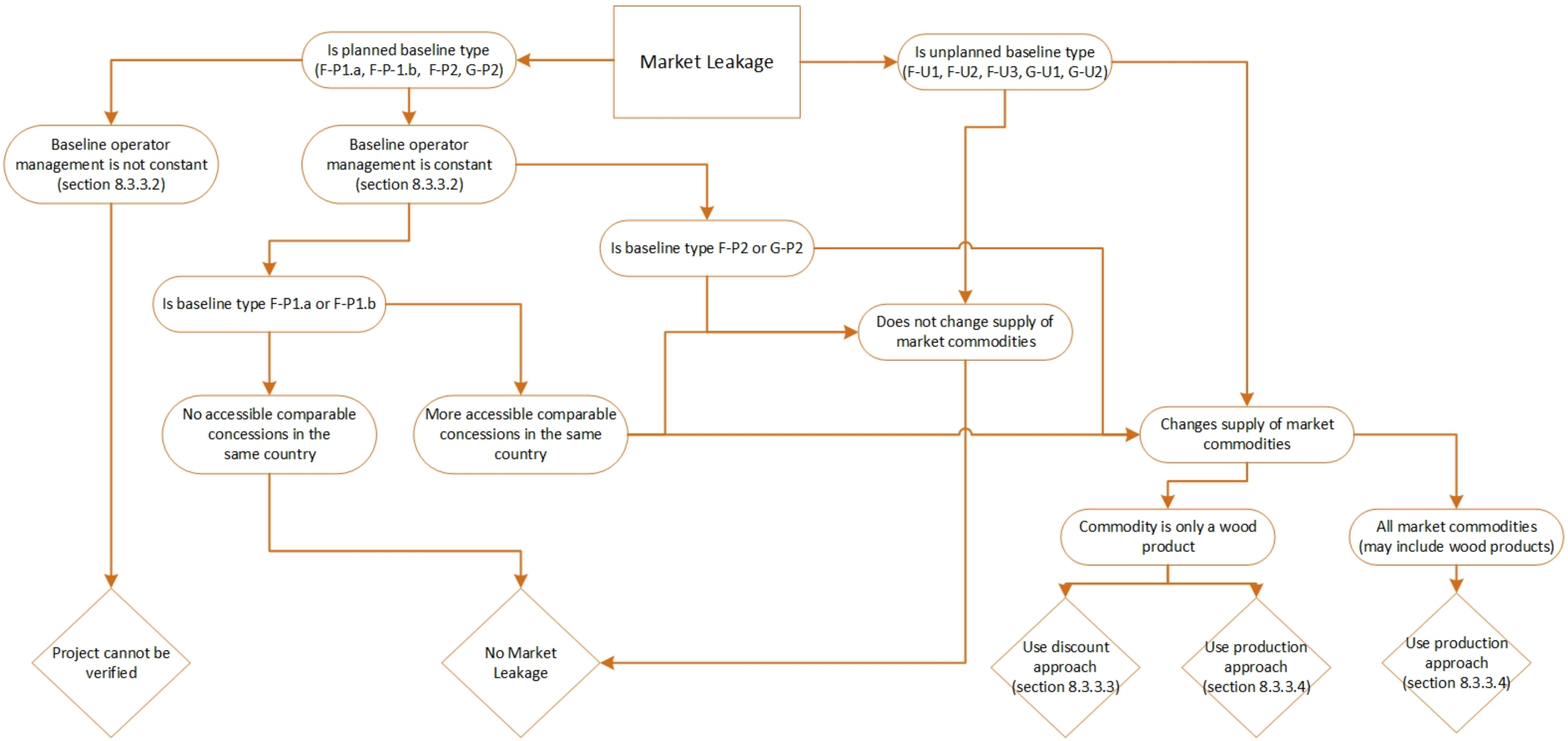
In baseline types F-P1.a and F-P1.b, market leakage is partially an effect of the reduction in timber harvested from the project area. In the case that all available comparable concessions (those with equivalent or substitutable products) within the same national boundaries have been allocated, and all legally sanctioned operators are cutting to the maximum allowable limit, then the supply of legal timber from the national market is fixed. In this case, there is no more timber legally available for harvest, and so a change in the harvest volume to meet demand cannot occur. If there are barriers to an alteration of the rate of illegal logging which follows legal logging (ie, primary and secondary agents) or illegal logging cannot increase in the same country, then leakage from illegal logging may be *de minimis* or not occur.

If, on the other hand, comparable concessions are available or other legal or illegal operators can increase their harvest volumes, then leakage can occur as a result of the project. In this eventuality, project proponents must apply the discount approach to determine market leakage from wood products (section 8.3.3.3) and the production approach (section 8.3.3.4) for other commodities.

The proponent must demonstrate that no leakage has occurred inside the project proponent's ownership per section 8.3.3.1.

Monitoring Requirements: Determining Emissions from Market Leakage
The monitoring report must include the following: **MR.60** The selected approach to determining emissions from market leakage. **MR.61** Estimated cumulative emissions from market leakage for the current monitoring period $E_{L\,ME}^{[m]}$ and supporting calculations. **MR.62** Calculated cumulative emissions from market leakage for the prior monitoring periods $E_{L\,ME}^{[m]}$.

Figure 12: Decision Tree to Determine Mrket Leakage Approach.



8.3.3.1 Ensuring No Leakage Within Project Proponent's Ownership

The project proponent must demonstrate that no leakage occurs outside the project area but within the project proponent's operations, including areas where the project proponent owns, manages, or has legally sanctioned rights to use land within the country where the project is located. The project proponent must identify other locations under its control and show that management plans and land-use designations have not changed as a result of the project.

In cases where the project proponent is an entity with a conservation mission, this requirement may be satisfied with documented evidence that it is against the organization's policy to change the land use of other owned and managed lands, along with evidence that such a policy has been followed historically.

Monitoring Requirements: Ensuring No Leakage Within Project Proponent's Ownership
The monitoring report must include the following: **MR.63** Provide location-by-location evidence that management plans and land-use designations of all areas under the project proponent's control within the country have not changed as a result of the project. For entities with a conservation mission, provide evidence of the organization's policy not to change the land use of other owned and managed lands, and evidence of compliance with such a policy.

8.3.3.2 Ensuring Constancy of Baseline Operator Management

For baseline types F-P1.a F-P-1.b, F-P2 and G-P2, if the specific agent of conversion is known, the management plan and/or land-use designations for the baseline agent's other lands must be demonstrated to have been unchanged due to project implementation.

Monitoring Requirements: Ensuring Constancy of Baseline Operator Management
The monitoring report must include the following: **MR.64** Provide evidence in the form of GIS imagery, PRA evidence, or the baseline operator's management plan that management plans or land-use designations have not changed in the baseline operator's other lands.

8.3.3.3 Discount Approach for Wood Products

If the projects that affect the supply of wood products, lead to increased GHG emissions in other locations in the same country, then market leakage has occurred. The discount approach to determining emissions is one of three methods to determine a discount factor $p_{L\,ME}$:

1. Use the most conservative discount factor of 0.7 from Table 7,
2. Quantify the ratio of merchantable biomass to biomass in a market leakage area and use Table 7, or
3. Identify and justify a discount factor using peer-review publication, government publication or scientific literature.

If necessary, establish the market leakage area per section 8.3.3.3.1. In the market leakage area, estimate $c_{L\ AGMT}$ and $c_{L\ BM}$, where $c_{L\ BM}$ is given by [F.50] and $\mathcal{B}$ is the set of all selected carbon pools in biomass (from AGMT, AGOT, AGNT, BGMT, BGOT and BGNT). These estimates must be established at the time of validation using Appendix B or literature. Cumulative emissions from market leakage are quantified by [F.51].

Table 6: Market Discount Factors by Proportion of Merchantable Biomass (ie, market leakage area to project area)

$p_{L\ ME}$	Condition
0.1*	Project activity leads to a shift in harvests across time periods but minimal change in total timber harvest over time
0.2	$\frac{c_{L\ AGMT}}{c_{L\ BM}} > \frac{c_{P\ AGMT}^{[m=1]}}{c_{P\ BM}^{[m=1]}}$
0.4	$\frac{c_{L\ AGMT}}{c_{L\ BM}} > \frac{c_{P\ AGMT}^{[m=1]}}{c_{P\ BM}^{[m=1]}} + 0.15$
0.4	$\frac{c_{L\ AGMT}}{c_{L\ BM}} < \frac{c_{P\ AGMT}^{[m=1]}}{c_{P\ BM}^{[m=1]}} - 0.15$
0.7	$\frac{c_{L\ AGMT}}{c_{L\ BM}} < \frac{c_{P\ AGMT}^{[m=1]}}{c_{P\ BM}^{[m=1]}}$

* If the lowest factor in the table is selected, it must be justified by the project proponent.

PD Requirements: Determining the Market Discount Factor	
The project description must include the following:	
PDR.110	The selected discount factor $p_{L\ ME}$.
PDR.111	Calculations of $c_{L\ AGMT}$ in the market leakage area, including references to literature if cited.

If the lowest discount factor (0.1) is selected from Table 7 or is not determined using a market leakage area (such as from literature), the project description must include the following:

PDR.112 Justification for the selection of the discount factor.

8.3.3.3.1 Delineating the Market Leakage Area

The market leakage area must be in the same country as the project area, but not necessarily adjacent to the project area. As of the project start date, the market leakage area must be entirely un-converted (ie, still forest or native grassland) and be as large as or larger than the project accounting area. The market leakage area must not include the project area or the reference area. The market leakage area must not be altered after the time of validation.

PD Requirements: Delineation of the Market Leakage Area
The project description must include the following information with respect to the market leakage area if such an area is defined:
PDR.113 A map of the delineated boundaries.
PDR.114 Maps of the landscape configuration, including: • Topography (elevation, slope, aspect); • Recent land use and land cover (either a thematic map created by the project proponent or publicly available map); • Access points; • Soil class maps (if available); • Locations of important markets; • Locations of important resources like waterways or roads; and • Land ownership/tenure boundaries.
PDR.115 A narrative describing the rationale for selection of market leakage area boundaries.
PDR.116 Results of a spatial analysis to demonstrate the market leakage area is entirely forested as of the project start date.
PDR.117 Results of a spatial analysis to demonstrate the market leakage area is as large or larger than the project accounting area.

8.3.3.4 Production Approach for Other Commodities

If changes have occurred in the supply of market commodities or wood products, then market leakage has occurred. If the commodities are only wood products, then the discount approach (section 8.3.3.3) or the production approach may be used to calculate leakage. However, if the commodities include any commodities other than wood products, the production approach must be used to calculate market leakage. To calculate market leakage using the production approach, apply the VCS *Global Commodity Leakage Module: Production Approach* and the relevant criteria and procedures from the associated JNR Leakage Tool. Such module and tool must be applied in a manner appropriate to project-level application. Where VCS issues a relevant project-level leakage tool and production approach leakage module, project proopnents must apply the latest version of such module and the relevant criteria and procedures from the associated tool.

For use of the VCS production approach, the total area of avoided conversion of forest to non-forest and avoided conversion of native grassland to non-grassland must be calculated, which as stated above, is referred to in the above-mentioned VCS leakage tool generally as “area of avoided deforestation.” To calculate the “area of avoided deforestation” $A_{B\,\Delta\,PAA}^{[m]}$ referenced in the tool, use [F.52]. The cumulative emissions from market leakage for the prior monitoring periods $E_{L\,ME}^{[m]}$ must be the sum of all calculated market leakage per the tool, across all current and prior monitoring periods. It is important to note that the methodology accounts for market leakage on a cumulative basis while the tool on a monitoring period basis (hence the Δ in the subscript of $A_{B\,\Delta\,PAA}^{[m]}$).

If no carbon pools in biomass are selected (see section 5.4) then let $c_{P\,BM}^{[m]} - c_{B\,BM}^{[m]} = 1$ in [F.52] and the calculation of $E_{B\,BM}^{[m]}$.

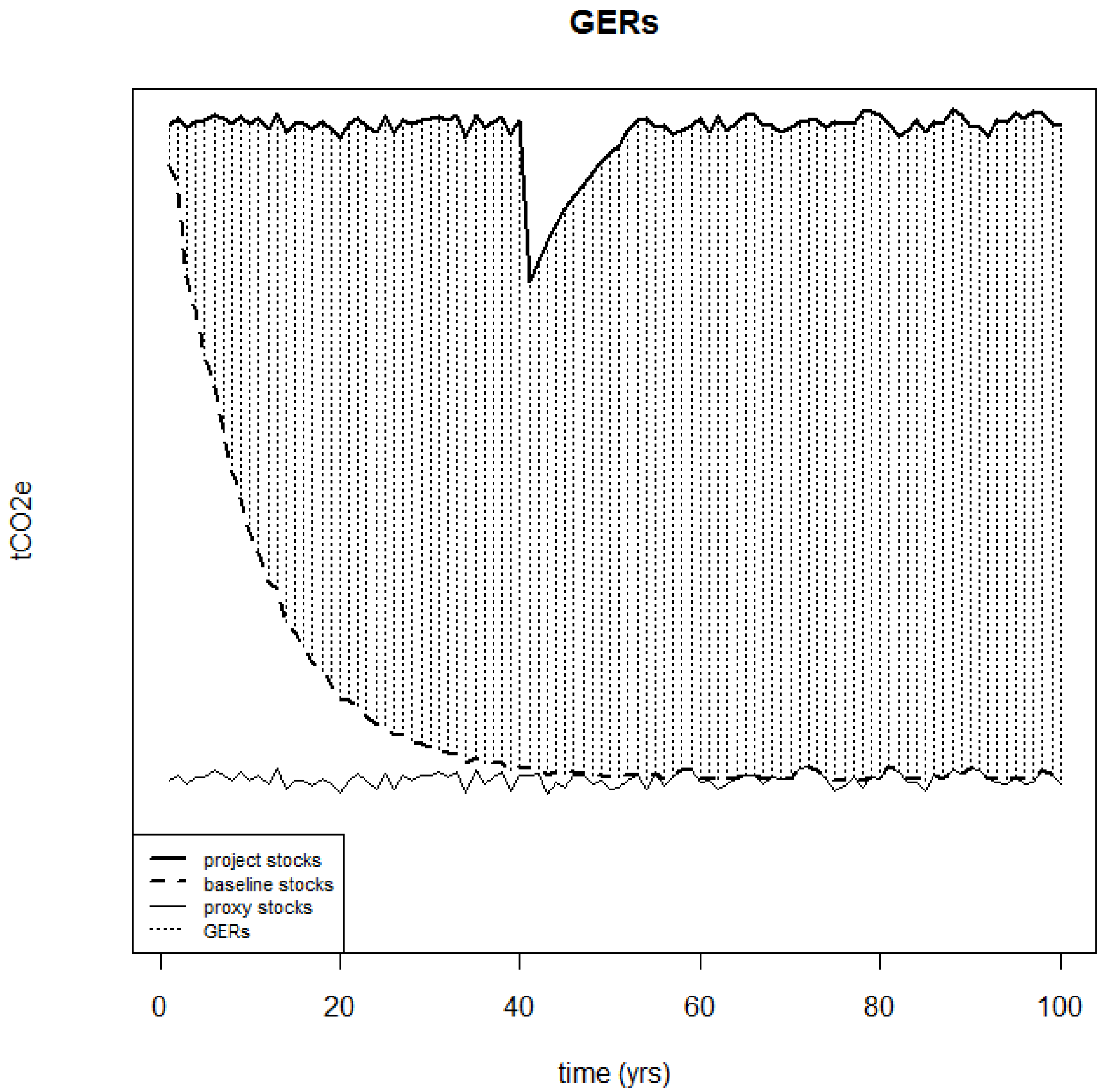
8.4 Summary of GHG Emission Reductions and/or Removals

To quantify NERs, first quantify GERs including the confidence deduction (if any) and subtract the buffer account allocation. For validation and planning purposes, *ex-ante* estimates may be generated (see sections 8.4.1 and 8.4.3). *Ex-ante* estimates are not eligible for crediting (see section 8.4.7). These quantities should be calculated for each project accounting area. If multiple project accounting areas exist in the project area, then NERs should be summed across project accounting areas per section 8.4.5.

8.4.1 Quantifying Gross Emissions Reductions

The GERs for a monitoring period $[m]$ and project accounting area are quantified as [F.53]. Quantified GERs should be rounded down to the nearest whole number.

Figure 13: Hypothetical Graph of Gross Emissions Reductions Over Time.



This figure represents hypothetical GERs over time, where the difference between the project and the baseline stocks are the GERs, and monitored proxy stocks determine the lowest possible stocks in the baseline. The temporary drop in GERs in year 40 of this graph represents a major emissions event such as fire or hurricane that resulted in an efflux of GHG gases from the project. This hypothetical graph does not show discounts for leakage or uncertainty.

Monitoring Requirements: Quantification of GERs
The monitoring report must include the following: **MR.65** Quantified GERs for the current monitoring period including references to calculations. **MR.66** Quantified GERs for the prior monitoring period. **MR.67** A graph of GERs by monitoring period for all monitoring periods to date.

8.4.1.1 Determining Deductions for Uncertainty

The confidence deduction $E_U^{[m]}$ is determined by [F.57], which is a linear combination of weighted standard errors of estimates from baseline emissions models and carbon stock measurements. The confidence deduction is not based on propagation of error. If the confidence deduction $E_U^{[m]}$ is negative, then it should be set to zero.

Monitoring Requirements: Confidence Deduction
The monitoring report must include the following: **MR.68** The confidence deduction $E_U^{[m]}$ and estimated standard errors used to determine the confidence deduction. **MR.69** Reference to calculations used to determine the confidence deduction.

8.4.1.2 Using a Linear Model for Gross Emissions Reductions

A linear model for GERs may be used for project accounting areas with baseline type F-U1 or G-U1 if the GERs predicted by the linear model are conservatively less than GERs quantified by [F.53] for each project accounting area.

A linear model for GERs may be optionally used for other project accounting areas as long as the GERs generated by the linear model are conservatively less than GERs quantified by [F.53] for each project accounting area.

When using a linear model, the quantified GERs must be rounded down to the nearest whole number. The linear model may change from monitoring period to monitoring period as long as the GERs predicted by the linear model are conservatively less than [F.53], and emissions at time zero are zero (ie, the model intercept is zero).

Monitoring Requirements: Quantification of NERs Using a Linear Model
The monitoring report must include the following if a linear model is selected: **MR.70** The linear model used to generate GERs for the current monitoring period. **MR.71** A graph of GERs from the linear model by monitoring period for all monitoring periods to date that used a linear model.

8.4.2 Determining Reversals

In the event that the quantified GERs for any monitoring period are negative as a result of carbon stock losses, the project proponent must follow the VCS procedures for loss events. If subsequent to baseline reevaluation per section 6.20, the new baseline emissions models fall below the old model this does not constitute a reversal. Rather, if credits were generated from avoided conversion prior to baseline reevaluation at a level greater than predicted by the new baseline model after baseline reevaluation, then the project proponent may not generate any new credits from avoided conversion until the new baseline emissions models reaches the previous level of predicted conversion that generated these credits.

At the end of the project crediting period, the project proponent must estimate the final level of cumulative baseline emissions using the most current baseline emissions model and use this estimate to quantify the total number of cumulative credits per equation [F.53]. If this estimate is greater than the number of credits issued during the project crediting period, then this difference must be addressed through the AFOLU Pooled Buffer Account.

Monitoring Requirements: Reversal Event
The monitoring report must include the following if there is a reversal: **MR.72** A description of the reversal including which pools contributed to the reversal and reasons for its occurrence.

8.4.2.1 Determining Reversals as a Result of Baseline Reevaluation

If immediately upon baseline reevaluation GERs for the current monitoring period $E_{\Delta\,\mathrm{GER}}^{[m]}$ (as determined by [F.53]) are negative, this event does not constitute a reversal if the project proponent can demonstrate that this event was caused by new data observed in the reference area. However if this event is not a reversal, the project is not eligible for crediting until the sum of GERs to-date $E_{GER}^{[m]}$ as determined by [F.54] are once again positive.

If after baseline reevaluation GERs for subsequent monitoring periods after the monitoring period immediately following the baseline reevaluation are negative, those GERs $E_{\Delta\, GER}^{[m]}$ constitute reversals.

Monitoring Requirements: Reversal Event as a Result of Baseline Reevaluation
The monitoring report must include the following if there is a reversal as a result of baseline reevaluation:
MR.73 A description of the reversal including a summary of new data obtained in the reference area.

8.4.3 Quantifying Net Emissions Reductions for a PAA

The total NERs generated during a monitoring period $[m]$ are determined by [F.55], which are GERs minus buffer account allocation.

Monitoring Requirements: Quantification of NERs for a PAA
The monitoring report must include the following:
MR.74 Quantified NERs for the current monitoring period including references to calculations.
MR.75 Quantified NERs for the prior monitoring period.
MR.76 A graph of NERs by monitoring period for all monitoring periods to date.

8.4.4 Determining Buffer Account Allocation

Determining the allocation of GERs to the buffer account should conform to current VCS requirements. Those GERs allocated to the buffer account are denoted by $E_{BA}^{[m]}$.

Monitoring Requirements: Buffer Account
The monitoring report must include the following:
MR.77 Reference to the VCS requirements used to determine the buffer account allocation.
MR.78 Reference to calculations used to determine the buffer account allocation.

8.4.5 Quantifying Net Emissions Reductions across PAAs

In the case where there are multiple project accounting areas in a single project area, the NERs for each project accounting area will be quantified individually, and then summed to determine the total NERs for the current monitoring period for the project.

Monitoring Requirements: Quantification of NERs across PAAs
The monitoring report must include the following: **MR.79** Quantified NERs for the current monitoring period including references to calculations. **MR.80** Quantified NERs for the prior monitoring period. **MR.81** A graph of NERs by monitoring period for all monitoring periods to date.

8.4.6 Determining Vintages in a Monitoring Period

When the current monitoring period spans more than one calendar year, NERs must be allocated by year proportional to the number of calendars days in each year relative to the total number of days in the current monitoring period.

Monitoring Requirements: Vintages
The monitoring report must include the following: **MR.82** Quantified NERs by vintage year for the current monitoring period including references to calculations.

8.4.7 *Ex-Ante* Estimation of NERs

Under the VCS, *ex-ante* estimates of the net carbon benefits of the project are only required to determine whether decreases in carbon pools or increases in GHG emissions are insignificant and need not be measured and monitored. Additionally, *ex-ante* estimates of project benefits may be useful to project proponents for planning purposes. Use the project crediting period to estimate *ex-ante* project benefits.

The most significant factor in estimating project carbon benefits is likely to be an estimate of avoided baseline emissions, which is derived from an estimate of carbon stocks and the baseline models. Estimates of *ex-ante* avoided baseline emissions can be made by assuming that the total carbon stock in the project area is equal to the initial carbon stock for each future monitoring period. This conservatively ignores growth of the existing forest or native grassland, assuming that each carbon pool is at a steady state prior to project initiation. The projected avoided baseline emissions are estimated by applying the baseline emissions models as described in sections 6 where monitoring period $[m]$ always indicates the initial carbon stock or IPCC defaults.

If project activities include woody biomass burning, controlled grassland burning, or the sustainable production of charcoal or logging, estimates of emissions due to these activities should be included in the *ex-ante* estimate of project benefits using the procedures in sections 8.4.1 and 8.4.3. The project proponent may assume that the demand for charcoal remains constant at a rate determined prior to project implementation. Because *ex-ante* data for leakage monitoring are unlikely to be available, *ex-ante* estimates of leakage should be estimated using expert knowledge and, if available, experience with past projects. For the purpose of assessing the significance of decreases in carbon pools or increases of emissions due to project activities, it is conservative to underestimate avoided baseline emissions and overestimate leakage and project emissions in *ex-ante* estimates of carbon benefits.

Using the assumptions outlined above, estimate the *ex-ante* NERs $E_{\Delta\,NER}^{[m]}$ for each monitoring period $[m]$ as [F.55] where $E_{\Delta\,GER}^{[m]}$ is GERs for the current monitoring period, $E_{U}^{[m]}$ is the confidence deduction and $E_{BA}^{[m]}$ is the buffer account allocation.

Reporting of *ex-ante* estimates is only required if the project proponent demonstrates that a carbon pool is expected to increase in the baseline or a project emissions source is excluded from accounting under the *de minimis* rule.

PD Requirements: *Ex-Ante* Estimation of NERs
In the case when *ex-ante* estimates are used to prove the significance of emissions sources or estimate the quantity of NERs over the project crediting period, the project description must include the following: **PDR.118** The projected avoided baseline emissions, project emissions and leakage for each monitoring period and vintage year over the lifetime of the project. **PDR.119** A narrative description of sources used to estimate the leakage rate and demonstration that the estimated rate is conservative. **PDR.120** If included in project activities, a description of procedures used to estimate the rate of biomass burning, charcoal production or logging and demonstration that these estimates are conservative.

8.4.8 Evaluating Project Performance

Project performance must be evaluated each monitoring event and deviations from ex-ante NERs must be described. Deviations in credit generation from *ex-ante* estimates may result from changes in the quality of data (literature estimates versus carbon stock estimates), occurrence of disturbance events or baseline re-evaluation.

Monitoring Requirements: Evaluating Project Performance
The monitoring report must include the following: **MR.83** Comparison of NERs presented for verification relative to NERs from *ex-ante* estimates. **MR.84** Description of the cause and effect of deviations from *ex-ante* estimates.

9 MONITORING

The procedures appropriate for estimating the carbon stock in each pool to be monitored are detailed in Appendix B. They provide a means of estimating the total carbon stock in selected pools within the project accounting area and the uncertainty of that estimate at a given point in time. These procedures are used both for establishing the initial carbon stock within the project accounting area and the carbon stock at each monitoring event $[m]$. Project proponents may deviate from the procedures detailed in Appendix B per current VCS requirement, including a description of the deviation and justification for the deviation.

In addition to monitoring carbon stocks, project proponents must monitor species and heads of livestock within the project area to determine greenhouse gas emissions from grazing activities. The procedures for the measurement of livestock heads are detailed in Appendix B. Project proponents may deviate from the procedures detailed in Appendix B per current VCS requirement, including a description of the deviation and justification for the deviation.

9.1 Data and Parameters Available at Validation

See,below for a complete list of all variables, data and parameters and a description of the frequency of monitoring for each, these variables are also shown in Appendix G. These are the only variables that must be reported in the PD.

Data / Parameter	α
Data unit	Unitless
Description	Combined effects of β and θ at the start of the historic reference period
Equations	[F.3], [F.5], [F.6], [F.8]
Source of data	Reference area and historic reference period
Value applied	

Justification of choice of data or description of measurement methods and procedures applied	Time and place in which the logistic model is fit.
Purpose of Data	
Comments	

Data / Parameter	β
Data unit	Unitless
Description	Effect of time on the cumulative proportion of conversion over time
Equations	[F.2], [F.3], [F.4], [F.5], [F.6], [F.7], [F.8]
Source of data	Reference area and historic reference period
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Time and place in which the logistic model is fit.
Purpose of Data	
Comments	

Data / Parameter	γ
Data unit	Days
Description	Time shift from beginning of historic reference period to project start date
Equations	[F.3], [F.6]
Source of data	Historic reference period
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Time in which the logistic model is fit.
Purpose of Data	
Comments	

Data / Parameter	θ
Data unit	Unitless

Description	Effect of certain covariates on the cumulative proportion of conversion over time
Equations	[F.2], [F.3], [F.4], [F.5], [F.6], [F.7], [F.8]
Source of data	Reference area and historic reference period
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Time and place in which the logistic model is fit.
Purpose of Data	
Comments	

Data / Parameter	λ_{SOC}
Data unit	Proportion (unitless)
Description	Exponential soil carbon decay parameter
Equations	[F.9], [F.33]
Source of data	Default values, literature estimates or empirical estimation based on reference area sampling
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	A conservative default or values derived from direct measurement by the project proponent or from the literature are acceptable.
Purpose of Data	
Comments	

Data / Parameter	$\hat{\sigma}_{EM}$
Data unit	Standard deviation (unitless)
Description	The estimated standard deviation of the state observations used to fit the logistic function
Equations	[F.12], [F.14], [B.31]
Source of data	Remote sensing image interpretation
Value applied	
Justification of choice of data or description of	

measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	$\mathcal{B}$
Data unit	Set
Description	The set of all selected carbon pools in biomass. Is a subset of $\mathcal{C}$
Equations	[F.17], [F.18], [F.23], [F.50]
Source of data	PDD
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	$\mathcal{C}$
Data unit	Set
Description	The set of all selected carbon pools
Equations	
Source of data	Monitoring records
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	$\mathcal{I}$
Data unit	Set

Description	The set of all observations of conversion. When superscripted with a monitoring period, the conversion observations are taken for leakage analysis
Equations	[F.13]
Source of data	Remote sensing image interpretation or field observations in the leakage area
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	$\mathcal{M}$
Data unit	Set
Description	The set of all monitoring periods
Equations	[F.32], [F.33], [F.36], [F.54], [F.56]
Source of data	Monitoring records
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	$\mathcal{T}$
Data unit	Set
Description	The set of all species/categories of livestock
Equations	[F.43]
Source of data	Monitoring records
Value applied	
Justification of choice of data or description of	

measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	A_{PAA}
Data unit	ha
Description	Area of project accounting area
Equations	[F.2], [F.3], [F.4], [F.5], [F.6], [F.7], [F.8], [F.41], [F.52], [F.57]
Source of data	GIS analysis prior to sampling
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	A_{PX}
Data unit	ha
Description	Area of proxy area
Equations	[F.57]
Source of data	GIS analysis prior to sampling
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	$c_{L\ p}$
Data unit	t CO_2e / ha
Description	Carbon stocks in project leakage area
Equations	[F.50]

Source of data	Leakage area sampling
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Direct measurement
Purpose of Data	
Comments	

Data / Parameter	$f_{LS\ i}$
Data unit	kg CH_4 head^{-1} yr^{-1}
Description	Emission factor for the defined livestock population, i
Equations	[F.43]
Source of data	IPCC default values
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Obtained directly from IPCC default values.
Purpose of Data	
Comments	

Data / Parameter	m
Data unit	t CO_2e / yr
Description	Average carbon in merchantable trees cut each year as a result of legally-sanctioned commercial logging
Equations	[F.2]
Source of data	Timber harvest plans or measurement of carbon stocks in merchantable trees in the *project accounting area*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Should use the most accurate of the two data sources if both are available
Purpose of Data	
Comments	

Data / Parameter	n_d
Data unit	
Description	Number of spatial points in the reference area
Equations	[F.14]
Source of data	Remote sensing image interpretation
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	o_i
Data unit	Binary
Description	State observation for the i^{th} sample point in the reference area
Equations	[F.13]
Source of data	Remote sensing image interpretation
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	$p_{L\,ME}$
Data unit	Unitless
Description	Portion of leakage related to market
Equations	[F.51]
Source of data	8.3.3
Value applied	

Justification of choice of data or description of measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	q
Data unit	Days
Description	Lag between start of degradation and conversion
Equations	[F.3], [F.4], [F.5]
Source of data	Expert knowledge, results from the PRA or reports from peer-reviewed literature
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Commonly accepted methods in the social sciences, choice determined and justified by project proponent
Purpose of Data	
Comments	

Data / Parameter	$r_{CF\ b}$
Data unit	Unitless
Description	Carbon fraction of biomass for burned wood or herbaceous material *b*
Equations	[F.42]
Source of data	Literature estimates or direct measurement
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	r_{RS}

Data unit	Unitless
Description	Expansion factor for above-ground biomass to below-ground biomass (root/shoot ratio)
Equations	[F.30]
Source of data	Reviewed literature, allometry, or IPCC default values
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	r_U
Data unit	Unitless
Description	Onset proportion of conversion immediately adjacent to project area
Equations	[F.4]
Source of data	GIS analysis and image interpretation
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Positions the baseline emissions models relative to the instantaneous rate of conversion
Purpose of Data	
Comments	

Data / Parameter	t
Data unit	Days
Description	Time since project start date
Equations	[F.2], [F.3], [F.4], [F.5], [F.6], [F.7], [F.8], [F.10]
Source of data	Monitoring records
Value applied	
Justification of choice of data or description of	

measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	t_i
Data unit	Days
Description	The point in time of the observation made at point *i*
Equations	[F.11], [A.6]
Source of data	Remote sensing image interpretation
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	t_{PA}
Data unit	Days
Description	Time prior to the project start date when the primary agent began commercial logging in the project accounting area
Equations	[F.1], [F.2], [F.3], [F.6]
Source of data	Harvest plans prepared for the project accounting area, or by public record
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Should use the most accurate of the two data sources if both are available
Purpose of Data	
Comments	

Data / Parameter	t_m
Data unit	Days

Description	Length of project or logging in baseline scenario
Equations	[F.1]
Source of data	PD
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	t_{PL}
Data unit	Days
Description	Length of project crediting period
Equations	[F.5]
Source of data	PD
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	t_{PAI}
Data unit	Days
Description	Number of days after the project start date for the start of a project activity instance in a grouped project
Equations	[F.2], [F.3], [F.4], [F.5], [F.6], [F.7], [F.8]
Source of data	PD
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Should use the most accurate of the two data sources if both are available

Purpose of Data	
Comments	

Data / Parameter	t_{SA}
Data unit	Days
Description	Arrival time of secondary agents after start of commercial logging
Equations	[F.2]
Source of data	Participatory rural appraisal, or expert knowledge
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Should use the most accurate of the two data sources if both are available
Purpose of Data	
Comments	

Data / Parameter	w_i
Data unit	Unitless
Description	Weight applied to the i^{th} sample point in the reference area
Equations	[A.6], [F.13]
Source of data	Remote sensing image interpretation
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	x
Data unit	Unitless
Description	Covariate values
Equations	[F.2], [F.3], [F.4], [F.5], [F.6], [F.7], [F.8]
Source of data	Participatory Rural Appraisal, analysis of public records, and/or expert interpretation of inventory data or remotely sensed imagery

Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Should use the most accurate of the data sources if both are available
Purpose of Data	
Comments	

Data / Parameter	x_i
Data unit	Geographic coordinates
Description	Latitude of the i^{th} sample point
Equations	[F.11], [A.6]
Source of data	Remote sensing image interpretation
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of Data	
Comments	

Data / Parameter	x_o
Data unit	Unitless
Description	Covariate values as of the project start date
Equations	[F.4], [F.5], [F.6], [F.7], [F.8]
Source of data	Participatory Rural Appraisal, analysis of public records, and/or expert interpretation of inventory data or remotely sensed imagery
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Should use the most accurate of the data sources if both are available
Purpose of Data	
Comments	

Data / Parameter	x_{SA}

Data unit	Unitless
Description	Covariate values as of the arrival of the secondary agents
Equations	[F.2]
Source of data	Participatory Rural Appraisal, analysis of public records, and/or expert interpretation of inventory data or remotely sensed imagery
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Should use the most accurate of the data sources if both are available
Purpose of Data	
Comments	

Data / Parameter	y_i
Data unit	Geographic coordinates
Description	Longitude of the i^{th} sample point
Equations	[F.11], [A.6]
Source of data	Remote sensing image interpretation
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of Data	
Comments	

PD Requirements: Data and Parameters Available at Validation
The project description must include the following: **PDR.121** The value for each variable in Appendix G.

9.2 Data and Parameters Monitored

See below for a complete list of all variables monitored, data and parameters and a description of the frequency of monitoring for each, these variables are also shown in Appendix H. These variables must be reported in the monitoring report along with metrics for leakage mitigation per section 8.3.1.

Generally, Appendix B should be used to monitor the project accounting area, activity-shifting leakage area and proxy area. However, the project proponent can request a deviation from these methods provided in Appendix B. All deviations must be identified in the monitoring plan.

Data / Parameter:	$\mathcal{W}^{[m]}$
Data unit:	Set
Description:	The set of all burned wood or herbaceous material
Equations	[F.42]
Source of data:	Monitoring records
Description of measurement methods and procedures to be applied:	N/A
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$A_{B\,\Delta\,PAA}^{[m]}$
Data unit:	ha
Description:	Area of avoided conversion
Equations	[F.52]
Source of data:	Generated from equation
Description of measurement methods and procedures to be applied:	8.3.3.4
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records

Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$A_{P\ 1}^{[m=0]}$
Data unit:	ha
Description:	Area of project accounting area stratum 1 prior to first verification event
Equations	[F.24]
Source of data:	GIS analysis prior to sampling
Description of measurement methods and procedures to be applied:	GIS analysis of best available data B.1.1
Frequency of monitoring/recording:	First monitoring period
QA/QC procedures to be applied:	Cross-check of GIS analysis
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$A_{P\ 2}^{[m=0]}$
Data unit:	ha
Description:	Area of project accounting area stratum 2 prior to first verification event
Equations	[F.24]
Source of data:	GIS analysis prior to sampling
Description of measurement methods and procedures to be applied:	GIS analysis of best available data B.1.1
Frequency of monitoring/recording:	First monitoring period
QA/QC procedures to be applied:	Cross-check of GIS analysis

Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$A_{P\ n}^{[m=0]}$
Data unit:	ha
Description:	Area of project accounting area stratum n prior to first verification event
Equations	[F.24]
Source of data:	GIS analysis prior to sampling
Description of measurement methods and procedures to be applied:	GIS analysis of best available data B.1.1
Frequency of monitoring/recording:	First monitoring period
QA/QC procedures to be applied:	Cross-check of GIS analysis
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$B_{b}^{[m]}$
Data unit:	Tonnes
Description:	Biomass in burned wood or herbaceous material b
Equations	[F.42]
Source of data:	Measurements of biomass
Description of measurement methods and procedures to be applied:	Scale
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records

Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$c_B^{[m]}$
Data unit:	tCO_2e / ha
Description:	Baseline carbon stocks at the end of the current monitoring period
Equations	[F.2], [F.3], [F.4], [F.5], [F.6], [F.7], [F.57]
Source of data:	Proxy area sampling
Description of measurement methods and procedures to be applied:	B.2,6.4
Frequency of monitoring/recording:	Every time measured (≤ 5 yrs)
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$C_{B\ BGB}^{[m]}$
Data unit:	tCO_2e
Description:	Carbon not decayed in BGB at the end of the current monitoring period
Equations	[F.16]
Source of data:	Proxy area sampling
Description of measurement methods and procedures to be applied:	8.1.4
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records

Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$C_{B\ DW}^{[m]}$
Data unit:	tCO_2e
Description:	Carbon not decayed in DW at the end of the current monitoring period
Equations	[F.16]
Source of data:	Proxy area sampling
Description of measurement methods and procedures to be applied:	8.1.3
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$C_{B\ SOC}^{[m]}$
Data unit:	tCO_2e
Description:	Carbon not decayed in SOC at the end of the current monitoring period
Equations	[F.16]
Source of data:	Proxy area sampling
Description of measurement methods and procedures to be applied:	8.1.5
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records

Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$C_{B\ WP}^{[m]}$
Data unit:	tCO_2e
Description:	Carbon not decayed in WP at the end of the current monitoring period
Equations	[F.16]
Source of data:	Proxy area sampling
Description of measurement methods and procedures to be applied:	Appendix C
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$c_{B\ AGMT}^{[m]}$
Data unit:	tCO_2e / ha
Description:	Baseline carbon stocks in above-ground merchantable trees at the end of the current monitoring period
Equations	[F.37], [F.38], [F.39], [F.40]
Source of data:	Proxy area sampling
Description of measurement methods and procedures to be applied:	Appendix B.2.1
Frequency of monitoring/recording:	Every time measured (≤ 5 yrs)
QA/QC procedures to be applied:	Review of monitoring records

Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$C_{B\ BGMT}^{[m]}$
Data unit:	tCO_2e / ha
Description:	Baseline carbon stocks in below-ground merchantable trees at the end of the current monitoring period
Equations	[F.37], [F.38], [F.39], [F.40]
Source of data:	Proxy area sampling
Description of measurement methods and procedures to be applied:	Appendix B.2.1
Frequency of monitoring/recording:	Every time measured (≤ 5 yrs)
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$C_{P\ AGMT}^{[m=0]}$
Data unit:	tCO_2e
Description:	Project carbon stocks in above-ground merchantable trees at project start
Equations	[F.1]
Source of data:	Project accounting area sampling
Description of measurement methods and procedures to be applied:	Appendix B.2.1
Frequency of monitoring/recording:	First monitoring period
QA/QC procedures to be applied:	Review of monitoring records

Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$C_{P\ BGMT}^{[m=0]}$
Data unit:	tCO_2e
Description:	Project carbon stocks in below-ground merchantable trees at project start
Equations	[F.1]
Source of data:	Project accounting area sampling
Description of measurement methods and procedures to be applied:	Appendix B.2.3
Frequency of monitoring/recording:	First monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$c_{B\ b}^{[m]}$
Data unit:	tCO_2e / ha
Description:	Baseline scenario average carbon stock in selected carbon pools
Equations	[F.18] [F.24]
Source of data:	Proxy area sampling
Description of measurement methods and procedures to be applied:	Appendix B.1.5
Frequency of monitoring/recording:	Every time measured (≤ 5 yrs)
QA/QC procedures to be applied:	Review of monitoring records

Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$c_{B\ BM}^{[m]}$
Data unit:	tCO_2e / ha
Description:	Baseline carbon stocks in biomass at the end of the current monitoring period
Equations	[F.19], [F.20], [F.21], [F.24], [F.52]
Source of data:	Appendix B.2
Description of measurement methods and procedures to be applied:	Every time measured (≤ 5 yrs)
Frequency of monitoring/recording:	Review of monitoring records
QA/QC procedures to be applied:	
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$c_{B\ SOC}^{[m]}$
Data unit:	tCO_2e / ha
Description:	Baseline soil carbon stocks at the end of the current monitoring period
Equations	[F.25], [F.27], [F.28]
Source of data:	Proxy area sampling
Description of measurement methods and procedures to be applied:	Appendix B.2.6
Frequency of monitoring/recording:	Every time measured (≤ 5 yrs)
QA/QC procedures to be applied:	Review of monitoring records

Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$c_P^{[m]}$
Data unit:	tCO_2e / ha
Description:	Project carbon stocks at the end of the current monitoring period
Equations	[F.41], [F.57]
Source of data:	Project accounting area sampling
Description of measurement methods and procedures to be applied:	Appendix B.2
Frequency of monitoring/recording:	Every time measured (≤ 5 yrs)
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$c_P^{[m-1]}$
Data unit:	tCO_2e / ha
Description:	Project carbon stocks at the beginning of the current monitoring period
Equations	[F.41]
Source of data:	Project accounting area sampling
Description of measurement methods and procedures to be applied:	Appendix B.2
Frequency of monitoring/recording:	Prior monitoring period
QA/QC procedures to be applied:	Already reviewed

Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$c_P^{[m=0]}$
Data unit:	tCO_2e / ha
Description:	Project carbon stocks prior to first verification event
Equations	[F.7]
Source of data:	Project accounting area sampling
Description of measurement methods and procedures to be applied:	Appendix B.2
Frequency of monitoring/recording:	First monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$c_{P\ 1\ BM}^{[m=0]}$
Data unit:	tCO_2e / ha
Description:	Project carbon stocks in biomass in stratum 1 prior to first verification event
Equations	[F.24]
Source of data:	Project accounting area sampling
Description of measurement methods and procedures to be applied:	Appendix B.2
Frequency of monitoring/recording:	First monitoring period
QA/QC procedures to be applied:	Review of monitoring records

Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$c_{P\ 2\ BM}^{[m=0]}$
Data unit:	tCO_2e / ha
Description:	Project carbon stocks in biomass in stratum 2 prior to first verification event
Equations	[F.24]
Source of data:	Project accounting area sampling
Description of measurement methods and procedures to be applied:	Appendix B.2
Frequency of monitoring/recording:	First monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$c_{P\ 3\ BM}^{[m=0]}$
Data unit:	tCO_2e / ha
Description:	Project carbon stocks in biomass in stratum 3 prior to first verification event
Equations	[F.24]
Source of data:	Project accounting area sampling
Description of measurement methods and procedures to be applied:	Appendix B.2
Frequency of monitoring/recording:	First monitoring period
QA/QC procedures to be applied:	Review of monitoring records

Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$c_{P\ n\ BM}^{[m=0]}$
Data unit:	tCO_2e / ha
Description:	Project carbon stocks in biomass in stratum n prior to first verification event
Equations	[F.24]
Source of data:	Project accounting area sampling
Description of measurement methods and procedures to be applied:	Appendix B.2
Frequency of monitoring/recording:	First monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$c_{P\ AGMT}^{[m=0]}$
Data unit:	tCO_2e / ha
Description:	Project carbon stocks in above-ground merchantable trees prior to first verification event
Equations	[F.37], [F.38], [F.39], [F.40]
Source of data:	Project accounting area sampling
Description of measurement methods and procedures to be applied:	Appendix B.2.1
Frequency of monitoring/recording:	First monitoring period
QA/QC procedures to be applied:	Review of monitoring records

Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$c_{P\ BM}^{[m=0]}$
Data unit:	tCO_2e
Description:	Project carbon stocks in biomass prior to first verification event
Equations	[F.19], [F.20], [F.21], [F.52]
Source of data:	Project accounting area sampling
Description of measurement methods and procedures to be applied:	Appendix B.2
Frequency of monitoring/recording:	First monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$c_{P\ b}^{[m]}$
Data unit:	tCO_2e / ha
Description:	Average carbon in biomass in the project accounting area
Equations	[F.17]
Source of data:	Project accounting area sampling
Description of measurement methods and procedures to be applied:	Appendix B.2
Frequency of monitoring/recording:	Every time measured (≤ 5 yrs)
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	

Calculation method:	
Comments:	

Data / Parameter:	$c_{P\ s\ b}^{[m]}$
Data unit:	tCO_2e / ha
Description:	Average carbon in biomass for each project accounting area stratum s
Equations	[F.23]
Source of data:	Project accounting area sampling
Description of measurement methods and procedures to be applied:	Appendix B.2
Frequency of monitoring/recording:	Every time measured (≤ 5 yrs)
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$c_{P\ SOC}^{[m=0]}$
Data unit:	tCO_2e / ha
Description:	Project soil carbon stocks prior to first verification event
Equations	[F.25], [F.27], [F.28]
Source of data:	Project accounting area sampling
Description of measurement methods and procedures to be applied:	Appendix B.2.6
Frequency of monitoring/recording:	First monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	

Calculation method:	
Comments:	

Data / Parameter:	$C_{P\,\Delta\,WP}^{[m]}$
Data unit:	tCO_2e
Description:	Project carbon stocks in wood products at the end of the current monitoring period
Equations	[F.41]
Source of data:	Project accounting area sampling
Description of measurement methods and procedures to be applied:	Appendix C
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{\Delta\,GER}^{[m]}$
Data unit:	tCO_2e
Description:	GERs for the current monitoring period
Equations	[F.55], [F.57]
Source of data:	Area measurements
Description of measurement methods and procedures to be applied:	8.4.1
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of GER calculations

Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{\Delta\ GER}^{[i]}$
Data unit:	tCO_2e
Description:	GERs for monitoring period i
Equations	[F.54]
Source of data:	Area measurements
Description of measurement methods and procedures to be applied:	8.4.1
Frequency of monitoring/recording:	Prior monitoring period
QA/QC procedures to be applied:	Review of GER calculations
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{\Delta\ NER}^{[i]}$
Data unit:	tCO_2e
Description:	NERs for monitoring period i
Equations	[F.56]
Source of data:	Area measurements
Description of measurement methods and procedures to be applied:	8.4.3
Frequency of monitoring/recording:	Prior monitoring period
QA/QC procedures to be applied:	Review of NER calculations
Purpose of data:	

Calculation method:	
Comments:	

Data / Parameter:	$E_B^{[m]}$
Data unit:	tCO_2e
Description:	Cumulative baseline emissions at the end of the current monitoring period
Equations	[F.15]
Source of data:	Proxy area measurements
Description of measurement methods and procedures to be applied:	8.1
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_B^{[m-1]}$
Data unit:	tCO_2e
Description:	Cumulative baseline emissions at the beginning of the current monitoring period
Equations	[F.15]
Source of data:	Proxy area measurements
Description of measurement methods and procedures to be applied:	8.1
Frequency of monitoring/recording:	Prior monitoring period

QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{B\,\Delta}^{[m]}$
Data unit:	tCO_2e
Description:	Change in baseline emissions
Equations	[F.9], [F.10], [F.14], [F.53], [F.57]
Source of data:	Proxy area measurements
Description of measurement methods and procedures to be applied:	8.1
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{B\,\Delta\,BGB}^{[i]}$
Data unit:	tCO_2e
Description:	Change in baseline emissions from below-ground biomass during monitoring period i
Equations	[F.32]
Source of data:	Monitoring the proxy area
Description of measurement methods and procedures to be applied:	Appendix B.2.3
Frequency of monitoring/recording:	Prior monitoring period

QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{B\,\Delta\,DW}^{[i]}$
Data unit:	tCO_2e
Description:	Baseline emissions from dead wood in monitoring period i
Equations	[F.36]
Source of data:	Measurements in the proxy area
Description of measurement methods and procedures to be applied:	Appendix B.2.4 and B.2.5
Frequency of monitoring/recording:	Prior monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{B\,\Delta\,SOC}^{[m]}$
Data unit:	tCO_2e
Description:	Baseline change in emissions from soil carbon
Equations	[F.15],[F.33]
Source of data:	Measurements in the proxy area
Description of measurement methods and procedures to be applied:	8.1.2.1, 8.1.2.2, 8.1.2.3, Appendix B.2.6
Frequency of monitoring/recording:	Every monitoring period

QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{B\ \Delta\ SOC}^{[i]}$
Data unit:	tCO_2e
Description:	Baseline emissions from soil carbon in monitoring period i
Equations	[F.33]
Source of data:	Measurements in the proxy area
Description of measurement methods and procedures to be applied:	8.1.2.1, 8.1.2.2, 8.1.2.3, Appendix B.2.6
Frequency of monitoring/recording:	Prior monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{B\ AGMT}^{[m]}$
Data unit:	tCO_2e
Description:	Cumulative baseline emissions from above-ground commercial trees at the end of the current monitoring period
Equations	[F.34], [F.51]
Source of data:	Measurements in the proxy area
Description of measurement methods and procedures to be applied:	8.1.6.1, 8.1.6.2, 8.1.6.3

Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{B\ BGB}^{[m]}$
Data unit:	tCO_2e
Description:	Cumulative baseline emissions from below-ground biomass at the end of the current monitoring period
Equations	[F.31]
Source of data:	Measurements in the proxy area
Description of measurement methods and procedures to be applied:	8.1.4
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{B\ BGB}^{[m-1]}$
Data unit:	tCO_2e
Description:	Cumulative baseline emissions from below-ground biomass at the beginning of the current monitoring period
Equations	[F.31]
Source of data:	Measurements in the proxy area
Description of measurement methods	8.1.4

and procedures to be applied:	
Frequency of monitoring/recording:	Prior monitoring period
QA/QC procedures to be applied:	N/A
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{B\ BM}^{[m]}$
Data unit:	tCO_2e
Description:	Cumulative baseline emissions from biomass at the end of the current monitoring period
Equations	[F.16], [F.30], [F.52]
Source of data:	Measurements in the proxy area
Description of measurement methods and procedures to be applied:	8.1.1, 8.1.1.5.1
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{B\ DW}^{[m]}$
Data unit:	tCO_2e
Description:	Cumulative baseline emissions from dead wood at the end of the current monitoring period
Equations	[F.35]
Source of data:	Measurements in the proxy area

Description of measurement methods and procedures to be applied:	8.1.3
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{B\ DW}^{[m-1]}$
Data unit:	tCO_2e
Description:	Cumulative baseline emissions from dead wood at the beginning of the current monitoring period
Equations	[F.35]
Source of data:	Measurements in the proxy area
Description of measurement methods and procedures to be applied:	8.1.3
Frequency of monitoring/recording:	Prior monitoring period
QA/QC procedures to be applied:	N/A
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{B\ SOC}^{[m]}$
Data unit:	tCO_2e
Description:	Cumulative baseline emissions from soil carbon at the end of the current monitoring period
Equations	[F.16], [F.26]
Source of data:	Measurements in the proxy area

Description of measurement methods and procedures to be applied:	8.1.2.1, 8.1.2.2, 8.1.2.3
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{B\ SOC}^{[m-1]}$
Data unit:	tCO_2e
Description:	Cumulative baseline emissions from soil carbon at the beginning of the current monitoring period
Equations	[F.26]
Source of data:	Measurements in the proxy area
Description of measurement methods and procedures to be applied:	8.1.2.1, 8.1.2.2, 8.1.2.3
Frequency of monitoring/recording:	Prior monitoring period
QA/QC procedures to be applied:	N/A
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{BA}^{[m]}$
Data unit:	tCO_2e
Description:	Cumulative emissions allocated to the buffer account at the end of the current monitoring period
Equations	[F.55]
Source of data:	N/A

Description of measurement methods and procedures to be applied:	8.4.4
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_L^{[m]}$
Data unit:	tCO_2e
Description:	Cumulative emissions from leakage at the end of the current monitoring period
Equations	[F.44]
Source of data:	Measurements in the leakage area(s)
Description of measurement methods and procedures to be applied:	8.3
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_L^{[m-1]}$
Data unit:	tCO_2e
Description:	Cumulative emissions from leakage at the beginning of the current monitoring period
Equations	[F.44]
Source of data:	Measurements in the leakage area(s)

Description of measurement methods and procedures to be applied:	8.3
Frequency of monitoring/recording:	Prior monitoring period
QA/QC procedures to be applied:	N/A
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{L\ \Delta}^{[m]}$
Data unit:	tCO_2e
Description:	Change in emissions due to leakage
Equations	[F.53]
Source of data:	N/A
Description of measurement methods and procedures to be applied:	8.3
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{L\ ASF}^{[m]}$
Data unit:	tCO_2e
Description:	Cumulative emissions from activity-shifting leakage in forested strata at the end of the current monitoring period
Equations	[F.45]
Source of data:	Measurements in the activity-shifting leakage area

Description of measurement methods and procedures to be applied:	8.3
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{L\ ASG}^{[m]}$
Data unit:	tCO_2e
Description:	Cumulative emissions from activity-shifting leakage in native grassland strata at the end of the current monitoring period
Equations	[F.44],[F.45]
Source of data:	Measurements in the activity-shifting leakage area
Description of measurement methods and procedures to be applied:	8.3.3.4
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{L\ ME}^{[m]}$
Data unit:	tCO_2e
Description:	Cumulative emissions from market leakage at the end of the current monitoring period
Equations	[F.45]
Source of data:	Measurements in the market leakage area

Description of measurement methods and procedures to be applied:	8.3
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{P\ \Delta}^{[m]}$
Data unit:	tCO_2e
Description:	Change in project emissions
Equations	[F.53]
Source of data:	Monitoring records for Forest Fire, Burning, logging, wood products, and natural disturbance events
Description of measurement methods and procedures to be applied:	8.2
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{P\ \Delta BRN}^{[m]}$
Data unit:	tCO_2e
Description:	Cumulative project emissions due to burning at the end of the current monitoring period
Equations	[F.41]
Source of data:	Monitoring plots in the project

Description of measurement methods and procedures to be applied:	8.2.2
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{P\ \Delta\ LS}^{[m]}$
Data unit:	tCO_2e
Description:	Cumulative project emissions due to livestock grazing within the project area.
Equations	[F.43]
Source of data:	Monitoring in the project area
Description of measurement methods and procedures to be applied:	8.2.4
Frequency of monitoring/recording:	Every time measured (≤ 5 yrs)
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$E_{P\ \Delta\ SF}^{[m]}$
Data unit:	tCO_2e
Description:	Cumulative project emissions due to the use of synthetic fertilizers within the project area.
Equations	[F.53]
Source of data:	Monitoring in the project area

Description of measurement methods and procedures to be applied:	8.2.5
Frequency of monitoring/recording:	Every time measured (≤ 5 yrs)
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	Estimation of direct and indirect (eg, leaching and runoff) nitrous oxide emission from nitrogen fertilization

Data / Parameter:	$E_U^{[m]}$
Data unit:	tCO_2e
Description:	Cumulative confidence deduction at the end of the current monitoring period
Equations	[F.55]
Source of data:	N/A
Description of measurement methods and procedures to be applied:	8.4.1.1
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$n_{LS\ i}$
Data unit:	Count
Description:	The number of head of livestock species / category i in the project area
Equations	[F.43]

Source of data:	Monitoring in the project area
Description of measurement methods and procedures to be applied:	8.2.4
Frequency of monitoring/recording:	Every time measured (≤ 5 yrs)
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$p_{L\ DEG}^{[m]}$
Data unit:	Proportion (unitless)
Description:	Portion of leakage due to degradation in forest at the end of the current monitoring period
Equations	[F.46], [F.47], [F.48], [F.49]
Source of data:	Monitoring in the leakage area
Description of measurement methods and procedures to be applied:	8.3.2.3
Frequency of monitoring/recording:	Every time measured (≤ 5 yrs)
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$p_{L\ DEG}^{[m=0]}$
Data unit:	Proportion (unitless)
Description:	Portion of leakage due to degradation prior to first verification event
Equations	[F.48]

Source of data:	Monitoring in the leakage area
Description of measurement methods and procedures to be applied:	8.3.2.3
Frequency of monitoring/recording:	First monitoring period
QA/QC procedures to be applied:	Project verification
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$p_{L\ CON\ G}^{[m=0]}$
Data unit:	Proportion (unitless)
Description:	Portion of leakage due to native grasslands prior to the first verification event
Equations	[F.47], [F.49]
Source of data:	Monitoring in the leakage area
Description of measurement methods and procedures to be applied:	8.3.2.4
Frequency of monitoring/recording:	First monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$p_{L\ CON\ G}^{[m]}$
Data unit:	Proportion (unitless)
Description:	Portion of leakage due to native grasslands conversion at the beginning of the current monitoring period
Equations	[F.47], [F.49]

Source of data:	Monitoring in the leakage area
Description of measurement methods and procedures to be applied:	8.3.2.4
Frequency of monitoring/recording:	Every time measured (≤ 5 yrs)
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$p_{L\ CON\ G}^{[m-1]}$
Data unit:	Proportion (unitless)
Description:	Portion of leakage due to native grasslands conversion at the end of the current monitoring period
Equations	[F.47], [F.49]
Source of data:	Monitoring in the leakage area
Description of measurement methods and procedures to be applied:	8.3.2.4
Frequency of monitoring/recording:	Every time measured (≤ 5 yrs)
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$p_{SL}^{[m]}$
Data unit:	Proportion (unitless)
Description:	Proportion of AGMT that is not merchantable and goes into slash estimated from inventory
Equations	[F.34]

Source of data:	Estimated from inventory
Description of measurement methods and procedures to be applied:	8.1.6.3
Frequency of monitoring/recording:	Every time measured (≤ 5 yrs)
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$t^{[i-1]}$
Data unit:	Days
Description:	Time from project start date to beginning of monitoring period i
Equations	[F.32], [F.33]
Source of data:	Monitoring records
Description of measurement methods and procedures to be applied:	N/A
Frequency of monitoring/recording:	Prior monitoring period
QA/QC procedures to be applied:	N/A
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$t^{[m]}$
Data unit:	Days
Description:	Time from project start date to end of current monitoring period
Equations	[F.19], [F.20], [F.24], [F.21], [F.25], [F.27], [F.28], [F.32], [F.33], [F.36], [F.37], [F.38], [F.39], [F.40]
Source of data:	Monitoring records

Description of measurement methods and procedures to be applied:	N/A
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$t^{[m-1]}$
Data unit:	Days
Description:	Time from project start date to beginning of current monitoring period
Equations	[F.10], [F.36]
Source of data:	Monitoring records
Description of measurement methods and procedures to be applied:	N/A
Frequency of monitoring/recording:	Prior monitoring period
QA/QC procedures to be applied:	N/A
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$U_B^{[m]}$
Data unit:	tCO_2e
Description:	Total uncertainty in proxy area carbon stock estimate
Equations	[F.57]
Source of data:	N/A

Description of measurement methods and procedures to be applied:	N/A
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$U_{EM}^{[M]}$
Data unit:	tCO_2e
Description:	Total uncertainty in Baseline Emissions Models
Equations	[F.57]
Source of data:	N/A
Description of measurement methods and procedures to be applied:	N/A
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$U_{P}^{[m]}$
Data unit:	tCO_2e
Description:	Total uncertainty in project accounting area carbon stock estimate
Equations	[F.57]
Source of data:	N/A

Description of measurement methods and procedures to be applied:	N/A
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$wc_{Pi}^{[m=o]}$
Data unit:	tCO_2e
Description:	Weighted average carbon stocks for biomass or SOC in the project for the set of selected strata
Equations	[F.29] [F.24]
Source of data:	Inventory
Description of measurement methods and procedures to be applied:	Inventory, GIS
Frequency of monitoring/recording:	Every monitoring period
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Data / Parameter:	$x^{[m]}$
Data unit:	Varies
Description:	Covariate values
Equations	[F.19], [F.20], [F.21], [F.24], [F.25], [F.27], [F.28], [F.37], [F.38], [F.39], [F.40],

Source of data:	Participatory Rural Appraisal, analysis of public records, and/or expert interpretation of inventory data or remotely sensed imagery
Description of measurement methods and procedures to be applied:	N/A
Frequency of monitoring/recording:	Every time measured (≤ 5 yrs)
QA/QC procedures to be applied:	Review of monitoring records
Purpose of data:	
Calculation method:	
Comments:	

Monitoring Requirements: Data and Parameters Monitored
The monitoring report must include the following: **MR.85** List of parameters from Appendix H, their values and the time last measured. **MR.86** Quality assurance and quality control measures employed for each. **MR.87** Description of the accuracy of each.

9.3 Description of the Monitoring Plan

The requirements for sampling depend on the baseline type identified for the project and the selected carbon pools. Pools may be conservatively excluded if the sum of all emissions from optional pools not selected is less than 5% of the total project benefit for the project lifetime. The conservative exclusion of *de minimis* pools can be demonstrated using *ex-ante* estimates (see section 8.4.7). Conservative exclusions must always meet current VCS requirements. All plots must be measured for the first verification. All leakage plots, proxy area plots and project accounting area plots must be remeasured at least every five years, or after a significant event that changes stocks in the proxy or project accounting areas. Note that plots may not be re-measured every monitoring period if the length of the monitoring period is less than five years and there are no significant events that change carbon stocks. All heads of livestock being grazed within the project area must be measured for the first verification (unless deemed to be *de minimis*) and remeasured at least every five years.

All deviations from Appendix B must be described in the monitoring report. At every monitoring (verification) event, new deviations to the monitoring plan must be described in the monitoring report.

PD Requirements: Description of the Monitoring Plan
In the case when *ex-ante* estimates are used to prove the significance of emissions sources or estimate the quantity of NERs over the project crediting period, the project description must include the following: **PDR.122** Summary of sampling procedures for the project accounting areas, with a copy of a sampling protocol used to carry out measurements. **PDR.123** Summary of sampling procedures for the proxy areas, with a copy of a sampling protocol used to carry out measurements. **PDR.124** Summary of sampling procedures for the activity-shifting leakage areas, with a copy of a sampling protocol used to carry out measurements.

Monitoring Requirements: Description of the Monitoring Plan
The monitoring report must include the following: **MR.88** Documentation of training for field crews. **MR.89** If included in project activities, a description of procedures used to estimate the rate of biomass burning and charcoal production and demonstration that these estimates are conservative. **MR.90** Documentation of data quality assessment such as a check cruise and plots of the data such as diameter distributions by strata or plot. **MR.91** Maps of a stratification (if any) and references to plot allocation. **MR.92** List of plot GPS coordinates. **MR.93** Description of plot sizes and layout (such as the use of nests and their sizes) for each carbon pool. **MR.94** If applicable, a detailed description of the process used to develop allometric equations, to include:

Sample size

Distribution (eg, diameter) of the sample

Model fitting procedure

Model selection

MR.95 The estimated carbon stock, standard error of the total for each stock, and the sample size for each stratum in the area selected.

MR.96 Log export monitoring records and standard operating procedure in the project area, if there is commercial harvest in the project scenario.

MR.97 Deviations from the measurement methods set out in Appendix B or the monitoring plan, per current VCS requirement.

MR.98 The frequency of monitoring for each plot for all plots – all plots should be measured for the first verification. All leakage plots should be measured every verification, and all proxy and project accounting area plots at least every five years, or after a significant event that changes stocks.

9.3.1 Monitoring Carbon Stocks

This methodology employs fixed area plots coupled with allometric equations for estimating carbon stocks in trees. Carbon stocks in dead wood are estimated using fixed area plots for the standing dead wood pool and line intersect sampling for the lying dead wood pool. Allometric equations or destructive sampling may be used for estimating non-tree carbon stocks. Soil carbon is estimated using soil samples collected from soil cores or pits. Carbon in log production to wood products is estimated by estimating merchantable volume on fixed area measurement plots. These sampling procedures are designed to detect both increases in carbon stocks, such as those that occur as a result of forest growth, and decreases in carbon stocks, such as changes that may take place as a result of degradation or natural disturbance events.

Carbon stocks must be estimated for the first monitoring period by sampling all plots in all strata in the project, activity-shifting leakage and proxy areas. After the first monitoring period, all plots and all strata in the project and the activity-shifting leakage areas must be re-measured at least every five years, a process which may be accomplished on an intermittently rotating basis. If the baseline scenario includes commercial wood products and the project proponent elects to use the market leakage area, the proponent must measure AGMT in the market leakage area.

Project proponents must install a stratified random sample of permanent plots in the project area and leakage areas and, if required based on the selected pools and guidance above, the proxy area. It is recommended that all quantities selected for measurement be measured on the same plots (as described in Appendix B), but different sampling schemes for each pool may be employed if the project proponent determines that this improves the efficiency of sampling. In particular, soil carbon stocks may require a sampling framework distinct from that applied for other pools.

9.3.2 Monitoring Livestock

If livestock grazing is occurring within the project area boundary, the number of each species of livestock being grazed must be determined. It is recommended that the project proponent conduct a headcount of all livestock species within the project area to determine exact population numbers, but different sampling schemes for livestock estimation may be employed if the project proponent finds that this improves the efficiency of sampling. For a detailed description of procedures for monitoring livestock populations within the project area, refer to Appendix B. It is always conservative to overcount the number of livestock being grazed in the project area.

9.3.3 Allometric Equations

When available, allometric equations from existing IPCC, government, or peer reviewed literature may be used. Equations should be derived from trees of a wide range of diameters and, if included, heights and should not be used beyond the size range for which they were developed. When equations are selected from literature, justification must be provided for their applicability to the project area considering climatic, edaphic, geographical and taxonomic similarities between the project location and the location in which the equation was derived. When possible, species-specific equations should be used. If generalized equations developed for wide scale application are used, they must be validated using the procedures below.

Allometric equations may change or be supplemented each monitoring period as allometry improves. Every monitoring period all selected equations must be justified per the following sections.

Monitoring Requirements: Sources of Allometry	
The monitoring report must include the following:	
MR.99	A list of all selected allometric equations used to estimate biomass for trees and non-trees.
MR.100	For each selected allometric equation, a list of species to which it is being applied and the proportion of the total carbon stocks predicted by the equation.
MR.101	For each selected allometric equation, indication of when it was first employed to estimate carbon stocks in the project area (monitoring period number and year of monitoring event).
MR.102	For each selected allometric equation, indication of whether was validated per sections 9.3.3.1 or 9.3.3.2.

MR.103	Documentation of the source of each selected allometric equation and justification for their applicability to the project area considering climatic, edaphic, geographical and taxonomic similarities between the project location and the location in which the equation was derived.

9.3.3.1 Validating Previously Developed Allometric Equations

When equations are taken or modified from existing literature that is not similar to the project area as described above or are selected from a biome-wide database, such as those provided in Tables 4.A.1 to 4.A.3 of the GPG-LULUCF (IPCC, 2006), they must be verified by measurements of trees within the project area or in stands similar to the project stands in the same forest type as project stands and near the project area. It is always best and most accurate to use equations developed from trees in the project area or from existing literature that is based on research in areas similar to the project area. The project proponent should commit to improve and update allometric equations over time to reduce uncertainty.

Equations may be validated by showing good correspondence of predictions from the equation to field measurements of biomass based on: (a) destructive harvesting of trees in or near the project area, (b) direct physical measurements of at least the bole, and major branch segments combined with valid expansion factors for branches and foliage or, (c) a combination of direct measurement of boles and use of conservative expansion factors or a sampling approach for branches that precludes double-counting branch and bole measurement.

An equation must be validated using a representative sample within the size range observed in the inventory. The sample size must be at least 30 unless the number of trees to which it is being applied is less than 100, in which case it must be equal to 30% of the number of trees to which it is being applied.

An equation is valid if:

1. The predicted biomass is within +/- 15% of that measured, using the measurement methods described above, determined by the ratio of the sum of all measurements to the sum of all predictions (ratio of sums).
2. OR the cumulative biomass for all measured trees in the validation sample are greater than that predicted by the equation.
3. OR an adjustment factor is applied to the equation that results in the predicted biomass being within +/-15% of the measured biomass using the methods described above.

In the case where the representative sample does not include a tree that is as large or larger than the largest tree in the inventory (a right-censored sample), the project proponent must demonstrate that the equation selected does not over-predict biomass for very large trees by demonstrating two additional criteria.

1. That the biomass measurement of the largest tree in the representative sample is greater than its predicted biomass by the equation.
2. That the equation behaves similarly beyond the range of measurements taken for the representative sample. To demonstrate this, do the following:
    a. Find the first order derivative of the equation.
    b. Determine the value of the derivative given the measurements of the largest tree in the representative sample.
    c. Determine the value of the derivative given the measurements of the largest tree in inventory to which the equation is applied.
    d. Compare the values from (b) and (c). The value from (c) must be no more than 10% greater than the value from (b).

Monitoring Requirements: Validating Previously Developed Allometry	
The monitoring report must include the following:	
MR.104	A list of allometric equations validated by destructive sampling.
MR.105	For each, the number of trees (or non-trees) destructively sampled and the location where the measurement were made relative to the project area.
MR.106	A field protocol used to measure destructively sampled trees (or non-trees).
MR.107	Justification that the field protocol for the destructive measurement method conservatively estimates biomass.
MR.108	For each allometric equation in the list, a figure showing all the descriptive measurements of biomass compared to predicted values from its selected allometric equation.

9.3.3.2 Validating Newly Developed Allometric Equations

If allometric equations are developed for the project area, the guidance provided by Parresol (1999) should be used to fit appropriate statistical models. New models must be validated using leave-one-out cross validation as follows:

Assume a model of the form $y = f(\boldsymbol{x})$, where y is measured biomass and $\boldsymbol{x}$ is a vector of regressors.

1. Temporarily remove observation $(y_{i,}\boldsymbol{x}_i)$ from the dataset used to fit the model.

1. Refit the model, f_{-i} , with the remaining data points and use it to estimate $\hat{y}_i$, the predicted biomass at the point that was removed from the dataset prior to model fitting as given by equation [B.24].
2. Estimate the cross-validated error for this data point, $\hat{e}_i$, expressed as a proportion of the true biomass using equation [B.25].
3. Repeat 1-3 for each observation.
4. Calculate the mean cross-validated error $\bar{E}$ as equation [B.26], where $\mathcal{X}$ is the set of all observations used in model fitting.

The developed equation is considered valid if $\bar{E} < 15\%$.

Monitoring Requirements: Validating Newly Developed Allometry
The monitoring report must include the following: **MR.109** A list of allometric equations cross validated. **MR.110** For each, the number of trees (or non-trees) destructively sampled to build the equation and the location where the measurements were made relative to the project area. **MR.111** A field protocol used to measure trees (or non-trees) when developing the equation. **MR.112** Justification that the field protocol for the measurement method to build the equation conservatively estimates biomass. **MR.113** For each allometric equation in the list, the value of $\bar{E}$.

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Winjum, J., Brown, S., & Schlamadinger, B. (1998). Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science*, *44*(2), 272–284. Retrieved from http://www.ingentaconnect.com/content/saf/fs/1998/00000044/00000002/art00012

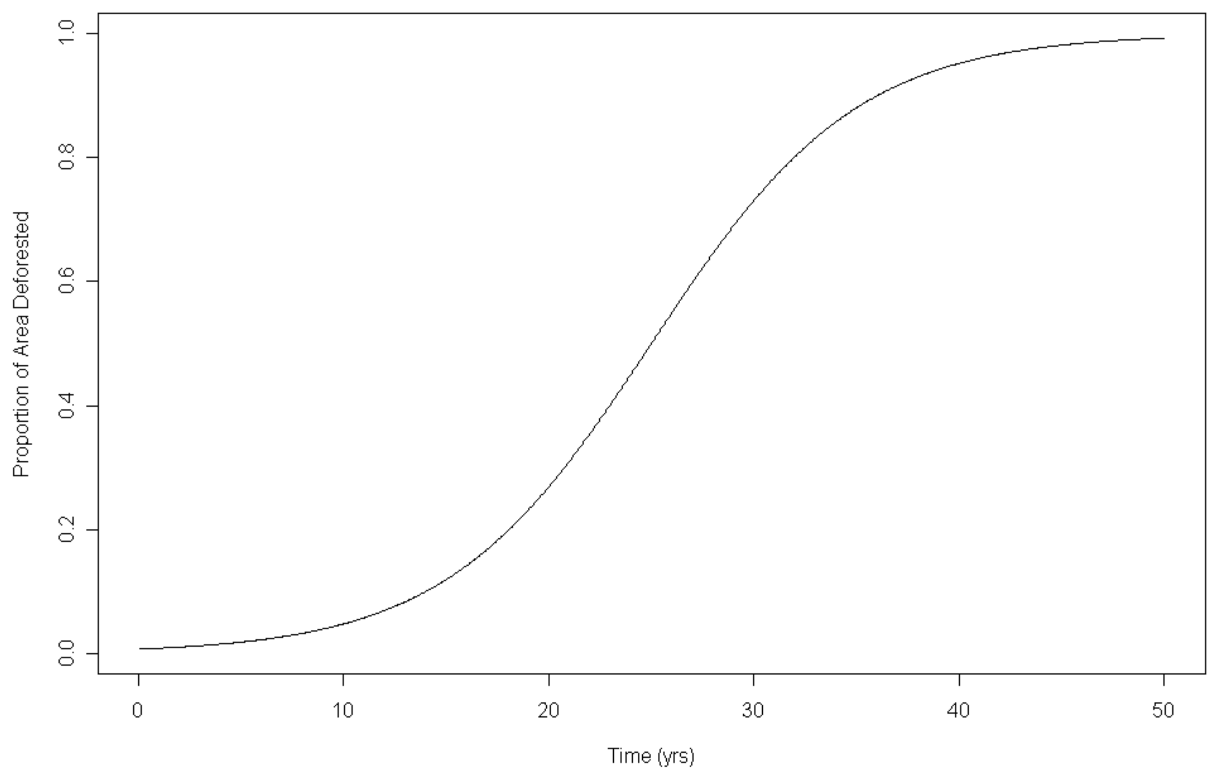
APPENDIX A: THEORETICAL BACKGROUND

A.1 Logistic Function for α, β and θ

This background section contains general information about the model and the selected approach to fitting the model rather than specific methods used to build the baseline emissions models, and is not required to run the model itself.

Natural resource conversion over time is inherently bounded by the size of the area that is subject to conversion and has been shown to exhibit logistic behavior over time (Arellano-Neri & Frohn, 2001; Kaimowitz, Mendez, Puntodewo, & Vanclay, 2002; Linkie, Smith, & Leader-Williams, 2004; Ludeke, Maggio, & Reid, 1990; Mahapatra & Kant, 2005). Figure 14 illustrates this behavior: the rate of ecosystem conversion is low at beginning, steadily increases and tapers off at the end of the time period.

Figure 14: Generalized Graph of Logistic Conversion Over Time
The logistic model of conversion, showing the transition from forest to non-forest of a given area



This behavior can be interpreted using economic theory (eg, see Reis and Guzman 1992). At the beginning of conversion in an area, agents are scarce and resources are plentiful; this leads to increasing resource exploitation. Conversely, toward the end, agents are plentiful and resources are scarce, decreasing exploitation.

Based on these concepts and their support in the literature as described above, this methodology assumes that ecosystem conversion is logistic when bounded by the reference area or project accounting area(s). Specifically, it assumes that conversion over time exhibits the implicit form defined by equation [A.4].

The parameter vector $\boldsymbol{\theta}$ included in equation [A.4] represents the aforementioned numeric covariates to conversion which are identified using expert knowledge or the participatory rural appraisal. The function η is called the linear predictor given time and conversion covariate parameters $\boldsymbol{\theta}$. Fitting equation [A.4] is equivalent to estimating the linear predictor as $\hat{\eta}$ where the linear predictor is defined by equation [A.5].

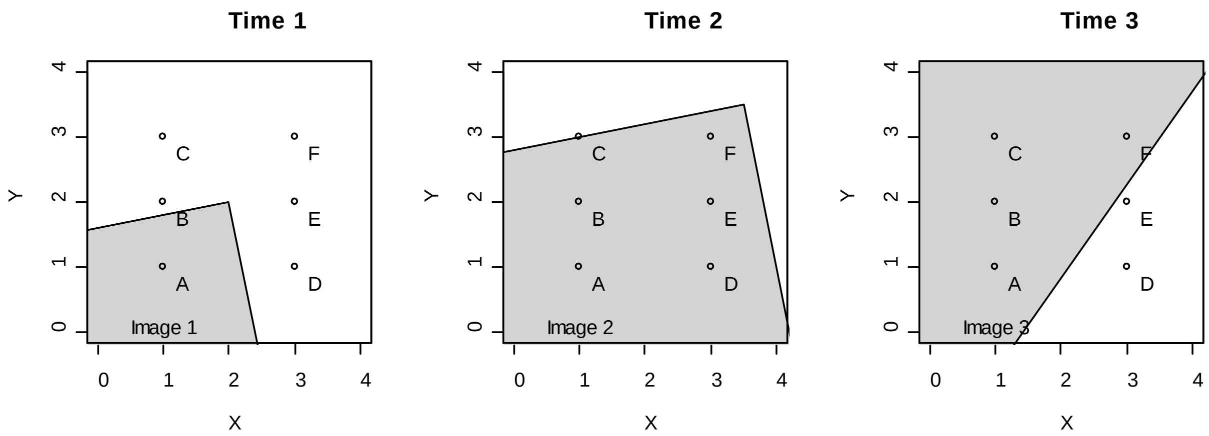
A.1.1 Probabilities and Weights for Conversion State

Fitting [A.4] requires some historic information about the land cover state in the space of the reference area over time. Observations of land cover state in the reference area can be made over the reference period as a first step to fitting equation [A.4]. These observations can be made using a sample of unique points in time and space where the state observation for the i^{th} sample point is defined by [F.11], which is a function of time t_i, latitude x_i and longitude y_i. State observations in space can be made at random or on a lattice (systematic grid). Since states are observed in historic images, however, observations in time can only be made at the times for which imagery is available.

Spatial availability of historic imagery over the reference area might not be uniform. Additionally, the entire space of the reference area might not be equally observed over time. To correct for any resulting bias, we estimate the probability of observing any one particular sample point using equation [A.1]. The probability of observing an image in time is not independent of space. For example, consider a scenario in which a government entity obtained aerial imagery along a highway for a road expansion project in the reference area five years prior to the project start date. Then, a second set of imagery was obtained after the road expansion was complete. Equation [A.3] accounts for the fact that the probability of observing an image in the reference area at any given time is dependent on that image’s proximity to the construction project.

The conditional probability of observing a sample point in space given time is [A.2] and the probability of observing any sample point in time is simply the intensity of the process [A.3]. Hence the correction factor is proportional to the inverse of the probability of observing any one particular sample point which is [A.6], and is called the observation weight.

Figure 15: Examples for Calculating Observation Weights
An example of three images at different times used to calculate the observation weights of sample points.



For example, to calculate the observation weight of a point (x, y, t) as defined by equation [A.6], one must know the number of times the point was observed in the reference area and the number images that the point falls onto during the reference period where the point falls onto in the cloud-free portion of each image. If there are six points in the reference area and three images in the historic reference period, as shown in Figure 15, then the weight of point A at time 3 in the figure is calculated as

$$\frac{1}{3 \times 4} = \frac{1}{12}$$

while the weight of point D at time 2 is calculated as

$$\frac{1}{1 \times 5} = \frac{1}{5}.$$

Point D at time 2 is given more weight than point A at time 3 because it is observed less often.

The model defined by equation [A.4] is fit using iteratively reweighted least squares (IRLS) with initial weights $\boldsymbol{w}$, the observation weights, and given the observed covariates and states $\boldsymbol{o}$ in vector format. See Venables & Ripley (2002) for information on how to fit a logistic model with IRLS using the free statistical program R.

Akaike Information Criterion (AIC) is used to select the best nested model in $\boldsymbol{\theta}$. See Davidson (2003) or Freedman (2009) for information about linear predictors and logistic models.

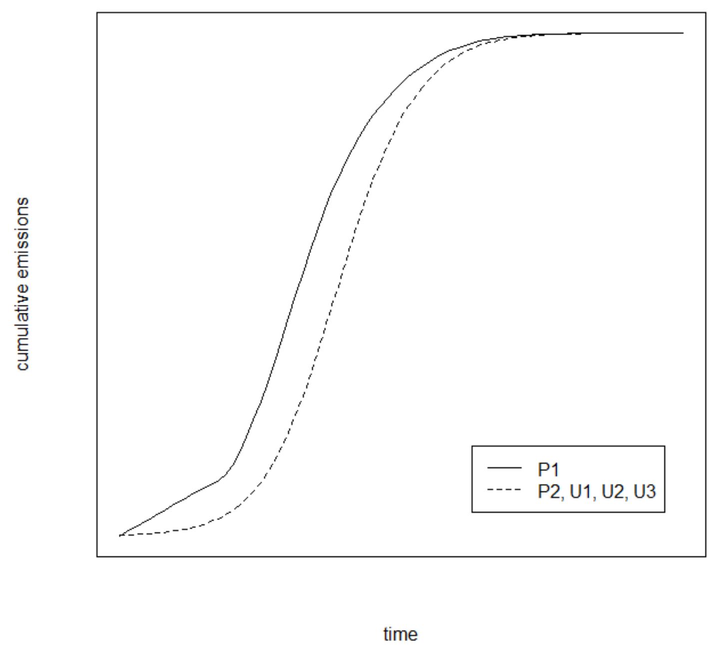
The residuals of the model defined by equation [A.4] are assumed to be stationary over the reference period. That is, the mean and variance of the residuals are time invariant.

After model selection and fitting, the cumulative conversion as a proportion of an area can be predicted for future times using equation [A.4].

A.1.2 Linear Behavior of Emissions from Legally-Sanctioned Commercial Logging

In a planned commercial scenario, a baseline operator would degrade the forest at a given linear rate mandated by the cutting limits placed by the national government or the concession. When harvest is not sustainable (eg, more volume is extracted than incremental growth in a given time and space) than the forest is degraded. If the baseline operator protects the area harvested from deforestation during forest operations but not afterwards, deforestation is preceded by linear degradation.

Figure 16: Graph of Cumulative Emissions from Conversion for the Different Baseline Types
The figure shows a generalized graph of cumulative emissions over time. An equal volume per unit time is degraded under a planned commercial scenario until secondary agents arrive and begin deforestation, following a logistic model after t_{sa} for type F-P1.a and F-P1.b, while for other baseline types emissions follow the logistic model from t_0.



The combined emissions from the linear degradation and the subsequent logarithmic deforestation are explained by the baseline emissions model, equation [F.19], and illustrated by the above generalized graph of linear degradation followed by deforestation.

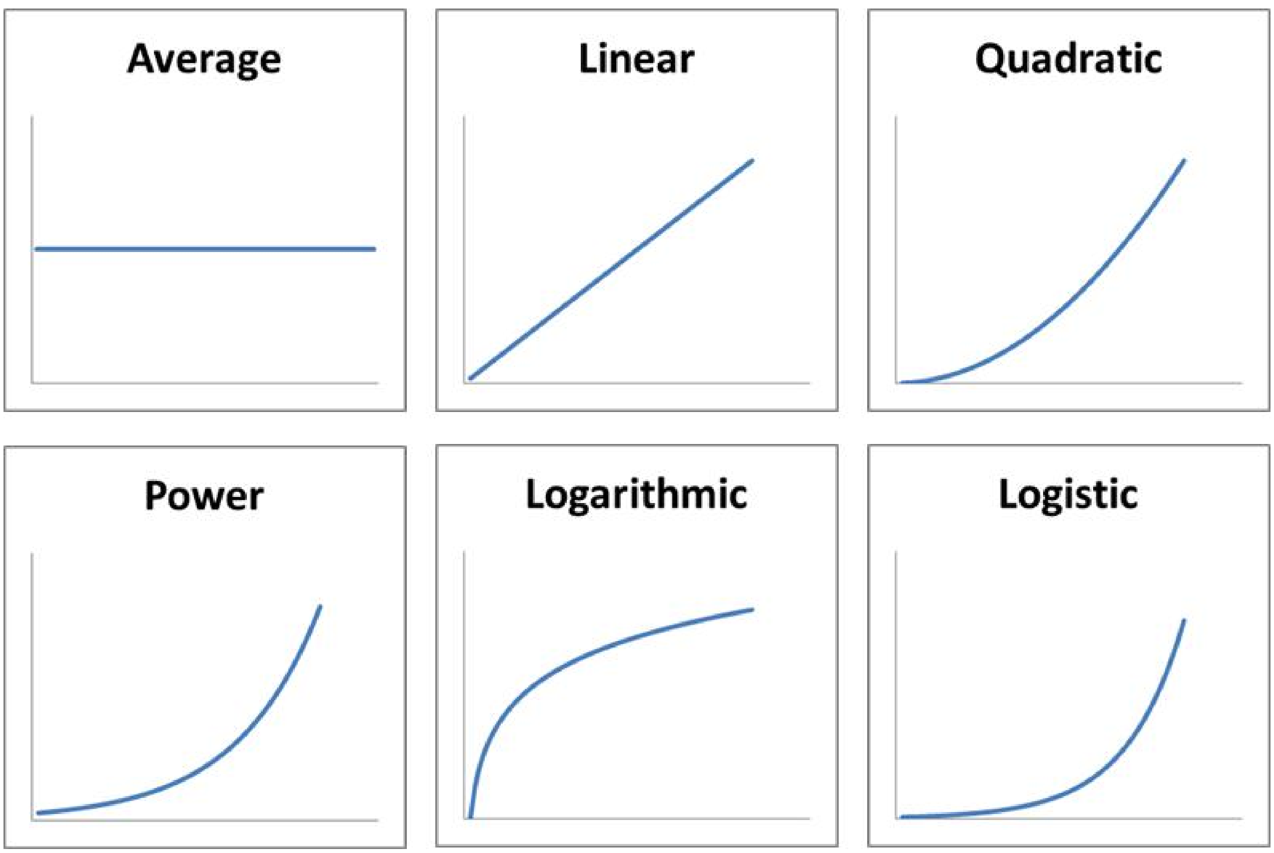
A.1.3 Relationship of the Logistic Function to Other Function Types

The logistic function specified by [A.4] is related to a variety of rate functions employed in other REDD+ programs and methodologies. The rate function of [A.4] corresponds to its first-order derivative with respect to its linear predictor:

$$\frac{\exp[\eta(t,\boldsymbol{\theta})]}{(1+\exp[\eta(t,\boldsymbol{\theta})])^2}.$$

The different types of functions are displayed graphically in Figure 17. Traditionally, other REDD+ national and sub-national programs and methodologies have employed linear functions to estimate future conversion rate trends. The logistic function specified by [A.4] represents the economic theory of resource consumption (ie, ecosystem conversion) within a discrete area over time, as presented in section [A.1]. None of the other rate functions generally used in REDD+ programs provide the same depiction of this resource economic theory. If the economic theory presented in section A.1 is accepted as the most realistic depiction of resource consumption, it can then be stated that the logisitic function may be a more reasonable approximation of the conversion process than other function types.

Figure 17: Graphs of General Functional Forms



A.2 Soil Exponential Decay Model

This background section contains general information about the exponential decay model for soil which underpins the SEM and the selected approach to fitting the exponential decay model, rather than specific instructions on how to build the model.

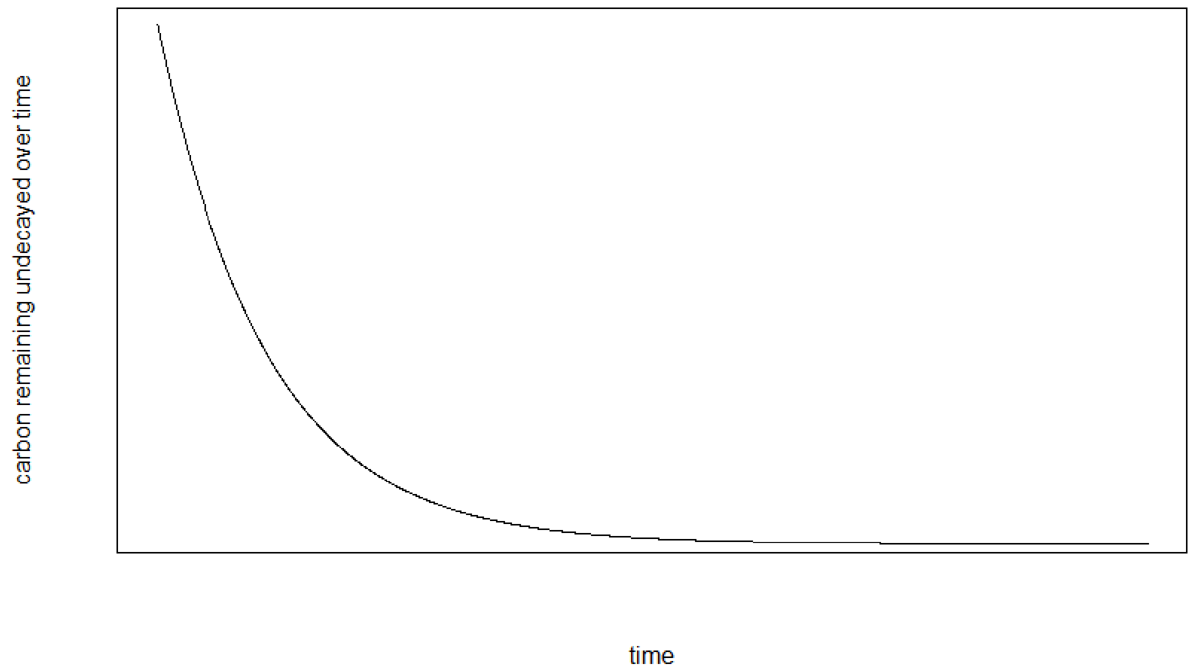
Literature suggests that the amount of carbon loss in soil following conversion from forest to non-forest or from native grassland to anthropogenic conversion follows an exponential decay (loss) curve due to decomposition processes. The majority of loss occurs within the uppermost soil horizons (eg, top 20-30 cm) for soil and within the first few years for all decaying pools (Olson 1963, Davidson and Ackerman 1993). An exponential decay function integrates cumulative loss, where λ represents the exponential soil C decay parameter and describes decay of the carbon that will eventually be lost. Following ecosystem conversion, only a portion of the carbon stock is lost; ie, organic carbon stocks decline towards a new equilibrium level over time, reaching some maximum carbon loss proportion that ultimately depends on both the depth of the soil column and cultivation practices over time for soil. These factors vary on a project-by-project basis. Hence a project developer's selected value for λ be evaluated on a project-by-project basis (see section 6.19).

Per section 6.19, project proponents must select an exponential decay parameter, λ, by either

1. Using a value from peer-reviewed scientific literature that is as appropriate for the project (see section 6.19.4),
2. Estimate the parameter, $\hat{\lambda}$, using empirically measured data per section 6.19.3, or
3. Utilize the conservative default value for the selected pool. The default value provided in this methodology is only appropriate for the tropics (see section 6.19.2).

If the project proponent choses option 2, measurement sampling of soil carbon from the proxy area (see section 6.4) is used to estimate λ_{SOC} using a process known as a "space for time substitution", a well documented method in the ecological literature. This process assumes that soil C stocks in the proxy area (that has been previously converted) are representative of the soil C levels that would be obtained over time in the project area if it were to be converted to some end land use. If the sample data are obtained from soil columns with equal depth and the data are collected from agricultural soils of known age, then the sample mean should be used to estimate λ_{SOC}, per Davidson & Ackerman, 1993. It should be noted that this methodology does not explicitly prescribe duration of time required to accurately derive a value for λ_{SOC}. The authors were purposely inexplicit in this regard, as it is in the proponent's best interest to collect data that represents a period of time after the soil carbon stock has reached a new equilibrium state (no longer declining). If $\lambda_{SOC}$is derived from converted areas that are "too recent", clearly the estimate of proportional soil loss, λ_{SOC} will be biased toward less decay than may ultimately occur. It is therefore recommended to sample in farms between 5 and 20 years in age to capture complete soil carbon decay in tropical ecosystems.

Figure 18: Exponential Decay Model
This figure depicts the exponential nature of decay in the soil carbon pool.



A.3 Model for Spatial Component

The spatial model applies to baseline type U3. This model does not attempt to determine where ecosystem conversion is most likely to have occurred in the project, but rather conservatively assumes that the stratum with the lowest carbon stocks is harvested first. Strata are then assumed to be deforested sequentially moving from lowest to the highest stocked strata.

This approach is thus the most conservative accounting possible for the potential patterns of conversion. It avoids the complexities and sources of error inherent in attempts to predict the spatial patterns of conversion that could lead to an over-issuance of NERs.

A.4 Equations for Theoretical Background

$P(t_i, x_i, y_i) = P(x_i, y_i \mid t_i)P(t_i)$	[A.1]
Variables	$P(t_i, x_i, y_i)$= probability of observation in a point in space and time t_i= the time of the i^{th} sample point x_i= the latitude of the i^{th} sample point y_i= the longitude of the i^{th} sample point
Section References	A.1.1
Comments	Probability of observing any one sample point in space and time.

$P(t_i, x_i, y_i) = \frac{\#(observations\ at\ x_i, y_i) \times \#(observations\ at\ t_i)}{\#(historic\ images) \times \#(total\ observations)}$	[A.2]
Variables	$P(t_i, x_i, y_i)$= probability of observation in a point in space and time t_i= the time of the i^{th} sample point x_i= the latitude of the i^{th} sample point y_i= the longitude of the i^{th} sample point
Section References	A.1.1
Comments	The conditional probability of observing a sample point in space given time.

$P(t_i) = \frac{1}{\#(historic\ images)}$	[A.3]
Variable	$P(t_i)$ = probability of observing any sample point in time
Section References	A.1.1, 6.8.4
Comments	The probability of observing any sample point in time with a given number of historical images

$$F_{DF}(t,\eta) = \frac{1}{1+\exp[-\eta(t,\theta)]}$$ [A.4]	
Variables	F_{DF} = proportion of cumulative conversion η = linear predictor given time and conversion covariates; t = time θ = parameter vector of covariates
Section References	A.1, 6.8.8
Comments	Logistic model of cumulative conversion bounded by a reference or project area. (Arellano-Neri & Frohn, 2001; Kaimowitz et al., 2002; Linkie et al., 2004; Ludeke et al., 1990; Mahapatra & Kant, 2005)

$$\eta = \alpha + \beta t + \theta x^T + \delta_{PR}$$ [A.5]	
Variables	α = combined effects of β and θ at the start of the historic reference period β = effect of time on the cumulative proportion of conversion over time t = time since project start date θ = parameter vector of covariates x^T = covariate value δ_{PR} = project lag parameter
Section References	A.1
Comments	linear predictor given time and conversion covariates

$$w_i \propto \frac{1}{\#(observations\ at\ x_i, y_i) \times \#(observations\ at\ t_i)}$$ [A.6]	
Variables	w_i = observation weight of point i $\#(observations\ at\ x_i, y_i)$ = number of observations throughout time at point x_i, y_i $\#(observations\ at\ t_i)$ = number of observations across space at time t_i
Section References	A.1.1

Comments	Observation weight

APPENDIX B: CARBON STOCK AND LIVESTOCK MEASUREMENT

B.1 General Sampling Guidelines for Carbon Stocks

Sample plots are used to estimate carbon stocks in selected pools at a particular point in time. Changes in measured carbon stocks are used in conjunction with the cumulative emissions model to quantify the net GHG emissions or removals as a result of project activities. Changes on measured plots should reflect both changes due to natural processes such as growth and mortality and changes due to human activity, such as management, harvest, or degradation. In order to avoid bias, plots should be marked inconspicuously, so that if degradation or management activities do occur in the area, they apply uniformly to both areas within an established monitoring plot and areas outside of those plots.

Project proponents may carry out their inventory using either a random or a systematic (grid-based) sample within each stratum. Systematic sampling helps ensure uniform coverage of the area sampled and can be cost efficient, but risks bias if the sampling units coincide with periodicity in the population. To minimize this risk:

- Project proponents must identify any periodic variation potentially present in the project area due to topography, management history, or other factors and document how the sampling design avoids bias that may result from these periodicities.
- If line-plot cruises or other linearly based methods are used, effort should be made to make cruise lines run perpendicular to slopes, rather than along contours, whenever possible.
- Systematic samples should employ a randomized start point.

The optimum plot size in a carbon inventory is a function of the variability in carbon stocks inherent in the population and measurement costs, including the cost of traveling between plots within the area to be measured. In general, as plot size increases, the variance in carbon stocks across plots within a population decreases. Aside from stratification, inventory precision can be improved by increasing either the size or number of plots measured. Plot size should be chosen by the project proponent based on experience with similar forest types, reviews of technical literature, and, optionally, a pilot sample. If a pilot sample is used, plots can optionally be installed using the largest plot radius under consideration and measurements of distance from plot center to each tree recorded. This allows for the synthetic construction of plots of smaller size. The required sample size to obtain the targeted precision level for each plot radius under consideration can then be computed using the appropriate equations described below. If a pilot sample is not feasible or desired, the between-plot variance of a new plot size can be estimated from the between plot variance of a known plot size using equation [B.1]. It should be noted that many project proponents perform "feasibility studies" in a potential project area; this presents an optimal opportunity to establish and measure a pilot sample and explore alternative sampling methodologies (which may require a deviation from the methods provided in this appendix).

Project proponents may use different-sized plots for different carbon pools. For example, project proponents may choose to use a nested plot design in which small trees are measured on a plot of smaller radius than the radius of the plot for large trees.

B.1.1 Stratification for Improving Sampling Efficiency

Stratification is recommended (but not strictly required) as a tool for minimizing sampling error. If two or more strata can be identified within the project area with similar carbon stocks and relatively small variance in relation to the variance of the total project area, stratification should reduce uncertainty in carbon stock estimation. The equations presented here assume stratification is used. However, if the project area is not stratified, the equations listed in this section are still applicable. In this case, all sums across strata include only a single element. The standard error equations given in this methodology assume that stratum sizes are known exactly. To ensure this assumption is valid, strata should be delineated prior to and independent of sampling. Stratification may be revised at any monitoring period prior to subsequent forest re-measurement.

B.1.2 Stratification for Delineating Harvestable Areas

A GIS analysis should be used to delineate harvestable areas considering slope, access constraints, local regulations (eg, required stream buffers or restrictions on harvest unit size), forest type, available harvest and skidding techniques, management plans, etc. Estimates of carbon stocks in merchantable tree and wood products ratios should be calculated only from data collected in strata classified as harvestable according to this analysis. Document all assumptions used to delineate harvestable areas. In the project area the sum delineated harvestable areas will probably be equal to the size of one or more project accounting areas.

B.1.3 Estimating Required Sample Size and Plot Allocation

This methodology makes no specific requirements with regard to the sample size used in a carbon stock inventory. Rather, guidelines for estimating required sample size as a function of desired precision are provided. The methodology discounts credit generation based on the magnitude of sampling error that results from an inventory. If an inventory does not achieve a desired degree of precision *ex-post*, project proponents may choose to install additional plots in order to decrease uncertainty and reduce confidence deductions, regardless of the sample sizes suggested by the equations provided in this section.

Each stratum must contain at least two sample plots. In planning inventory activities, the project proponent may use the following guidelines for estimating sample size and allocating plots to strata. This step is not required, but may be useful in planning an inventory of carbon stocks that minimizes expenditures required to achieve a specified precision level. The three methods below can be used to estimate the number of plots and allocation of those plots to strata that will maximize sampling efficiency based on the amount of information available prior to sampling. A pilot sample or literature review may be conducted to initially estimate the mean and standard deviation of carbon stocks in each stratum before making use of these guidelines. For more information on how to determine the size of a pilot sample see (Avery & Burkhart, 2002)

B.1.3.1 Proportional Allocation

If the only information available is the area of each stratum as delineated on a GIS, proportional allocation can be used. Determine the total estimated sample size $\hat{n}_{TOTAL}$ using equation [B.2], then determine the number of plots $\hat{n}_k$ in each stratum k using equation [B.3].

B.1.3.2 Neyman Allocation

If the area of each stratum as well as an estimate of the population variance of each stratum is available, Neyman allocation can be expected to improve sampling efficiency over proportional allocation, and is thus preferred. First determine the proportion of plots, w_k, that will fall in each stratum using equation [B.4]. Estimate the total sample size $\hat{n}_{TOTAL}$ using equation [B.5] where $\hat{\sigma}_k^2$ can be estimated from a pilot sample using equation [B.8]. Finally, estimate the number of plots $\hat{n}_k$ in each stratum k using equation [B.7].

B.1.3.3 Optimal Allocation

If for the area, an estimate of variance and an estimate of the relative cost of sampling is available for each stratum, optimal allocation can be used. First determine the proportion of plots, w_k, that will fall in each stratum using equation [B.6]. Estimate the total sample size $\hat{n}_{TOTAL}$ using equation [B.5] where $\hat{\sigma}_k^2$ can be estimated from a pilot sample using equation [B.8]. Finally, estimate the number of plots $\hat{n}_k$ in each stratum k using equation [B.7]. The cost estimate need not be in any particular unit, only a relative cost is required (eg, if the sampling cost of one stratum is twice that of another due to remote access, the values 1 and 2 may be used for the relative costs).

B.1.4 Estimating Means, Totals and Standard Errors for Stratified Samples

The estimated total quantity of interest within a sampled area is given by equation [B.9], where $\boldsymbol{y}_{j,k}$ is the plot-level quantity of interest from plot $\mathbf{j}$ in stratum $\boldsymbol{k}$, given in units per unit area. For example, if the quantity of interest is total carbon stock in trees, $\boldsymbol{y}_{j,k}$ would represent the result of applying an allometric equation to each measured tree in plot $\mathbf{j}$, converting to carbon units, summing the results, and dividing by the area of plot $\boldsymbol{j}$ as described in the procedures given below for estimating carbon stocks in above-ground trees. In the case of monitoring degradation in the activity-shifting leakage area, $\boldsymbol{y}_{j,k}$ is the observed degradation on a leakage plot (see section B.2.8).

The standard error of the total is estimated first by calculating the between-plot variance $\hat{\sigma}_k^2$ within each stratum using equation [B.8], then estimating the standard error using equation [B.10]. This estimate includes the finite population correction factor $\frac{N_{P,k}-\#(\mathcal{P}_k)}{N_{P,k}}$. Note that $N_{P,k}$, the total number of possible plots in stratum k, is given by dividing the area of the stratum by the plot size. The finite population correction factor can be conservatively excluded from the standard error formula and should not be used in estimating soil carbon stocks. Also note that separate variance estimators are used for line intersect samples of lying dead wood and are provided in that section below.

In the case that a project area is not stratified, the provided equations are still applicable, but summations across strata include only a single element.

B.1.5 Summing Pools and Uncertainties

Total carbon stocks within an area can be estimated by simply summing the totals estimated using the methods given below as shown in equation [B.33]. The standard error of such a sum can be estimated from the individual standard errors using equation [B.34].

B.2 Stock Estimation Techniques Applicable to Specific Carbon Pools

B.2.1 Estimating the Average Carbon in AGMT and AGOT

Variables: $c_{AGMT}^{[m]}$ and $c_{AGOT}^{[m]}$

Carbon stocks in live trees are estimated using allometric equations. Allometric equations commonly require recording the diameter at breast height and species or species group for each tree within the measurement plots. Some equations require additional measurements, such as height or wood density. When wood density measurements are required, the guidance provided by Williamson & Wiemann (2010) should be followed in data collection. Allometric equations should be chosen or developed based on the guidance in section 9.3.3. It is very important to use or develop high quality allometric equations that are applicable to the region and species being inventoried.

To ensure a consistent inventory across monitoring periods, the project proponent should clearly document tree measurement procedures, including procedures for locating and monumenting plots; recording and archiving data; calibrating equipment; including or excluding trees that fall on the edge of a plot; and rules for measuring trees that lean, have irregular stems, buttresses, or stilt roots.

Note that merchantable and non-merchantable trees are sampled using identical methods and utilize the same plots, but stock estimates for each pool must be computed separately for use in the baseline emissions model. Prior to sampling, the project proponent must conduct a GIS analysis as described in section B.1.2 to determine which strata of the project area are harvestable. Further, project proponents must document clear rules for classifying individual trees as merchantable or non-merchantable. These rules should consider, at a minimum, species, size class, and defect. Merchantability status of each measured tree should be assigned in the field, and recorded on field data sheets. Training should be provided to field crews to ensure that the application of these rules is consistent.

Project proponents may elect to use different plot sizes (ie, a nested design) for measurement of trees based on their size to improve inventory efficiency.

To estimate the average carbon stock in merchantable or non-merchantable above-ground trees:

1. Estimate the carbon stock of each measured tree using an appropriate allometric equation as given in equation [B.11] (see section 9.3.3 to determine appropriate allometric equations). Note that this equation assumes the selected allometric equation computes biomass in kilograms, and may need to be modified if equations with other units are applied.
2. Sum the biomass of all trees within each plot and divide by plot area as given in equation [B.14], where $x_{i,j,k}$ is the carbon stock in tonnes CO2e of tree i on plot j in stratum k as estimated in step 3. This provides an estimate of the plot level total biomass per unit area.
3. Use equation [B.9] as discussed in section B.1.4 to estimate the average carbon stock in above-ground trees, where $y_{j,k}$ is the plot level estimate of CO2e/ha produced in step (2).
4. Use equations [B.8] and [B.10] to estimate the standard error of the total carbon stock in above-ground trees, where $y_{j,k}$ is the plot level estimate of CO2e/ha produced in step (2).

B.2.1.1 Palm Biomass

The allometric equation based methods described for trees can be applied to estimating above-ground biomass of palms as well. Table 4.A.2 of the IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry provides a source of allometric equations relevant to palms. Additionally, more locally relevant equations may be available in the technical literature. Allometric equations for palms typically are based upon height, rather than diameter. Height can be measured using an electronic hypsometer, height pole, or clinometer and tape. Procedures for conducting these measurements must be clearly documented and be consistent with the expected inputs of the selected equations. Total palm biomass and its associated standard error can be calculated using the steps above as described for above-ground tree biomass.

B.2.2 Estimating the Average Carbon in AGNT

Variables: $c_{AGNT}^{[m]}$

Non-tree biomass includes grasses, sedges, herbaceous plants, woody shrubs and any trees smaller than the minimum diameter specified for using the methods described for tree biomass. Non-tree biomass can be estimated using either destructive sampling in a clipped plot, allometric equations, or a combination of the two approaches. Clip plots are appropriate for annual plants and small shrubs. Allometric equations are appropriate for perennials and large shrubs. If both methods are used simultaneously, clear rules must be established to ensure no double counting of non-tree biomass occurs.

B.2.2.1 Destructive Sampling Method

In this method, above-ground biomass is estimated by harvesting the biomass in a plot of known area, drying and weighing the harvested sample, and calculating the mass per unit area. Alternatively, wet mass may be measured on each plot and empirically adjusted to compensate for moisture content. These plots constitute separate measurement units from the plots used for tree biomass estimation, though they may exist inside the tree plot. The area of the clipped plot will typically be much smaller than the area of tree biomass plots and may be selected by the project proponent. Large plots allow for more precision in the estimation of carbon stocks, but require more effort to sample. If permanent plots are used, the location of the clip plot within the larger tree plot should not be the same during each measurement period to avoid bias that may result from clipping the same area during each measurement period, as repeated clipping may impact the productivity of the site. If the plot happens to fall in a location with little to no non-tree biomass (for example, because a large tree occupies most of the plot area), the plot should not be moved. In the field, a sampling frame can be placed over the ground to accurately determine the area to be clipped. All vegetation originating within this frame should be clipped to a consistent height above the ground, preferably as near to ground level as is feasible. Each sample should then be dried and weighed.

1. Clip all above-ground biomass within each clip plot and determine its dry mass. This can be done by either (a) collecting biomass and later drying and weighing it in a lab, or (b) collecting a representative and well mixed subsample of biomass to estimate average moisture content. This subsample is then dried and weighed in the lab and equation [B.16] can be used to estimate the dry biomass.
2. Estimate the plot level carbon stock in tonnes CO2e on each plot using equation [B.15].
3. Use equation [B.9] as discussed in section B.1.4 to estimate the average carbon stock in above-ground non-tree biomass, where $y_{j,k}$ is the plot level estimate of CO2e/ha produced in step (2).
4. Use equations [B.8] and [B.10] to estimate the standard error of the total carbon stock in above-ground non-tree biomass, where $y_{j,k}$ is the plot level estimate of CO2e/ha produced in step (2).

B.2.2.2 Allometric Equation Method

Allometric equations can be applied to estimate the above-ground biomass of non-trees. These equations might be size-class or species-specific, and may be based on, eg, stem diameter, percent cover, or number of stems. The general procedure for estimating carbon stocks in above-ground trees is applicable to non-trees when applying allometric equations.

1. Estimate the carbon stock represented by each measurement using an appropriate allometric equation as given in equation [B.12] (see section 9.3.3 to determine appropriate allometric equations). Note that this equation assumes the selected allometric equation computes biomass in kilograms, and may need to be modified if equations with other units are applied.

2. Sum the biomass of all trees within each plot and divide by plot area as given in equation [B.14], where $x_{i,j,k}$ is the carbon stock in tonnes CO2e of tree i on plot j in stratum k as estimated in step 3. This provides an estimate of the plot level total biomass per unit area.

3. Use equation [B.9] as discussed in section B.1.4 to estimate the average carbon stock in above-ground non-tree biomass, where $y_{j,k}$ is the plot level estimate of CO2e/ha produced in step (4).

4. Use equations [B.8] and [B.10] to estimate the standard error of the total carbon stock in above-ground trees, where $y_{j,k}$ is the plot level estimate of CO2e/ha produced in step (4).

B.2.3 Estimating the Average Carbon in BGMT, BGOT and BGNT

Variables: $c_{BGMT}^{[m]}$, $c_{BGOT}^{[m]}$, and $c_{BGNT}^{[m]}$

Below-ground biomass is estimated by applying a root to shoot ratio (such as those given in Table 4.4 of the IPCC Guidelines for NI Greenhouse Gas Inventories) or equation (such as those documented by Cairns et al 1997) to the above-ground biomass estimate for the above-ground large tree, above-ground small tree, and above-ground non-tree carbon pools. Ratios or equations are to be selected by the project proponent. They must be suited to the region and vegetation type to which they are to be applied and must be justified by the project proponent through a review of peer-reviewed scientific literature or through supporting field evidence.

1. Estimate the above-ground carbon stock of the relevant pool (trees or non-tree biomass) using the guidance of that section.

2. Estimate the below-ground biomass by multiplying the selected root: shoot ratio by the above-ground biomass estimate (when a ratio is selected), or by applying the selected equation to the above-ground estimate for each tree or non-tree carbon stock estimate.

3. Sum the below-ground biomass of all measurement units within each plot and divide by plot area as given in equation [B.14] where $x_{i,j,k}$ is the below-ground carbon stock in tonnes CO2e of tree i on plot j in stratum k as estimated in step 3. This provides an estimate of the plot level below-ground biomass per unit area.

4. Use equation [B.9] as discussed in section B.1.4 to estimate the average carbon stock in below-ground biomass, where $y_{j,k}$ is the plot level estimate of CO2e/ha produced in step (3).

5. Use equations [B.8] and [B.10] to estimate the standard error of the total carbon stock in below-ground biomass, where $y_{j,k}$ is the plot level estimate of CO2e/ha produced in step (3).

B.2.4 Estimating the Average Carbon in SD

Variables: $c_{SD}^{[m]}$

Carbon in standing dead wood is estimated on fixed area plots by first categorizing standing dead trees into two decomposition classes:

- Trees with branches and twigs that resemble live trees (except for leaves) (Class I)
- Trees that show loss of twigs, branches or bole mass (Class II)

B.2.4.1 Decay Class I

The carbon stock in trees of decay Class I (intact trees) is estimated using the allometric equation approach as described for live trees:

1. Estimate the carbon stock represented by each tree using an appropriate allometric equation as given in equation [B.13] (see section 9.3.3 to determine appropriate allometric equations). Note that this equation assumes the selected allometric equation computes biomass in kilograms, and may need to be modified if equations with other units are applied.

B.2.4.2 Decay Class II

The carbon stock of standing trees in decay Class II is conservatively estimated as the biomass in only the remaining bole. Diameter at breast height and height and density should be measured on each tree in decomposition class 2. The diameter at the top of the stem can be measured using a relascope or similar instrument, or it can be conservatively assumed to be zero. Wood density should be estimated using a sample taken from each tree. See Williamson & Wiemann (2010) for proper techniques for estimating specific gravity and converting between specific gravity and density estimates. The volume of the bole of each dead tree is then estimated as the frustum of a cone. To estimate the carbon stock for each decay Class II dead tree:

1. Estimate the volume of the bole using equation [B.17].
2. Estimate the carbon stock for each dead tree using equation [B.18] where $v_{i,j,k}$ is the volume of the i^{th} tree in decay class II in plot j, stratum k as calculated in step (1).

B.2.4.3 Total Standing Dead Wood

To estimate the total carbon stock in the standing dead pool:

1. Sum the carbon stocks of dead trees within each plot (both decay Class I and decay Class II) and divide by plot area as given in equation [B.14] where $x_{i,j,k}$ is the carbon stock in tonnes CO2e of tree i on plot j in stratum k as estimated for the relevant decay class as described above. Use trees in both decay classes for this summation. This provides an estimate of the plot level total biomass per unit area.
2. Use equation [B.9] as discussed in section 6.5.5 to estimate the average carbon stock in standing dead wood, where $y_{j,k}$ is the plot level estimate of CO2e/ha produced in step (1).

3. Use equations [B.8] and [B.10] to estimate the standard error of the total carbon stock in above-ground standing dead wood, where $y_{j,k}$ is the plot level estimate of CO2e/ha produced in step (1).

B.2.5 Estimating the Average Carbon in LD

Variables: $c_{LD}^{[m]}$

Lying dead wood is sampled using the line intersect method. At each plot, establish two transects of at least 50m length through the plot center. The first transect should be oriented at a random angle, while the second transect should be oriented perpendicularly to the first transect. Record the diameter and density class of each piece of lying dead wood that intersects the vertical plane established by each transect. The diameter should be measured at the point of intersection. If a piece of lying dead wood is forked and intersects the transect at more than one point, each point of intersection should be recorded separately. The minimum measurement diameter may be established on a project-specific basis, but should be documented and held constant across all measurement periods. Each piece of measured wood should be classified as sound, intermediate or rotten using the machete test as recommended by the IPCC Good Practice Guidance for Land-Use, Land Use Change and Forestry (4.3.3.5.3) (IPCC, 2006). The mean oven dry density of dead wood, $\bar{\rho}_d$, in each decay class d, must be estimated as the mean of a sample taken down logs within the project area. See Williamson & Wiemann (2010) for proper techniques for estimating specific gravity and converting between specific gravity and density estimates. The sample should be large enough to achieve a standard error of the mean within +/- 15% at a 95% confidence level.

1. Estimate the total carbon stock $y_{j,k}$, per unit area for stratum k transect j as equation [B.19] where $x_{i,j,k,d}$ is the diameter of the i^{th} piece of lying dead wood equation in density class d, transect j, stratum k.
2. From $y_{j,k}$, estimate y_k, the total carbon stock in lying dead wood in stratum k as equation [B.20].
3. From $y_{j,k}$, estimate the variance of carbon in lying dead wood in stratum k,$\hat{\sigma}_k^2$, as equation [B.21].
4. Estimate the average stock in lying dead wood as equation [B.22].
5. Estimate the standard error of the total carbon stock in lying dead wood U_{LD} as equation [B.23].

The estimation of carbon in lying dead wood may be conservatively omitted at the discretion of the project proponent.

B.2.6 Estimating the Average Soil Organic Carbon

Variables: $c_{SOC}^{[m]}$

When the soil carbon pool is selected, soil carbon must be measured using a purposive sample in the proxy areas and a random sample in the project accounting areas. In designing this sample, project proponents should take care to ensure that the sampling scheme incorporates all types of land use and states that occur within the proxy area under the baseline scenario (ie, fallow fields, active fields, etc.). To derive a representative sample and reduce uncertainty, it is recommended that the proxy area be stratified (eg, soil taxonomic class, landscape position, land use) and the ensuing sampling scheme be designed according to these strata. A stratified random approach is suggested in order to achieve maximum explanation of agricultural variance in the reference area. The stratification scheme and sample size applied for estimation of soil carbon may be different from that used for estimation of carbon in biomass pools. It is further suggested that samples are taken from similar strata in the project area and reference area, so as to achieve an accurate comparison of different land use types present in the project ecosystem. Further guidance on sample allocation (eg, Neyman allocation) can be found section B.1.2 above.

Estimation of soil carbon stocks requires collection of soil samples from the field that are later analyzed in a laboratory. In general, three variables are required to estimate soil carbon content: bulk density, the organic carbon content, and soil depth. Multiple aliquots of soil, from different depths, may be measured separately, but when calculating the number of plots for the purpose of calculation statistical confidence intervals each location only counts as one sample. Soil carbon stocks are typically not estimated over the entire depth of the soil column, but are rather estimated in the upper horizons of the soil where the majority of soil carbon is present. Sample depth may be selected by the project proponent, but a consistent total depth for soil sampling should be established, and this depth should be no less than the depth to which soil is disturbed during farming, typically a minimum of 30cm.

Samples may be extracted using a soil core or by digging a soil pit. Because of the high degree of spatial variability in soil carbon stocks, it is recommended that several samples be taken from different randomly selected locations within each sampling site (ie, farm reference region or stand in project area) and mixed prior to measurement in the laboratory. Alternatively, several samples for different soil horizons may be analyzed separately and analysis results combined after-the-fact. If soil pits are used, multiple horizons should be extracted (at least 3 are recommended) to ensure that the soil is being measured to a sufficient spatial resolution along its depth. Bulk density and carbon concentration should be measured for each individual soil horizon, as it is important to apply these individual measurements to achieve mass-equivalent measurement. A consistent total depth for soil sampling should be established, and this depth should be no less than the depth to which soil is disturbed during farming, typically a minimum of 30cm. In soils with coarse fragments (> 2mm), both density and carbon concentration should be based on the fine fraction of the soil. To accomplish this, the soil sample must be sieved through a 2mm sieve, with the volume of coarse fragments determined separately (by water immersion or by weighing the fragments and dividing by the density of rock fragments, often given as 2.65 g/65). See correction factor in equation [B.27]. Also, the density of fine soil can be calculated by dividing the mass of fine soil by the total volume of the sample, without separate calculation of the volume or mass of coarse fragments. Whatever method used, it should be completely documented and consistently applied.

If bulk density for the within-project measurements differs significantly from the reference area measurements (such as due to compaction that results from harvesting operations), measurements should be evaluated on a mass-equivalent basis. See Ellert, Janzen & Entz, (2002) and Ellert & Bettany (1995) for appropriate methods.

The guidance provided in section 4.3.3.5.4 of the GPG-LULUCF (IPCC, 2006) should be adhered to when choosing laboratory methods for analyzing soil carbon content. Bulk density and carbon concentration should be evaluated by a laboratory that follows internationally recognized standards (eg, FAO standards) to minimize errors and bias.

To collect field samples suitable for laboratory estimates of organic carbon:

1. Remove all vegetation and litter from the surface of the selected sample location. Including even small amounts of surface organic material can significantly bias estimates of soil carbon stocks.
2. Insert a soil carbon probe to the selected depth (typically 30cm), using a rubber mallet if necessary due to soil compaction.
3. Extract soil from the corer or probe into a bag and clearly label with the sampling location and an indicator that the sample is for soil carbon determination (rather than bulk density)
4. It is recommended that this process be repeated several times at each sampling location (eg, each plot may contain four separate SOC samples) and results aggregated to reduce the impact of small scale spatial variability in soil carbon content.
5. Send the sample to a laboratory for organic carbon analysis.

To collect field samples suitable for laboratory analysis of bulk density:

1. Dig a soil pit at each sampling location to at least the selected soil sampling depth (typically 30 cm).
2. Insert a soil ring with known volume into the side of the pit to collect a known volume of soil. Care should be taken to ensure no soil falls from the ring, but do not pack soil into the ring.
3. Take additional samples throughout the depth of the pit to represent the change in bulk density with depth. For example, in a 30 cm pit one sample may be taken at the midpoint of the upper half of the sampling pit and a second sample and the midpoint of the lower half of the pit. Each sample increment should be taken from a different, undisturbed vertical column of soil from the side of the pit.
4. Combine the soil samples taken in a bag clearly labeled as a bulk density sample and record the representative volume of soil (volume of the ring multiplied by the number of rings taken.

5. Send the sample to a laboratory for bulk density analysis.

To estimate the total stock in soil carbon:

1. Calculate the corrected bulk density for each plot using equation [B.27].
2. Estimate the soil carbon stock per unit area, $SOC_{j,k}$, for plot j, stratum k using equation [B.28].
3. Estimate the average stock in soil carbon as equation [B.9].
4. Estimate the variance within each stratum as equation [B.8].
5. Estimate the standard error of the total carbon stock in soil carbon as equation [B.10], excluding the finite population correction factor $\left(\frac{N_{P,k}-\#(\mathcal{P}_k)}{N_{P,k}}\right)$.

B.2.7 Estimating the Proportion of Carbon in Slash and Wood Product Classes

Variables: $p_{SL}^{[m]}$, $p_{sawnwood}^{[m]}$, $p_{panels}^{[m]}$, $p_{roundwood}^{[m]}$, $p_{paper}^{[m]}$

Merchantable volume is used to compute carbon stocks in log production. These estimated stocks can then be compared to the total carbon in merchantable trees as described in section C.1 to estimate wood products ratios that are used in accounting for carbon stocks in long lived wood products. Measurements required for these calculations can be taken on the same plots used for carbon stock estimation. When sampling is used to estimate wood product ratios for input into harvested wood products calculations, project proponents must stratify the area to determine which areas are harvestable according to the guidance provided in section B.1.2. Data used for calculations in this section should be taken only from strata classified as harvestable.

For each merchantable tree measured in the field, record its likely product class among the following:

1. Sawnwood (dimension lumber, etc.)
2. Woodbase panels (plywood, decorative panels, etc.)
3. Other industrial roundwood (poles, pilings, fence posts, etc.)
4. Paper and paperboard

Determination of likely product classes should be based on local knowledge of markets and should consider, at a minimum, species, size class, and defects. Determine of likely product classes should be based on local knowledge of markets and should consider, at a minimum, species, size class, and defects. Merchantability should also consider the cost of extraction and where the cost of logging and transportation is greater than the market value of the wood, the trees should be classified as non-merchantable. Project proponents must document rules for assigning trees to product classes based on relevant local knowledge and training should be provided to field crews to ensure consistent application of these rules. Documented rules for merchantability should be applied consistently for a given monitoring period.

For each merchantable tree species, a volume equation must be selected. If locally derived volume equations or tables are available they should be used, with field sampling designed to collect the specific data required by the selected equation or table. Project proponents should document the source and justify the applicability of all volume equations utilized. If locally derived equations are not available, volume can be estimated using the equations provided in this methodology.

1. On each merchantable tree per measurement plot record the DBH, merchantable height, top diameter (or a fixed diameter that defines merchantable height), species, and likely product class. This can be done while making measurements for total above-ground carbon as described in section B.1.
2. Calculate the total above-ground carbon stock of each measured tree using an allometric equation as described in step (1) of section B.2.1.
3. Calculate the merchantable volume of each measured tree using equation [B.17] or a locally relevant equation or volume table.
4. Calculate the carbon stock in the merchantable part of the bole using equation [B.18] where $v_{i,j,k}$ is the volume of the i^{th} tree in plot j, stratum k as calculated in step (3).
5. Confirm that the carbon stock in the merchantable part of the bole is less than the carbon stock in the total above-ground biomass of the tree. If it is not, investigate the volume and allometric equations selected and check for calculation errors.
6. Calculate the carbon stock in slash by subtracting the bole carbon stock calculated in step (4) from the total carbon stock calculated in step 2 as given in equation [B.29].
7. For each plot, estimate the total carbon stock in slash and in the merchantable boles of each category and divide by plot area as given in equation [B.14] where $x_{i,j,k}$ is the carbon stock in either slash(step 6) or the merchantable part of the bole (step 4) as appropriate. This results in 5 quantities per plot ($c_{SL,j,k}$, $c_{sawnwood,j,k}$, $c_{panels,j,k}$, $c_{roundwood,j,k}$, and $c_{paper,j,k}$).
8. For each of the 5 quantities estimated in step 7 use equation [B.9] as discussed in section B.1.4 to estimate the total carbon in the relevant category where $y_{j,k}$ is the plot level estimate in tCO2e/ha produced in step (7).
9. Calculate the wood products ratio for each category by dividing the estimate of total carbon in the relevant category as calculated in step (8) by the sum of the five totals as given in equation [B.30]. The five resulting ratios should sum to 1.0.

B.2.8 Estimating Proportion of Degradation in Forests

Degradation in the activity-shifting leakage area must be assessed by a visual sample on plots within the activity-shifting leakage area. This sample is used at the end of the first monitoring period in order to estimate the lag period for the leakage model and at every subsequent monitoring period in order to estimate actual emissions due to leakage. Because the leakage area is unlikely to be under the control of the project proponent, the sampling methods described are designed to be fast and require no modification to the site. Project proponents must be able to access the leakage area, however, to perform the required sampling.

Within the activity-shifting leakage area, randomly select a sample of point locations with uniform probability with a minimum sample size $\hat{m}_L$ determined by equation [B.31]. These point locations become the corners of the fixed-area plots used to estimate degradation, deforestation and conversion in the leakage area permanently throughout the project lifetime. Select plot dimensions so that each plot area is large enough that degradation will be observed if degradation is occurring on the adjacent landscape. It is recommended that plots be at least one hectare (eg, a 100m x 100m square plot). The dimensions of all plots should be the same. Visit these plots to observe the proportion of degradation. The proportion of degradation can be estimated using either (a) estimates of crown cover taken with a spherical densitometer (for forested baseline types); (b) visual estimates of degradation.

Neither the plot boundaries nor locations should be visibly marked on the ground, as they most likely exist in areas outside the project's control and visible marking may lead to preferential treatment of these plots. Rather, they should be monumented using a GPS and optionally a buried monument.

These sample plots must be observed at least every five years to estimate leakage. Use equation [B.9] to estimate $p_{L\ DEG}$ where $y_{j,k}$ are plot-level measurements of degradation obtained using either method described below.

Regardless of the method applied, uncertainty in measurement should be reduced as much as possible by developing a field protocol for sampling forest degradation. Training should be provided to collection teams.

B.2.9 Spherical Densiometer Method

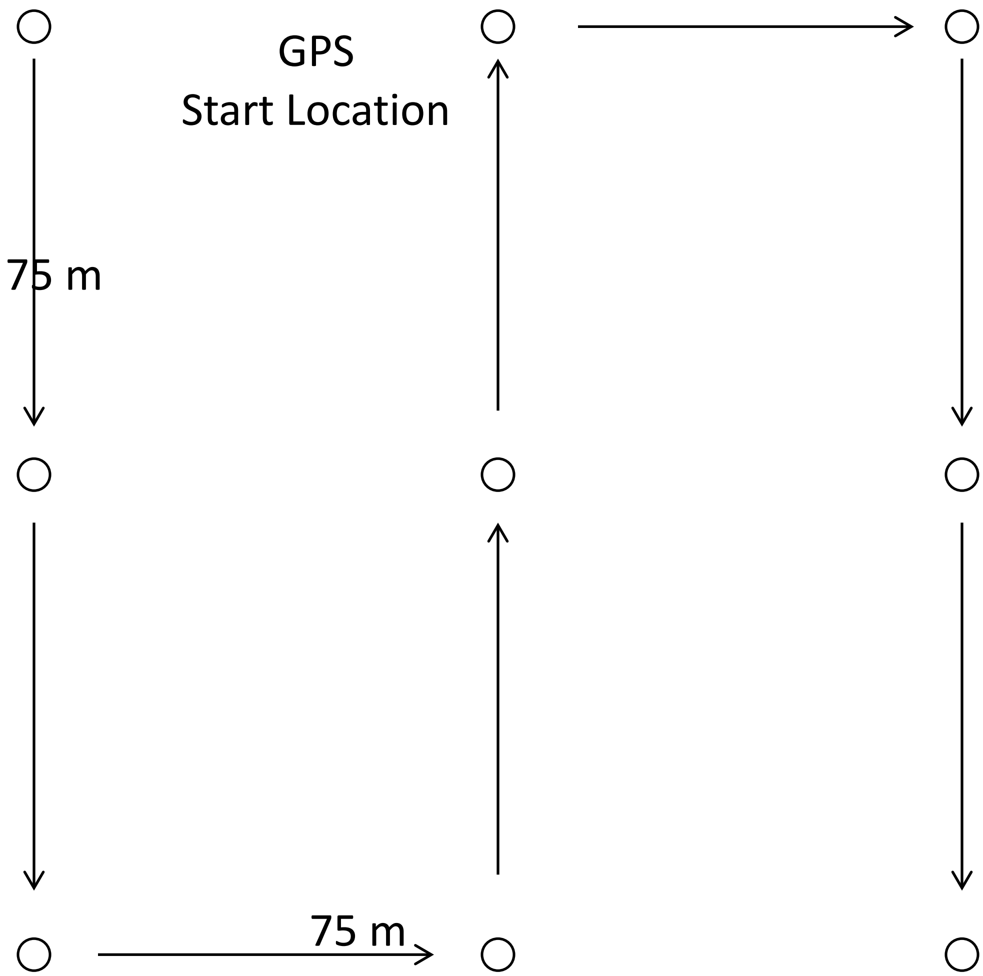
A spherical densitometer consists of a small hemispherical mirror engraved with a grid and is used to estimate crown closure by counting portions of the grid through which canopy gaps are visible. This method can be used for forested baseline types (F-P1.a, F-P1.b, F-P2, F-U1, F-U2 and F-U3). The spherical densiometer method of estimating percent degradation is more repeatable and less subjective than visual assessment, and thus should be preferred when feasible. At times, however, estimating degradation using this method will not be possible. For example, in drought-deciduous forests the dry season is most suitable for fieldwork, but at this time the canopy is in a leaf-off condition.

To use this method, crown cover must be estimated in both the leakage area and in non-degraded forest within the project area.

1. Navigate to the randomly determined plot location with a GPS.

2. Using a compass, walk a predetermined path through the degradation plot, stopping periodically to take crown cover estimates. A potential crown cover sampling scheme is illustrated in Figure 19.
3. Calculate the proportion of degradation in each leakage plot by dividing the average canopy cover in the leakage area plot by the average canopy cover measured in undegraded strata of the project area estimated using the same procedure.

Figure 19: Plot Sampling Scheme for Spherical Densiometer



In this sampling scheme, the random GPS start location is located at the northwest corner of the plot. By pacing and using a compass, the observer walks the perimeter and center of the 2.25 hectare plot and observes crown cover at 9 points in the plot, as illustrated. Crown cover should be observed according to the instructions provided with the spherical densiometer and converted to a percent. This typically involves mentally subdividing each grid cell on the densiometer into four smaller points and counting the number of points in which canopy openings are visible. The most common densiometers have 24 large squares which are then subdivided into a total of 96 points. The percent cover for these densiometers can be given by equation [B.32]. It is good practice to take four densiometer readings at each observation point, one facing in each cardinal direction, and average the results. The percent crown cover from all readings made within a plot should be averaged (ie, nine points with four readings at each point), with that average constituting a single observation for the entire plot.

B.2.10 Visual Estimates of Degradation

If the densiometer method is not practical, visual estimates of degradation can be made in the leakage area. Walk throughout each plot in the leakage area and observe the percentage of above-ground biomass that is absent as evidenced by presence of stumps for each plot area. Record a factor for each plot using the following ordinal scale in Table 10. Note that for native grassland baseline types (G-P2, G-U1 and G-U2), the ordinal scale may be confined to either 0 or 1 (not converted and converted, respectively). Also note that for native grassland baseline types, visual estimates of degradation may be obtained using remote-sensing data (such as Geo-Eye or Ikonos imagery).

Table 7: Factors for Visually Estimating Degradation.

Factor	Proportion of degradation
0.0	0%
0.2	0-19%
0.4	20-39%
0.6	40-59%
0.8	60-79% (severe degradation)
1.0	80-100% (including complete conversion)

Protocols for estimating the percentage of absent biomass must be developed by the project proponent and their conservativeness justified at validation and verification.

B.2.11 Estimating Activity-Shifting Leakage in Grasslands

Monitoring methods for activity-shifting leakage must use a land-use land-cover classification of the appropriate leakage area(s) to determine the land use conversion from native grasslands in these areas. This land-cover classification may be a supervised, pixel-based classification or use a point interpretation approach as in section 6.8. It should be noted that the activity-shifting leakage model is separate and unrelated to the BEM, and we suggest this choice of remote sensing classification types only for the activity-shifting leakage model. As stated in section 6.8.6, the BEM does not support automated, pixel-by-pixel classification techniques, and project proponents should not attempt to replace or sidestep manual image interpretation for the BEM with an automated process such as a maximum likelihood or nearest neighbor classifier. That said, whichever approach is selected for the activitiy shifting leakage model, it must meet the minimum tolerances for precision and accuracy required when constructing the project baseline.

If in the baseline native grasslands exist in a degraded state longer than a given monitoring period (eg, due to overgrazing), the project proponents must install permanent monitoring plots in the unconverted portion of the activity-shifting leakage area(s). All selected pools for native grasslands must be measured in these plots.

B.3 Guidelines for Determining Livestock Populations Within Project Area

A complete list of all livestock species and populations present within the project area boundary should be compiled. To determine the number of heads of livestock being grazed within the project area boundary, it is recommended that the project proponents conduct an inventory of the number of livestock within each species category. This may involve directly counting each animal that is grazed within the project area, if possible. The number of livestock heads that are grazed within the project area should accurately reflect changes in population size due to deaths or population growth. It is always conservative to overcount the number of headsof livestock grazed within the project area.

If the proposed method of inventory is impractical for determining the number of livestock grazed within the project area, the project proponent may choose to employ an alternative sampling scheme that they have determined to improve sampling efficiency. Any deviations from a direct count of individual livestock must be justified within the monitoring report per current VCS requirement. All samples must give an estimate of the number of heads of livestock by species with an overall precision of +/- 15% at the 90% confidence level.

B.4 Guidelines for Developing Allometric Equations

Allometric equations for shrubs can be developed by harvesting a representative sample from the project area, drying and weighing the sample, and relating the sampled biomass to variables easily measured in the field. The independent variables that are suitable for predicting shrub biomass may vary across environments and vegetation types and may include but are not limited to number of stems, stem diameter, height, size class, crown diameter, and percent cover. In some situations, developing a continuous equation that represents shrub mass as a function of one or more of the above variables is not practical. In this case, a simple average of the biomass of the sample collected per stem or per plant can be used instead. Where appropriate to project vegetation types, separate averages for different size classes and species of shrubs should be used.

When developing allometric equations for trees, measurements of tree volume, density or biomass must be made across a range of tree sizes. Models must be used to predict biomass based on covariate metrics such as diameter, height and specific gravity.

All allometric equations must be validated per section 9.3.3.2.

B.5 Minimizing Uncertainty and Collecting Consistent Data

To ensure that carbon stocks are estimated in a way that is accurate, verifiable, transparent, and consistent across measurement periods, the project proponent must establish and document clear standard operating procedures and procedures for ensuring data quality. At a minimum, these procedures must include:

- Comprehensive documentation of all field measurements carried out in the project area. This document must be detailed enough to allow replication of sampling in the event of staff turnover between monitoring periods.
- Training procedures for all persons involved in field measurement or data analysis. The scope and date of all training must be documented.
- A protocol for assessing the accuracy of plot measurements using a check cruise and a plan for correcting the inventory if errors are discovered.
- Protocols for assessing data for outliers, transcription errors, and consistency across measurement periods.
- Data sheets must be safely archived for the life of the project. Data stored in electronic formats must be backed up.

B.6 Equations for Carbon Stock Measurement

$$\hat{\sigma}_2^2 = \hat{\sigma}_1^2 \sqrt{\frac{a_1}{a_2}}$$ [B.1]	
Variables	$\hat{\sigma}_2^2$= variance of plot of size 2 (unknown plot) $\hat{\sigma}_1^2$ = variance of plot size 1 (known plot) a_1 = area of plot of size 1 a_2 = area of plot of size 2
Section References	B.1
Comments	This equation is used to estimate the effect of changing plot area on between-plot variance. a_1 is assumed to be a plot area associated with an estimated variance $\hat{\sigma}_1^2$, while a_2 is the plot area for which variance is to be estimated. Freese (1962)

$$\hat{n}_{TOTAL} = \frac{1}{\left(\frac{0.15 \times \bar{x}}{1.96 \times \hat{\sigma}_{\bar{x}}}\right)^2 + \frac{a_{plot}}{\sum_{k \in \mathcal{S}} A_k}}$$ [B.2]

Variables	$\hat{n}_{TOTAL}$ = estimated total number of plots required $\bar{x}$ = estimated mean of a quantity to be sampled in the area $\hat{\sigma}_{\bar{x}}$ = estimated standard deviation of a quantity to be sampled in the area a_{plot} = area of a plot $\mathcal{S}$ = set of all strata in the area. A_k = area of stratum k $\mathcal{S}$ = set of all strata in the area.
Section References	B.1.3.1
Comments	This equation is used to estimate sample size when stratum-specific estimates of standard deviation are unavailable. 0.15 represents an allowable error of 15% of the mean, while 1.96 represents the Z statistic from a normal distribution associated with the 95% confidence level. Avery & Burkhart (2002)

$$\hat{n}_k = \hat{n}_{TOTAL} \frac{A_k}{\sum_{k \in \mathcal{S}} A_k} \quad [B.3]$$

Variables	$\hat{n}_k$ = estimated total number of plots required in stratum k $\hat{n}_{TOTAL}$ = estimated total number of plots required A_k = area of stratum k $\mathcal{S}$ = set of all strata in the area.
Section References	B.1.3.2
Comments	This equation is used to estimate the required number of plots in stratum k under proportional allocation. Avery & Burkhart (2002)

$$w_k = \frac{A_k \hat{\sigma}_k}{\sum_{j \in \mathcal{S}} A_j \hat{\sigma}_j} \quad [B.4]$$

Variables	w_k = the proportion of plots allocated to stratum k A_j or A_k = area of stratum j or k $\hat{\sigma}_j$ or $\hat{\sigma}_k$= estimated standard deviation of a quantity to be sampled in stratum j or k $\mathcal{S}$ = set of all strata in the area.
Section References	B.1.3.2

Comments	This equation is used to estimate the proportion of plots in each stratum under Neyman allocation. Avery & Burkhart (2002); Shiver & Borders (1996)

$$\hat{n}_{total} = \frac{\sum_{k \in \mathcal{S}} \frac{A_k^2 \hat{\sigma}_k^2}{w_k}}{\left(\frac{0.15 \times \sum_{k \in \mathcal{S}} A_k \times \bar{x}}{1.96 \times a_{plot}}\right)^2 + \sum_{k \in \mathcal{S}} A_k \, \hat{\sigma}_k{}^2}$$ [B.5]	
Variables	$\hat{n}_{TOTAL}$ = estimated total number of plots required (count) A_k = area of stratum k w_k = the proportion of plots allocated to stratum k $\bar{x}$ = estimated mean of a quantity to be sampled in the project area $\hat{\sigma}_k$= estimated standard deviation of a quantity to be sampled in stratum k $\mathcal{S}$ = set of all strata in the area
Section References	B.1.3.2, B.1.3.3
Comments	This equation is used to estimate the total sample size of a stratified sample. Avery & Burkhart (2002); Shiver & Borders (1996)

$$w_k = \frac{A_k \hat{\sigma}_k / \sqrt{c_k}}{\sum_{j \in \mathcal{S}} A_j \, \hat{\sigma}_j / \sqrt{c_j}}$$ [B.6]	
Variables	w_k = the proportion of plots allocated to stratum k A_j or A_k = area of stratum j or k $\hat{\sigma}_j$ or $\hat{\sigma}_k$= estimated standard deviation of a quantity to be sampled in stratum j or k $\mathcal{S}$ = set of all strata in the area. c_j or c_k= estimated cost of sampling carbon stocks in stratum j or k
Section References	B.1.3.3
Comments	This equation is used to estimate the proportion of plots in each stratum under optimal allocation. Shiver & Borders (1996)

$$\hat{n}_k = \hat{n}_{TOTAL} w_k$$ [B.7]

Variables	$\hat{n}_{TOTAL}$ = estimated total number of plots required $\hat{n}_k$ = estimated total number of plots required in stratum k w_k = the proportion of plots allocated to stratum k
Section References	B.1.3.3
Comments	This equation is used to estimate the number of plots in each stratum. Shiver & Borders (1996)

$$\hat{\sigma}_k^2 = \frac{\sum_{j\in\mathcal{P}_k}(y_{j,k})^2 - \left(\sum_{j\in\mathcal{P}_k} y_{j,k}\right)^2/\#(\mathcal{P}_k)}{\#(\mathcal{P}_k)-1}$$ [B.8]	
Variables	$\hat{\sigma}_k^2$ = estimated variance in stratum k $y_{j,k}$= a quantity estimated for or measured on plot j in stratum k $\mathcal{P}_k$ = set of all plots in stratum k
Section References	B.1.4
Comments	The equation is used to estimate the within-stratum variance of the variable y for stratum k.

$$z = \frac{1}{\sum_{k\in\mathcal{S}} A_k}\sum_{k\in\mathcal{S}}\frac{A_k}{n_k}\sum_{j\in\mathcal{P}_k} y_{j,k}$$ [B.9]	
Variables	z = the estimated average in the sampled area, for carbon this is c and for degredation this is $p_{L\ DEG}$ A_k = the area of stratum k n_k = number of plots in stratum k $y_{j,k}$= a quantity estimated for or measured on plot j in stratum k $\mathcal{P}_k$ = set of all plots in stratum k $\mathcal{S}$ = set of all strata
Section References	B.1.4, B.2.1, B.2.2.2, B.2.3, B.2.4.3, B.2.6, B.2.7
Comments	This is a generic equation used to estimate totals from plot level estimates.

$$\text{U} = \sqrt{\sum_{k\in\mathcal{S}}\left[\frac{A_k^2\hat{\sigma}_k^2}{\#(\mathcal{P}_k)}\left(\frac{N_{P,k}-\#(\mathcal{P}_k)}{N_{P,k}}\right)\right]}$$ [B.10]

Variables	U = estimated standard error of the total for the selected carbon pool $\hat{\sigma}_k^2$ = estimated variance in stratum k A_k = area of stratum k $N_{P,k}$ = total number of possible plots in stratum k $\mathcal{P}_k$ = set of all plots in stratum k $\mathcal{S}$ = set of all strata in the area
Section References	B.2.1, B.2.2.1, B.2.2.2, B.2.3, B.2.4.3, B.2.6,
Comments	This equation is used to estimate the standard error of the total from a stratified sample from a finite population. Shiver & Borders (1996)

$$x_{i,j,k} = \frac{44}{12} \times \frac{1}{1{,}000} \times f_{SPC}(\bullet) \times p_{CF\ SPC} \quad [B.11]$$

Variables	$x_{i,j,k}$ = carbon stock in CO_2e represented by tree i on plot j in stratum k $f_{SPC}(\bullet)$ = allometric equation for species SPC $p_{CF\ SPC}$= carbon fraction for species SPC
Section References	B.2.1
Comments	This equation is for the determination of the above-ground carbon stock for each measured tree in the AGOT and AGMT carbon pools using an allomtetric equation. This equation is used to estimate the carbon stock for the i^{th} tree in plot j, stratum k. Note that this equation assumes the selected allometric equation computes biomass in kilograms, and may need to be modified if equations with other units are applied. Carbon fraction for species SPC are unitless. $\frac{44}{12}$ is the ratio of the mass of carbon dioxide to the mass of carbon and is used to convert to CO2e units. $\frac{1}{1{,}000}$ represents a conversion from kg to tonnes.

$$x_{i,j,k} = \frac{44}{12} \times \frac{1}{1{,}000} \times f_{SPC}(\bullet) \times p_{CF\ SPC} \quad [B.12]$$

Variables	$x_{i,j,k}$ = carbon stock in CO_2e represented by tree i on plot j in stratum k $f_{SPC}(\bullet)$ = allometric equation for species SPC $p_{CF\ SPC}$= carbon fraction for species SPC
Section References	B.2.2.2
Comments	This equation is for the determination of the above-ground carbon stock for the non-tree (AGNT) carbon pool using an allomtetric equation. This equation is used to estimate the carbon stock for the i^{th} non-tree in plot j, stratum k. Note that this equation assumes the selected allometric equation computes biomass in kilograms, and may need to be modified if equations with other units are applied. Carbon fraction for species SPC are unitless. $\frac{44}{12}$ is the ratio of the mass of carbon dioxide to the mass of carbon and is used to convert to CO2e units. $\frac{1}{1,000}$ represents a conversion from kg to tonnes.

$$x_{i,j,k} = \frac{44}{12} \times \frac{1}{1,000} \times f_{SPC}(\bullet) \times p_{CF\ SPC} \quad [B.13]$$

Variables	$x_{i,j,k}$ = carbon stock in CO_2e represented by tree i on plot j in stratum k $f_{SPC}(\bullet)$ = allometric equation for species SPC $p_{CF\ SPC}$= carbon fraction for species SPC
Section References	B.2.4.1
Comments	This equation is for the determination of the above ground carbon stock for each measured standing dead tree with decay class I using an allomtetric equation. This equation is used to estimate the carbon stock for the i^{th} standing dead wood in plot j, stratum k. Note that this equation assumes the selected allometric equation computes biomass in kilograms, and may need to be modified if equations with other units are applied. Carbon fraction for species SPC are unitless. $\frac{44}{12}$ is the ratio of the mass of carbon dioxide to the mass of carbon and is used to convert to CO2e units. $\frac{1}{1,000}$ represents a conversion from kg to tonnes.

$$y_{j,k} = \frac{1}{a_{j,k}} \sum_{i \in \mathcal{X}_{j,k}} x_{i,j,k}$$ [B.14]	
Variables	$y_{j,k}$= a quantity estimated for or measured on plot j in stratum k $a_{j,k}$ = area of plot j in stratum k $x_{i,j,k}$ = a quantity estimated for or measured for individual i on plot j in stratum k $\mathcal{X}_{j,k}$ = set of all measurements of a type in plot j in stratum k
Section References	B.2.1, B.2.2.2, B.2.3, B.2.4.3, B.2.7
Comments	This is a generic equation used to estimate plot level totals expressed per unit area from measurements made on individuals.

$$y_{j,k} = \frac{44}{12} \times \frac{1}{1{,}000} \times \frac{p_{CF\ SPC} \times m_{dry,j,k}}{a_{j,k}}$$ [B.15]	
Variables	$y_{j,k}$ = carbon stock in non-tree biomass that results from a destructive sample $p_{CF\ SPC}$ = carbon fraction for species SPC $a_{j,k}$ = area of plot j in stratum k $m_{dry,j,k}$ = dry mass of non-tree sample harvested from clip plots in plot j, stratum k
Section References	B.2.2.1
Comments	This equation is used to estimate the carbon stock in non-tree biomass that results from a destructive sample. $\frac{44}{12}$ is the ratio of the mass of carbon dioxide to the mass of carbon and is used to convert to CO2e units. $\frac{1}{1{,}000}$ represents a conversion from kg to tonnes.

$$m_{dry,j,k} = m_{wet,j,k} \frac{m_{dry,subsample}}{m_{wet,subsample}} \quad [B.16]$$

Variables	$m_{dry,j,k}$ = dry mass of non-tree sample harvested from clip plots in plot j, stratum k $m_{wet,j,k}$ = wet mass of non-tree sample harvested from clip plots in plot j, stratum k $m_{dry,subsample}$ = dry mass of subsample of non-tree biomass collected to estimate dry:wet ratio $m_{wet,subsample}$= wet mass of subsample of non-tree biomass collected to estimate dry:wet ratio
Section References	B.2.2.1
Comments	This equation is used to estimate dry biomass as a function of the ratio of dry to wet biomass in a subsample of harvested vegetation.

$$v_{i,j,k} = \frac{\pi h_{i,j,k}(r^2_{BASE,i,j,k} + r^2_{TOP,i,j,k} + r_{BASE,i,j,k} \times r_{TOP,i,j,k})}{3}$$	[B.17]
Variables	$v_{i,j,k}$ = volume of the i^{th} tree in plot j, stratum k $h_{i,j,k}$ = height of the i^{th} tree in plot j in stratum k $r_{BASE,i,j,k}$ = base radius of the i^{th} tree in plot j in stratum k $r_{TOP,i,j,k}$ = top radius of the i^{th} tree in plot j in stratum k
Section References	B.2.4.2, B.2.7
Comments	This equation is the volume of a truncated cone and is used to estimate the bole volume of standing dead trees in decay class II and merchantable volume of trees for wood products carbon estimates. Units for radius and height must be given in meters.

$$x_{i,j,k} = \frac{44}{12} \times p_{CF\ SPC} \times \rho_{SPC} \times v_{i,j,k}$$	[B.18]
Variables	$x_{i,j,k}$ = carbon stock for the i^{th} tree in decay class II in plot j, stratum k $p_{CF\ SPC}$ = carbon fraction for species SPC ρ_{SPC} = wood density of species SPC $v_{i,j,k}$ = volume of the i^{th} tree in decay class II in plot j, stratum k
Section References	B.2.4.2, B.2.7

Comments	This equation is used to estimate the carbon stock for the i^{th} tree in decay class II in plot j, stratum k. $\frac{44}{12}$ is the ratio of the mass of carbon dioxide to the mass of carbon and is used to convert to CO2e units.

$$y_{j,k} = \frac{44}{12} \times \frac{1}{10{,}000} \times \frac{1}{1{,}000} \times \sum_{d \in \mathcal{D}} \frac{p_{CF\ DW} \times \bar{\rho}_d \times \pi^2 \sum_{i \in \mathcal{X}_{j,k}} x_{i,j,k,d}^2}{8 l_j}$$ [B.19]	
Variables	$y_{j,k}$ = total carbon stock in lying dead wood for stratum k transect j $p_{CF\ DW}$ = carbon fraction of dry matter for dead wood $\bar{\rho}_d$= average density of dead wood in decay class d $x_{i,j,k,d}$ = diameter of i^{th} piece of lying dead wood on transect j in stratum k, decay class d l_j = length of transect j $\mathcal{D}$ = the set of all decay classes $\mathcal{X}_{j,k}$ = set of all measurements of lying dead wood in plot j in stratum k
Section References	B.2.5
Comments	This equation is used to estimate the carbon stock in lying dead wood per unit area for stratum k transect j The variables $x_{i,j,k,d}$ and l_j must be measured in meters. $\frac{44}{12}$ is the ratio of the mass of carbon dioxide to the mass of carbon and is used to convert to CO2e units. $\frac{1}{1{,}000}$ represents a conversion from kg to tonnes. $\frac{1}{10{,}000}$ represents a conversion from m^2 to hectares.

$$y_k = \frac{\sum_{j \in \mathcal{L}_k} l_j y_{j,k}}{\sum_{j \in \mathcal{L}_k} l_j}$$ [B.20]	
Variables	y_k = average carbon stock per unit area in lying dead wood in stratum k l_j = length of transect j used for measuring lying dead wood. $y_{j,k}$ = total carbon stock in lying dead wood for stratum k transect j $\mathcal{L}_k$ = set of all transects used for measurement of lying dead wood in stratum k

Section References	B.2.5
Comments	This equation is used to estimate the total carbon stock in lying dead wood in stratum k. This equation is a weighted average where the weights are proportional to transect length. In the common case where all transects are the same length, it simplifies to the average: $y_k = \frac{1}{\#(\mathcal{L}_k)} \sum_{j \in \mathcal{L}_k} y_{j,k}$ (Shiver & Borders, 1996)

$$\hat{\sigma}_k^2 = \frac{\sum_{j \in \mathcal{L}_k} \left(y_{j,k}\right)^2 - \left(\sum_{j \in \mathcal{L}_k} y_{j,k}\right)^2 / \#(\mathcal{L}_k)}{\#(\mathcal{L}_k) - 1} \quad \text{[B.21]}$$

Variables	$\hat{\sigma}_k^2$ = variance of carbon stock in lying dead wood for stratum k transect j $y_{j,k}$ = total carbon stock in lying dead wood for stratum k transect j $\mathcal{L}_k$ = set of all transects used for measurement of lying dead wood in stratum k
Section References	B.2.5
Comments	This equation is used to estimate the variance of carbon in lying dead wood in stratum k

$$c_{LD} = \frac{1}{\sum_{k \in \mathcal{S}} A_k} \sum_{k \in \mathcal{S}} A_k y_k \quad \text{[B.22]}$$

Variables	c_{LD} = estimated average carbon stock in lying dead wood at monitoring period A_k = area of stratum k y_k = average carbon stock per unit area in lying dead wood in stratum k $\mathcal{S}$ = set of all strata in the area
Section References	B.2.5
Comments	This equation is used to estimate the average carbon stock in lying dead wood.

$$U_{LD} = \sqrt{\sum_{k \epsilon \mathcal{S}} \left[\frac{A_k^2 \hat{\sigma}_k^2}{\#(\mathcal{L}_k)}\right]} \quad \text{[B.23]}$$

Variables	U_{LD} = estimated standard error of the total for carbon stock in lying dead wood A_k = the area of stratum k $\hat{\sigma}_k^2$ = estimated variance of lying dead wood samples in stratum k $\mathcal{S}$ = set of all strata in the area $\mathcal{L}_k$ = set of all transects used for measurement of lying dead wood in stratum k
Section References	B.2.5
Comments	This equation is used to estimate the standard error of the total from a line intersect sample used to estimate carbon in lying dead wood. Shiver & Borders (1996)

$$\hat{y}_i = f_{-i}(x_i) \quad [B.24]$$

Variables	$\hat{y}_i$ = predicted value for observation i f_{-i}= model fit using all points in dataset except observation i x_i = independent variable associated with observation i
Section References	9.3.3.2
Comments	This is the predicted value at observation i that results from fitting a model using all points but observation i during cross validation.

$$\hat{e}_i = \frac{\hat{y}_i - y_i}{y_i} \times 100\% \quad [B.25]$$

Variables	$\hat{e}_i$ = cross-validated residual for observation i $\hat{y}_i$ = predicted value for observation i y_i = observed dependent variable for observation i
Section References	9.3.3.2
Comments	This is the cross validated residual for point *i*, expressed as a percentage.

$$\bar{E} = \frac{\sum_{i \in \mathcal{X}} \hat{e}_i}{\#(\mathcal{X})} \quad [B.26]$$

Variables	$\bar{E}$ = mean cross-validated error $\hat{e}_i$ = cross-validated residual for observation i $\mathcal{X}$ = the set of all observations
Section References	9.3.3.2
Comments	This equation estimates mean cross-validated error, a measure of bias in the dataset $\mathcal{X}$.

$$\rho_{soil,j,k} = \frac{m_{soil,j,k} - m_{rf,j,k}}{v_{soil,j,k} - v_{rf,j,k}} \quad [B.27]$$

Variables	$\rho_{soil,j,k}$ = bulk density of fine portion of soil sample in plot j in stratum k $m_{soil,j,k}$ = dry mass of soil sample take from plot j in stratum k. $m_{rf,j,k}$ = dry mass of rock fraction of soil sample in plot j in stratum k $v_{soil,j,k}$ = total volume of soil sample in plot j in stratum k $v_{rf,j,k}$ = volume of coarse fragments (> 2mm) in soil sample taken in plot j in stratum k
Section References	B.2.6,
Comments	This equation estimates the bulk density of soil, corrected to exclude the rock fraction (fragments >2 mm).

$$SOC_{j,k} = \frac{44}{12} \times 10 \times p_{CF\ soil,j,k} \times \rho_{soil,j,k} \times d_{j,k} \times (1 - \frac{v_{rf,j,k}}{v_{soil,j,k}}) \quad [B.28]$$

Variables	$SOC_{j,k}$ = soil carbon stock in plot j stratum k $\rho_{soil,j,k}$ = bulk density of fine portion of soil sample in plot j in stratum k $p_{CF\ soil,j,k}$ = carbon fraction of soil sample in plot j in stratum k $d_{j,k}$ = depth of soil sample in plot j in stratum k $v_{soil,j,k}$ = total volume of soil sample in plot j in stratum k $v_{rf,j,k}$ = volume rock fragments (> 2mm) in soil sample taken in plot j in stratum k
Section References	B.2.6

Comments	This equation is used to estimate the carbon stock in soil in stratum k plot j $\frac{44}{12}$ is the ratio of the mass of carbon dioxide to the mass of carbon and is used to convert to CO2e units. The conversion factor 10 represents a conversion from kg to tonnes and from m^{-2} to ha^{-1}.

$$C_{slash,i,j,k} = C_{total,\mathrm{i},j,k} - C_{bole,i,jk}$$ [B.29]	
Variables	$C_{slash,i,j,k}$ = Carbon stock in slash for the i^{th} tree on plot j in stratum k $C_{total,i,j,k}$ = Total above-ground carbon stock for the i^{th} tree on plot j in stratum k $C_{bole,i,j,k}$ = Carbon stock in the merchantable part of the bole for the i^{th} tree on plot j in stratum k
Section References	B.2.7
Comments	This equation is an intermediate step in estimating the slash and wood products ratios.

$$p_i = \frac{C_i}{\sum_{i \in \mathcal{W}} C_i}$$ [B.30]	
Variables	p_i = Wood products ratio for class i C_i = Total carbon in wood products class i $\mathcal{W}$ = The set of all wood products classes (slash, sawnwood, woodbase panels, other industrial roundwood, and paper/paperboard)
Section References	B.2.7
Comments	This equation calculates their percentage of total carbon in log production expected to be allocated to each of the four wood products classes.

$$\hat{m}_L \geq \left(\frac{\hat{\sigma}_{DF} 1.64}{0.15}\right)^2$$ [B.31]	
Variables	$\hat{m}_L$ = the estimated minimum sample size in the leakage area. $\hat{\sigma}_{DF}$ = the estimated standard deviation of the state observations used to fit the logistic function
Section References	B.2.8, 6.8.10

Comments	The estimated sample size in the leakage area. Based on a normal approximation and rewritten from an approximate confidence interval at 90% with threshold of +/- 15% of the estimated mean. $\hat{m}_{FD}$ has an upper bound of 98, the maximum sample size. For a small estimated conversion rate, a larger sample than estimated is recommended. Lohr (2009)

$P = 100 - (1.04 * n)$ [B.32]	
Variables	P = percent cover estimate n = number of observed openings in densiometer reading
Section References	B.2.9
Comments	This formula applies to spherical densitometers with 24 grid cells, assuming four potential count points per grid cell.

For estimates of the project accounting area $$c_P = \sum_{j \in \mathcal{C}} c_j$$ [B.33] For estimates of the project accounting area $c_B = \sum_{j \in \mathcal{C}} c_j$	
Variables	c_P = average carbon stock in the project accounting area c_B = average carbon stock in the proxy area $\mathcal{C}$ = the set of selected carbon pools
Section References	B.1.5
Comments	This equation is used to estimate the average carbon stock in all selected carbon pools.

For estimates of the project accounting area $$U_P = \sqrt{\sum_{j \in \mathcal{C}} U_j^2}$$ For estimates of the proxy area $$U_B = \sqrt{\sum_{j \in \mathcal{C}} U_j^2}$$	[B.34]
Variables	U_P = estimated standard error of total carbon stocks in the project accounting area U_B = estimated standard error of total carbon stocks in the project accounting area $\mathcal{C}$ = the set of selected carbon pools U_j = estimated standard error of carbon pool j
Section References	B.1.5
Comments	This equation is used to combine the standard errors of the totals for selected carbon pools.

$$\frac{wc_{Sn} = c_1 A_1 + c_2 A_2 + \ldots c_i A_i}{A_i + A_2 + \ldots\ A_i}$$	[B.35]
Variables	wc_{Sn} = weighted average carbon stocks for selected strata, tCO2e/ha c_i = average carbon stocks in stratum i, tCO_2e/ha A_i = area of stratum i, ha
Section References	B.1.4
Comments	This equation calculates the average carbon stocks in terms of $tCO_2e\ ha^{-1}$ across a given set of strata weighted by pool size.

APPENDIX C: WOOD PRODUCTS

It is conservative to omit long-lived wood products as a result of project activities but required to consider them in the baseline scenario. If the project proponent chooses to estimate carbon stored in long-lived wood products as a result of the project activity, see section C.1 of this appendix.

Carbon in wood products remaining after 100 years is estimated using [C.1], which was derived from Winjum et al. (1998).

Wood products are classified as sawnwood, woodbase panels, other industrial roundwood, or paper & paperboard, each product type being considered separately. The fraction of wood lost to waste during the milling process (w), given in Table 11, is constant across product types but dependent upon country type. Table 12 provides fractions of wood products lasting at least 5 years (l_{ty}) by product type, and annual oxidation fractions (f_{ty}) for each of the three major forest regions by product type.

In order to estimate emissions-equivalent remaining sequestered in each wood product type (ty) after 100 years, the above-ground merchantable tree emissions are multiplied by the fraction remaining after milling ($1 - w$), the fraction of wood products that last 5 years or more (l_{ty}), and the fraction remaining after applying the oxidation fraction (f_{ty}) over the subsequent 95 years. All product types are summed to obtain the total emissions equivalent sequestered in wood products after 100 years.

Table 8: Milling Wood Waste Fraction ($\boldsymbol{w}$).

Country Type	$\boldsymbol{w}$
Developing	0.24
Developed	0.19

Proportion of wood lost during the milling process, from Winjum et al. (1998).

Table 9: Long-lived Wood Fractions ($\boldsymbol{l_{ty}}$) and Oxidation Fractions ($\boldsymbol{f_{ty}}$).

Product Type	$\boldsymbol{l_{ty}}$	$\boldsymbol{f_{ty}}$, Boreal	$\boldsymbol{f_{ty}}$, Temperate	$\boldsymbol{f_{ty}}$, Tropical
Sawnwood	0.8	0.005	0.01	0.02
Woodbase panels	0.9	0.010	0.02	0.04
Other industrial roundwood	0.7	0.020	0.04	0.08
Paper and paperboard	0.6	0.005	0.01	0.10

Proportion of timber remaining intact as wood products after 5 years, and annual rate of loss of wood products by forest region, both from Winjum et al. (1998).

If the project proponent wishes, the values for l_{ty} and f_{ty} in Table 13 may be applied to all product types in either the baseline or project scenario to ensure a conservative estimate. The use of these values assumes that all harvested wood goes into wood products in the baseline scenario, and none of it does in the project scenario.

Table 10: Conservative Values for Long-lived Wood Fractions ($\boldsymbol{l_{ty}}$) and Oxidation Fractions ($\boldsymbol{f_{ty}}$).

Scenario	$\boldsymbol{l_{ty}}$	$\boldsymbol{f_{ty}}$
Baseline	1	0
Project	0	1

Applicable to all wood product types.

C.1 Estimating Carbon Stored in WP Using Log Production

If as a result of project activities carbon is stored in wood products, use the methods provided in this appendix and equation [C.2] which is based on the measure log production.

C.2 Equations for Wood Products

$$C_{B\,WP}^{[m]} = (1-w)\left(E_{B\,AGMT}^{[m]}\right)\sum_{ty\in\mathcal{T}} p_{ty}^{[m]} l_{ty}\left(1-f_{ty}\right)^{95}$$ [C.1]	
Variable	$C_{B\,WP}^{[m]}$ = tCO2e sequestered in long-lived wood products after 100 years w = milling wood waste fraction ty = wood product type $E_{B\,AGMT}^{[m]}$= tCO2e sequestered in above-ground merchantable trees $\mathrm{p}_{ty}^{[M]}$ = portion of harvested carbon in product type ty (estimated using Appendix B) l_{ty} = fraction of wood products in product type ty remaining after 5 years f_{ty} = annual oxidation fraction of wood products in product type ty
Section References	8.1.6
Comments	Determining carbon stored in wood products in the baseline.

$$C_{P\,\Delta\,WP}^{[m]} = (1-w)\sum_{ty\in\mathcal{T}} C_{P\,ty}^{[m]} l_{ty}\left(1-f_{ty}\right)^{95}$$	[C.2]
Variable	$C_{P\,\Delta\,WP}^{[m]}$ = tCO2e sequestered in long-lived wood products after 100 years w = milling wood waste fraction ty = wood product type $C_{ty}^{[m]}$=Carbon measured in log production for each wood product class l_{ty} = fraction of wood products in product type ty remaining after 5 years f_{ty} = annual oxidation fraction of wood products in product type ty
Section References	8.2.3
Comments	Determining carbon stored in wood products in the project.

APPENDIX D: AREA SELECTION CRITERION

The boundaries and size of the area must address the following criteria in order to ensure that the agents and drivers of conversion in the area are similar to those of the project area:

1. The locations of the agents of conversion relative to the project area.
2. The mobilities of the agents of conversion relative to the project area.
3. The drivers of conversion including the following relative to the project area:
    a. Socio-economic conditions; and
    b. Cultural conditions.
4. Landscape configuration including the following relative to the project accounting area:
    a. Topographic constraints to conversion (slope, aspect, elevation);
    b. Land use and/or land cover constraints to ecosystem conversion;
    c. Access points that may constrain ecosystem conversion;
    d. Areas of limited soil productivity;
    e. Distance to important markets;
    f. Proximity to important resources (water, electricity, transportation); and
    g. Ownership/tenure boundaries that constrain conversion (government holdings, private holdings and reserves).

The interpretation of the above criteria is subjective and the project proponent should choose boundaries for the area that result in a conservative baseline scenario when evaluating the above criteria. Maps showing the following analyses may be helpful to the project proponent and VVB for identifying the boundaries and size of the area:

- Mapping the locations of agents of conversion.
- Buffering the locations of agents based on the distance of their mobility.
- Provincial, district-level or local maps showing the relative socioeconomic conditions of local communities.
- Mapping the locations of important cultural places.
- Digital elevation models.
- Maps of topographic surveys.
- Maps of land use and land cover.
- Mapping the locations of access points that may constrain conversion.
- Maps of soil productivity.
- Buffering the locations of important markets according to agent mobility.

- Maps of important resources (water, electricity, transportation).
- Maps of ownership boundaries (government holdings, private holdings and reserves).

The area may be similar to the project area by virtue that they are located in the same region and are probably subject to the same agents and drivers of conversion. However, for substantiation that the same agents or class of agents and drivers of conversion are present, the project proponent should clearly demonstrate similarity between the project area and area using the following criteria:

1. The area and project area must be located with the same proximity to the agents of conversion (for instance if the agents reside in a town, the project area and area must be similar in distance from a town in which agents of conversion reside. These may be the same agents, or they may be different, but similar agents.)
2. Agents of conversion must have access (legal or otherwise) to the area. The same agents need not have access to all areas, but the agents with access to each area must be similar in regards to the drivers of conversion identified in section E.2.
3. The area has similar conditions to the project area:
    a. Socio-economic conditions; and
    b. Cultural conditions.
4. The area has similar landscape configuration to the project accounting area (for instance, the same topography and land cover).
5. In the case of the reference area, it must have at least the same area of forest or native grassland cover as the project accounting area at some point in time during the historic reference period. This can be demonstrated by a thematic classification of land cover in the reference area at some point in the reference period and the project accounting area, analysis of a dot grid or by some other credible method.

APPENDIX E: THE PARTICIPATORY RURAL APPRAISAL

The participatory rural appraisal is a voluntary survey of the populace surrounding the project area and may be used to identify the agents and drivers of conversion, delineate the reference area and identify strategies to mitigate ecosystem conversion in the project area.

The participatory rural appraisal utilizes a questionnaire to identify the agents and drivers of conversion. The survey should sample as many community members, community leaders, customary leaders and public officials as possible given time and expense constraints. The sample size selected by the project proponent affects the creditability of the agents and drivers identified using the appraisal and a very low sample size may negatively affect the validation opinion. The questionnaire should be anonymous and may contain both closed and open-ended questions. The questionnaire can be issued in written form or administered orally to individuals or groups of people, as is deemed appropriate by local culture and custom. Incentives should be considered to increase the number of responses, taking care not to bias results with said incentives. The questions are designed by the project proponents on an individual project basis and should address the following issues:

1. Possible agents of conversion, including:
    a. Foreign groups;
    b. Local groups;
    c. Regional groups;
    d. Customary and traditional groups;
    e. Community groups;
    f. Authorities and governments;
    g. Illegal activities; and
    h. Other possible agents.
2. Possible drivers of conversion, including:
    a. Historic problems with community sustainability;
    b. Livelihoods;
    c. Economies;
    d. Rural wages;
    e. General scarcity issues;
    f. Prices of agricultural products;
    g. Costs of agricultural inputs;
    h. Human-wildlife interaction;
    i. Illegal or black markets;

   j. Historical and current forest uses;
   k. Population density;
   l. Socio-economic conditions; and
   m. Property-ownership systems;
   n. Other possible drivers.

3. Possible time components of degradation and conversion, including;
   a. Arrival of foreigners;
   b. Time between the beginning of degradation and ultimate conversion (see section 6.16);
   c. The length of time between the creation of access points into forest until secondary agents enter the forest resulting in degradation and ultimately conversion (see sections 6.10 and 6.11)
   d. Changes in transportation infrastructure;
   e. Events of significant importance such as droughts or floods;
   f. Regional climatic trends;
   g. Events of significant population growth;
   h. Events of significant economic growth or decline;
   i. Expected community needs;
   j. War or other conflicts;
   k. Changes in policies; and
   l. Other possible time components.

4. Possible constraints to degradation and conversion, including:
   a. Access issues;
   b. Soil productivity;
   c. Topography;
   d. Proximity to markets;
   e. Proximity to other resources (water, electricity, transportation);
   f. Protected areas;
   g. Ownership types (government, private, reserve) ; and
   h. Other possible constraints.

5. Relative importance of drivers and agents of conversion in respondents' estimation (a relative numerical rank).

6. Possible solutions to community un-sustainability.

E.1 Analyzing the Agents of Conversion

Analyze responses from the survey with respect to the agents of conversion by first enumerating the responses to agent-based questions. Then, group these responses by the agents identified in the responses. Next, rank groups by the number of responses that fall within any particular group. One response may fall into more than one group. Consider responders' ranking of relative importance when ranking groups. Sort the list of groups by decreasing rank and for each agent of conversion in the list, and describe its mobility. Also provide a description of the agent relative to possible drivers of conversion and any useful statistics about the agent obtained from published or unpublished sources.

The sorted list of agents forms the basis for developing project activities that mitigate conversion in order of importance. Elements of the list may identify possible covariates which could be included as numeric drivers of conversion in the baseline emissions models. These covariates must be quantifiable, such as population density data from periodic census or head of cattle in a local community.

E.2 Analyzing the Drivers of Conversion

Analyze responses from the survey with respect to the drivers of conversion by first enumerating the responses to driver-based questions. Then, group these responses by the drivers identified in the responses. Rank these groups by the numbers of responses that fall within in any particular group. One response may fall into more than one group. Consider responders' ranking of relative importance when ranking groups. Sort the list of groups by decreasing rank. Also provide any useful statistics about the driver obtained from published or unpublished sources.

The sorted list of drivers forms the basis for developing project activities that mitigate conversion in order of importance. Elements of the list may identify possible covariates which could be included as numeric drivers of conversion in the baseline emissions models.

APPENDIX F: EQUATIONS IN THE METHODOLOGY

$$\widehat{m} = \frac{365\left(C_{P\,AGMT}^{[m=0]} + C_{P\,BGMT}^{[m=0]}\right)}{t_{PL} - t_{PA}}$$	[F.1]
Variables	$C_{P\,AGMT}^{[m=0]}$, $C_{P\,BGMT}^{[m=0]}$, t_{PL}, t_{PA},
Section References	6.14
Comments	Average carbon in merchantable trees cut each year as a result of legally-sanctioned commercial logging, per hectare. $C_{P\,BGMT}^{[m=0]}$ should be set to zero if BGMT is not a selected pool.

$$BEM_{P1}(c_P, c_B, t, x) = \frac{m(t - t_{PA})}{365(1 + e^{t-t_{SA}-t_{PA}-t_{PAI}})} + \frac{A_{PAA}(c_P - c_B)e^{t-t_{SA}-t_{PA}-t_{PAI}} + \frac{HA_{P1}(c_P,c_B)t}{t_{PL}-t_{PAI}}}{(1 + e^{t-t_{SA}-t_{PA}-t_{PAI}})\left[1 + e^{\ln\left(\frac{365A_{PAA}(c_P-c_B)}{m(t_{SA}-t_{PAI})}-1\right)-\beta(t-t_{SA}-t_{PA}-t_{PAI})-\theta(x-x_{PAI}-x_{SA})^T}\right]} - HA_{P1}(c_P, c_B)$$ where $$HA_{P1}(c_P, c_B) = \frac{m}{365(1 + e^{-t_{SA}-t_{PA}-t_{PAI}})} + \frac{A_{PAA}(c_P - c_B)e^{-t_{SA}-t_{PA}-t_{PAI}}}{(1 + e^{-t_{SA}-t_{PA}-t_{PAI}})\left[1 + e^{\ln\left(\frac{365A_{PAA}(c_P-c_B)}{m(t_{SA}-t_{PAI})}-1\right)+\beta(t_{SA}+t_{PA}+t_{PAI})-\theta(x_o-x_{SA}-x_{PAI})^T}\right]}$$	[F.2]
Variables	m, $c_P^{[m]}$, $c_B^{[m]}$, x_o, t, β, θ, x, t_{PA}, t_{SA}, x_{SA}, A_{PAA}, t_{PL}, t_{PAI}
Section References	6.6
Comments	BEM for Types F-P1.a and F-P1.b. For F-P1.b, the spatial algorithm should be used for C_p

$$BEM_{P2}(c_P, c_B, t, x) = \frac{(c_P - c_B)A_{PAA} + \frac{HA_{P2}(c_P, c_B)t}{t_{PL} - t_{PAI}}}{1 + e^{-\alpha - \beta(t + \gamma + 0.5q - t_{PAI}) - \theta(x - x_{PAI})^T}} - HA_{P2}(c_P, c_B) \quad \text{[F.3]}$$

where

$$HA_{P2}(c_P, c_B) = \frac{(c_P - c_B)A_{PAA}}{1 + e^{-\alpha - \beta(\gamma + 0.5q - t_{PAI}) - \theta(x_0 - x_{PAI})^T}}$$

Variables	m, $c_P^{[m]}$, $c_B^{[m]}$, t_{PA}, t, α, β, γ, q, θ, x, A_{PAA}, t_{PL}, t_{PAI}
Section References	8.1.1, 6.6
Comments	BEM for Type F-P2 and G-P2

$$BEM_{U2,3}(c_P, c_B, t, x) = \frac{A_{PAA}(c_P - c_B) + \frac{HA_{U2,3}(c_P, c_B)t}{t_{PL}}}{1 + e^{\ln\left(\frac{1}{r_U}\right) - \beta(t + 0.5q) - \theta(x)^T}} - HA_{U2,3}(c_P, c_B) \quad \text{[F.4]}$$

where

$$HA_{U2,3}(c_P, c_B) = \frac{A_{PAA}(c_P - c_B)}{1 + e^{\ln\left(\frac{1}{r_U}\right) - \beta(0.5q) - \theta(x_0)^T}}$$

Variables	$c_P^{[m]}$, $c_B^{[m]}$, x_o, t, β, θ, q, x, A_{PAA}, t_{PL}, r_U, $t_{PAI}t_{PAI}$
Section References	8.1.1, 6.6
Comments	BEM for Types F-U2, G-U2 and F-U3

$$BEM_{U1}(c_P, c_B, t, x) = \frac{A_{PAA}(c_P - c_B)}{1 + e^{-\beta(t + 0.5q - t_{PAI}) - \theta(x - x_{PAI})^T - \alpha}} \quad \text{[F.5]}$$

Variables	$c_P^{[m]}$, $c_B^{[m]}$, x_o, t, α, β, θ, q, x, A_{PAA}, t_{PL}, $t_{PAI}t_{PAI}$
Section References	8.1.1, 6.6

Comments	BEM for Type F-U1 and G-U1

$$SEM_P(c_P, c_B, t, x) = \frac{A_{PAA}(c_P - c_B)}{1 + e^{-\alpha-\beta(t+\gamma-t_{PA}-t_{PAI})-\theta(x-x_{PAI})^T}}\left[1 + \frac{t}{t_{PL} + t_{PL}e^{-\alpha-\beta(\gamma-t_{PA}-t_{PAI})-\theta(x_0-x_{PAI})^T}}\right] - \frac{A_{PAA}(c_P - c_B)}{1 + e^{-\alpha-\beta(\gamma-t_{PA}-t_{PAI})-\theta(x_0-x_{PAI})^T}} \quad [F.6]$$

Variables	$c_B^{[m]}, c_P^{[m]}, t_{PA}, \alpha, \beta, \theta, \gamma, t, x, x_o, A_{PAA}, t_{PAI}$
Section References	8.1.1, 6.6
Comments	SEM for Types F-P1.a, F-P1.b, F-P2 and G-P2 (for F-P2 and G-P2, t_{PA} = 0). For F-P1.b, C_p should be calculated using the spatial algorithm

$$SEM_{U2,3}(c_P, c_B, t, x) = \frac{A_{PAA}(c_P - c_B)}{1 + e^{\ln\left(\frac{1}{r_U}\right)-\beta(t-t_{PAI})-\theta(x-x_{PAI})^T}}\left[1 + \frac{t}{t_{PL} + t_{PL}e^{\ln\left(\frac{1}{r_U}\right)-\theta(x_0-x_{PAI})^T+\beta t_{PAI}}}\right] - \frac{A_{PAA}(c_P - c_B)}{1 + e^{\ln\left(\frac{1}{r_U}\right)-\theta(x_0-x_{PAI})^T+\beta t_{PAI}}} \quad [F.7]$$

Variables	$c_{B\,SOC}^{[m]}\ c_B^{[m]}, c_P^{[m]}, x_o, \beta, \theta, t, x, A_{PAA}, r_U, t_{PAI}$
Section References	8.1.1, 6.6
Comments	SEM for Types F-U2, G-U2 and F-U3

$$SEM_{U1}(c_P, c_B, t, x) = \frac{A_{PAA}(c_P - c_B)}{1 + e^{-\beta(t - t_{PAI}) - \theta(x - x_{PAI})^T - \alpha}}\left[1 + \frac{1}{1 + e^{-\alpha - \theta(x_0 - x_{PAI})^T - \beta t_{PAI}}}\right] - \frac{A_{PAA}(c_P - c_B)}{1 + e^{-\alpha - \theta(x_0 - x_{PAI})^T - \beta t_{PAI}}}$$ [F.8]	
Variables	$c_B^{[m]}$, $c_P^{[m]}$, x_o, β, θ, t, x, A_{PAA} α, t_{PAI}
Section References	
Comments	SEM for Type F-U1 and G-U1

$$DEM_{SOC}\left(E_{B\,\Delta}^{[m]}, t, t^{[m-1]}\right) = E_{B\,\Delta}^{[m]} - \frac{365 E_{B\,\Delta}^{[m]}}{\lambda_{SOC}(t - t^{[m-1]})}\left[\frac{\lambda_{SOC}\left(t - t^{[m-1]}\right)}{365} + e^{-\frac{-\lambda_{SOC}\left(t - t^{[m-1]}\right)}{365}} - 1\right]$$ [F.9]	
Variables	t, $t^{[m-1]}$, λ_{SOC}, $E_{B\,\Delta}^{[m]}$
Section References	6.19
Comments	DEM for SOC

$$DEM_{DW,BGB}\left(E_{B\,\Delta}^{[m]}, t, t^{[m-1]}\right) = \frac{E_{B\,\Delta}^{[m]}}{1 + e^{t - t^{[m-1]} - 3650}}\left[1 - \frac{t - t^{[m-1]}}{3650}\right]$$ [F.10]	
Variables	$E_{B\,\Delta}^{[m]}$, $t^{[m]}$, $t^{[m-1]}$, t
Section References	6.18
Comments	DEM for DW and BGB

$$o_i = \begin{cases} 1 \; if \; deforested \; at \; (t_i, x_i, y_i) \\ 0 \; if \; forested \; at \; (t_i, x_i, y_i) \end{cases}$$ [F.11]	
Variables	t_i, x_i, y_i

Section References	6.8.5
Comments	Observation of forest state at a given point in space and time.

$$\widehat{m}_{EM} \geq \frac{1}{2}\left(\frac{\hat{\sigma}_{EM}1.64}{0.01}\right)^2$$	[F.12]
Variables	$\hat{\sigma}_{EM}$
Section References	6.8.5
Comments	The minimum sample size $\widehat{m}_{EM}$ in the space of the reference area required for fitting the logistic function. Based on a normal approximation and rewritten from an approximate confidence level at 90% with threshold of +/- 1% of the estimated mean. +/- 15% of the mean cannot be used as the threshold because of problems associated with peak variance. The ½ factor assumes at least double-coverage to get the sample size in the reference area. $\widehat{m}_{EM}$ has an upper bound of 4802, the maximum sample size. (Lohr, 2009) Constant 1.64 is the Z value at the 90% confidence level. Constant of 0.01 is the level of precision.

$$\hat{\sigma}_{EM} = \sqrt{\left[\sum_{i \in \mathcal{I}} w_i o_i\right]\left[1 - \sum_{i \in \mathcal{I}} w_i o_i\right]}$$	[F.13]
Variables	o_i, w_i, $\mathcal{I}$
Section References	6.8.5
Comments	Standard deviation of observed conversion derived from an estimate of variance for a Bernoulli random variable (Lohr, 2009).

$$U_{EM}^{[M]} = \frac{E_{B\,\Delta}^{[m]}\hat{\sigma}_{EM}}{\sqrt{n_d}}$$	[F.14]
Variables	$E_{B\,\Delta}^{[m]}$, n_d, $\hat{\sigma}_{EM}$
Section References	6.8.10

Comments	An approximate estimate of uncertainty for the logistic function of conversion, assuming a normal approximation (Lohr, 2009). Uncertainty in emissions models based on sample statistics for conversion parameters.

$$E_{B\,\Delta}^{[m]} = E_{B}^{[m]} - E_{B}^{[m-1]}$$ [F.15]	
Variables	$E_{B}^{[m]}$, $E_{B}^{[m-1]}$
Section References	8.1
Comments	baseline emissions for the current monitoring period

$$E_{B}^{[m]} = E_{B\,BM}^{[m]} + E_{B\,SOC}^{[m]} - C_{B\,SOC}^{[m]} - C_{B\,BGB}^{[m]} - C_{B\,DW}^{[m]} - C_{B\,WP}^{[m]}$$ [F.16]	
Variables	$E_{B\,BM}^{[m]}$, $\mathrm{E}_{\mathrm{B\,SOC}}^{[\mathrm{m}]}$, $\mathrm{C}_{\mathrm{B\,SOC}}^{[\mathrm{m}]}$, $C_{B\,BGB}^{[m]}$, $C_{B\,DW}^{[m]}$, $C_{B\,WP}^{[m]}$
Section References	8.1
Comments	cumulative baseline emissions

$$c_{P\,BM}^{[m]} = \sum_{b \in \mathcal{B}} c_{P\,b}^{[m]}$$ [F.17]	
Variables	$\mathrm{c}_{\mathrm{P\,b}}^{[\mathrm{m}]}$, B
Section References	8.1.1
Comments	Project scenario average carbon stock in selected carbon pools from AGMT, AGOT, AGNT, BGMT, BGOT and BGNT

$$c_{B\,BM}^{[m]} = \sum_{b \in \mathcal{B}} c_{B\,b}^{[m]}$$	[F.18]
Variables	$c_{B\,b}^{[m]}$, B
Section References	8.1.1
Comments	Baseline scenario average carbon stock in selected carbon pools from AGMT, AGOT, AGNT, BGMT, BGOT and BGNT

$$E_{B\,BM}^{[m]} = BEM_{P1}\left(c_{P\,BM}^{[m=0]}, c_{B\,BM}^{[m]}, t^{[m]}, x^{[m]}\right)$$	[F.19]
Variables	$c_{B\,BM}^{[m]}$, $t^{[m]}$, $c_{P\,BM}^{[m=0]}$, $x^{[m]}$
Section References	8.1.1, 8.1.1.1, A.1.2
Comments	cumulative baseline emissions from biomass, F-P1.a and F-P1.b

$$E_{B\,BM}^{[m]} = BEM_{P2}\left(c_{P\,BM}^{[m=0]}, c_{B\,BM}^{[m]}, t^{[m]}, x^{[m]}\right)$$	[F.20]
Variables	$c_{P\,BM}^{[m=0]}$, $c_{B\,BM}^{[m]}$, $t^{[m]}$, $x^{[m]}$
Section References	8.1.1, 8.1.1.2
Comments	cumulative baseline emissions from biomass, F-P2 and G-P2

$$E_{B\,BM}^{[m]} = BEM_{U2,3}\left(c_{P\,BM}^{[m=0]}, c_{B\,BM}^{[m]}, t^{[m]}, x^{[m]}\right)$$	[F.21]
Variables	$c_{P\,BM}^{[m=0]}$, $c_{B\,BM}^{[m]}$, $t^{[m]}$, $x^{[m]}$
Section References	8.1.1.4
Comments	cumulative baseline emissions from biomass, F-U2, G-U2 and F-U3

$$E_{B\ BM}^{[m]} = BEM_{U1}\left(c_{P\ BM}^{[m=0]}, c_{B\ BM}^{[m]}, t^{[m]}, x^{[m]}\right)$$ [F.22]	
Variables	$\boldsymbol{c_{P\ BM}^{[m=0]}}$, $c_{B\ BM}^{[m]}$, $t^{[m]}$, x
Section References	8.1.1.3
Comments	cumulative baseline emissions from biomass, F-U1 and G-U1

$$c_{P\ s\ BM}^{[m]} = \sum_{b \in \mathcal{B}} c_{P\ s\ b}^{[m]}$$ [F.23]	
Variables	$c_{P\ s\ b}^{[m]}$, B
Section References	8.1.1.5.1
Comments	average carbon in biomass for each stratum s

$$E_{B\ BM}^{[m]} = BEM_{SP}\left(c_{P\ 1\ BM}^{[m=0]}, c_{B\ BM}^{[m]}, t^{[m]}, x^{[m]}\right) = BEM_{U2,3/P1}(c_{P\ 1\ BM}^{[m=0]}, c_{B\ BM}^{[m]}, t^{[m]}, x^{[m]})$$ [F.24] when $E_{B\ BM}^{[m]} \geq A_{P\ 1}^{[m=0]}\left(c_{P\ 1\ BM}^{[m=0]} - c_{B\ BM}^{[m]}\right)$ then $E_{B\ BM}^{[m]} = BEM_{U2,3}(wc_{P\ 1,2\ BM}^{[m=0]}, c_{B\ BM}^{[m]}, t^{[m]}, x^{[m]})$ when $E_{B\ BM}^{[m]} \geq A_{P\ 1}^{[m=0]} c_{P\ 1\ BM}^{[m=0]} + A_{P\ 2}^{[m=0]} c_{P\ 2\ BM}^{[m=0]} - c_{B\ BM}^{[m]}\left(A_{P\ 1}^{[m=0]} + A_{P\ 2}^{[m=0]}\right)$ then $E_{B\ BM}^{[m]} = BEM_{U2,3/P1}(wc_{P\ 1,2,3\ BM}^{[m=0]}, c_{B\ BM}^{[m]}, t^{[m]}, x^{[m]})$ … $$E_{B\ BM}^{[m]} = A_{P\ 1}^{[m=0]} c_{P\ 1\ BM}^{[m=0]} + A_{P\ 2}^{[m=0]} wc_{P\ 1,2\ BM}^{[m=0]} + \cdots + A_{P\ n}^{[m=0]} wc_{P\ i,n\ BM}^{[m=0]} - c_{B\ BM}^{[m]}\left(A_{P\ 1}^{[m=0]} + A_{P\ 2}^{[m=0]} + \cdots + A_{P\ n}^{[m=0]}\right)$$	
Variables	$c_{P\ 1\ BM}^{[m=0]}$, $c_{B\ b}^{[m]}$, $t^{[m]}$, $A_{P\ 1}^{[m=0]}$, $A_{P\ 2}^{[m=0]} c_{P\ 3\ BM}^{[m=0]}$, $A_{P\ n}^{[m=0]}$, $c_{P\ n\ BM}^{[m=0]}$, $c_{B\ BM}^{[m]}$, $x^{[m]}$
Section References	8.1.1.5.1
Comments	Cumulative emissions for each selected carbon pool in biomass (spatial algorithm) used in Types F-P1.b and F-U3.

$$E_{B\ SOC}^{[m]} = SEM_P\left(c_{P\ SOC}^{[m=0]} c_{B\ SOC}^{[m]}, t^{[m]}, x^{[m]}\right)$$ [F.25]	
Variables	$c_{P\ SOC}^{[m=0]}$,$t^{[m]}$, $c_{B\ SOC}^{[m]}$, $t^{[m]}$, $x^{[m]}$
Section References	8.1.2.1
Comments	cumulative baseline emissions from SOC, Types F-P1.a, F-P2, and G-P2

$$E_{B\ \Delta\ SOC}^{[m]} = E_{B\ SOC}^{[m]} - E_{B\ SOC}^{[m-1]}$$ [F.26]	
Variables	$E_{B\ SOC}^{[m]}$ $E_{B\ SOC}^{[m-1]}$, $E_{B\ \Delta\ SOC}^{[m]}$
Section References	8.1.2.1, 8.1.2.2, 8.1.2.3
Comments	current baseline emissions from SOC, Types F-P1.a, F-P2, and G-P2

$$E_{B\ SOC}^{[m]} = SEM_{U1}\left(c_{P\ SOC}^{[m=0]} c_{B\ SOC}^{[m]}, t^{[m]}, x^{[m]}\right)$$ [F.27]	
Variables	$c_{P\ SOC}^{[m=0]}$ $c_{B\ SOC}^{[m]}$, $t^{[m]}$, $x^{[m]}$
Section References	8.1.2.2
Comments	cumulative baseline *emissions* from SOC, Types F-U1 and G-U1

$$E_{B\ SOC}^{[m]} = SEM_{U2,3}\left(c_{P\ SOC}^{[m=0]} c_{B\ SOC}^{[m]}, t^{[m]}, x^{[m]}\right)$$ [F.28]	
Variables	$c_{P\ SOC}^{[m=0]}$, $c_{B\ SOC}^{[m]}$, $t^{[m]}$, $x^{[m]}$
Section References	8.1.2.3

Comments	cumulative baseline emissions from SOC, Type F-U2 and G-U2

$$E_{B\ SOC}^{[m]} = SEM_{sp}\left(c_{P1\ SOC}^{[m=0]} c_{B\ SOC}^{[m]}, t^{[m]}, x^{[m]}\right) = SEM_{U2,3/P1}(c_{P1\ SOC}^{[m=0]}, c_{B\ SOC}^{[m]}, t^{[m]}, x^{[m]})$$ [F.29] when $E_{B\ SOC}^{[m]} \geq A_{P\ 1}^{[m=0]}\left(c_{P\ 1\ SOC}^{[m=0]} - c_{B\ SOC}^{[m]}\right)$ then $E_{B\ SOC}^{[m]} = SEM_{U2,3/P1}(wc_{P\ 1,2\ SOC}^{[m=0]}, c_{B\ SOC}^{[m]}, t^{[m]}, x^{[m]})$ when $E_{B\ SOC}^{[m]} \geq A_{P\ 1}^{[m=0]} c_{P\ 1\ SOC}^{[m=0]} + A_{P\ 2}^{[m=0]} c_{P\ 2\ SOC}^{[m=0]} - c_{B\ SOC}^{[m]}\left(A_{P\ 1}^{[m=0]} + A_{P\ 2}^{[m=0]}\right)$ then $E_{B\ SOC}^{[m]} = SEM_{U2,3/P1}(wc_{P\ 1,2,3\ SOC}^{[m=0]}, c_{B\ SOC}^{[m]}, t^{[m]}, x^{[m]})$ ... $$E_{B\ SOC}^{[m]} = A_{P\ 1}^{[m=0]} c_{P\ 1\ SOC}^{[m=0]} + A_{P\ 2}^{[m=0]} wc_{P\ 1,2\ SOC}^{[m=0]} + \cdots + A_{P\ n}^{[m=0]} wc_{P\ i,n\ SOC}^{[m=0]} - c_{B\ SOC}^{[m]}\left(A_{P\ 1}^{[m=0]} + A_{P\ 2}^{[m=0]} + \cdots + A_{P\ n}^{[m=0]}\right)$$	
Variables	$c_{P\ 1\ BM}^{[m=0]}, c_{B\ b}^{[m]}, t^{[m]}, A_{P\ 1}^{[m=0]}, A_{P\ 2}^{[m=0]} c_{P\ 3\ BM}^{[m=0]}, A_{P\ n}^{[m=0]}, c_{P\ n\ BM}^{[m=0]}, c_{B\ BM}^{[m]}, x^{[m]}$
Section References	8.1.2.4.1
Comments	Cumulative emissions for each selected carbon pool in SOC (spatial algorithm) used in Type F-P1.b, F-U3.

$$E_{B\ BGB}^{[m]} = \frac{r_{RS} E_{B\ BM}^{[m]}}{1 + r_{RS}}$$ [F.30]	
Variables	$r_{RS}, E_{B\ BM}^{[m]}$
Section References	8.1.4
Comments	cumulative emissions from BGB

$$E_{B\,\Delta\,BGB}^{[m]} = E_{B\,BGB}^{[m]} - E_{B\,BGB}^{[m-1]}$$	[F.31]
Variables	$E_{B\,BGB}^{[m]}$, $E_{B\,BGB}^{[m-1]}$
Section References	8.1.4
Comments	current emissions from BGB

$$C_{B\,BGB}^{[m]} = \sum_{i \in \mathcal{M}} DEM_{DW,BGB}\left(E_{B\,\Delta\,BGB}^{[i]}, t, t^{[m]}, t^{[i-1]}\right)$$	[F.32]
Variables	$t^{[m]}$, $t^{[i-1]}$, $E_{B\,\Delta\,BGB}^{[i]}$, M, t
Section References	8.1.4
Comments	carbon in non-decayed BGB

$$C_{B\,SOC}^{[m]} = \sum_{i \in \mathcal{M}} DEM_{SOC}\left(E_{B\,\Delta\,SOC}^{[i]}, t^{[m]}, t^{[i-1]}\right)$$	[F.33]
Variables	$t^{[m]}$, $t^{[i-1]}$,$E_{B\,\Delta\,SOC}^{[i]}$,$E_{B\,\Delta\,SOC}^{[m]}$, M
Section References	8.1.5
Comments	Cumulative carbon not decayed in SOC

$$E_{B\,DW}^{[m]} = p_{SL}^{[m]} E_{B\,AGMT}^{[m]}$$	[F.34]
Variables	$p_{SL}^{[m]}$, $E_{B\,AGMT}^{[m]}$
Section References	8.1.3
Comments	Cumulative emissions from DW

$$E^{[m]}_{B\,\Delta\,DW} = E^{[m]}_{B\,DW} - E^{[m-1]}_{B\,DW}$$ [F.35]	
Variables	$\mathrm{E}^{[m]}_{\mathrm{B\,DW}}$, $\mathrm{E}^{[m\text{-}1]}_{\mathrm{B\,DW}}$
Section References	8.1.3
Comments	Current emissions from DW

$$C^{[m]}_{B\,DW} = \sum_{i \in \mathcal{M}} DEM_{DW,BGB}\left(E^{[i]}_{B\,\Delta\,DW}, t, t^{[m]}, t^{[i-1]}\right)$$ [F.36]	
Variables	$\mathrm{E}^{[i]}_{\mathrm{B\,\Delta\,DW}}\mathrm{E}^{[m\text{-}1]}_{\mathrm{B\,DW}}$, $\mathrm{t}^{[m]}$, $\mathrm{t}^{[i\text{-}1]}$, t
Section References	8.1.3
Comments	cumulative carbon not decayed in DW

$$E^{[m]}_{B\,AGMT} = BEM_{P1}\left(c^{[m=0]}_{P\,AGMT} + c^{[m=0]}_{P\,BGMT}, c^{[m]}_{B\,AGMT} + c^{[m]}_{B\,BGMT}, t^{[m]}, x^{[m]}\right)\left(1 - \frac{r_{RS}}{1 + r_{RS}}\right)$$ [F.37]	
Variables	$\mathrm{c}^{[m=0]}_{\mathrm{P\,AGMT}}$, $\mathrm{C}^{[m=0]}_{\mathrm{P\,BGMT}}$, $\mathrm{c}^{[m]}_{\mathrm{B\,AGMT}}$, $\mathrm{C}^{[m]}_{\mathrm{B\,BGMT}}$, $\mathrm{t}^{[m]}$, $\mathrm{x}^{[m]}$, r_{RS}
Section References	8.1.6.1
Comments	cumulative emissions from AGMT, Type F-P1.a and F-P1.b

$$E^{[m]}_{B\,AGMT} = BEM_{P2}\left(c^{[m=0]}_{P\,AGMT} + c^{[m=0]}_{P\,BGMT}, c^{[m]}_{B\,AGMT} + c^{[m]}_{B\,BGMT}, t^{[m]}, x^{[m]}\right)\left(1 - \frac{r_{RS}}{1 + r_{RS}}\right)$$ [F.38]	
Variables	$\mathrm{c}^{[m=0]}_{\mathrm{P\,AGMT}}$, $\mathrm{C}^{[m=0]}_{\mathrm{P\,BGMT}}$, $\mathrm{c}^{[m]}_{\mathrm{B\,AGMT}}$, $\mathrm{C}^{[m]}_{\mathrm{B\,BGMT}}$, $\mathrm{t}^{[m]}$, $\mathrm{x}^{[m]}$, r_{RS}
Section References	8.1.6.2
Comments	cumulative emissions from AGMT, Type F-P2 and G-P2

$$E_{B\ AGMT}^{[m]} = BEM_{U1}\left(c_{P\ AGMT}^{[m=0]} + c_{P\ BGMT}^{[m=0]}, c_{B\ AGMT}^{[m]} + c_{B\ BGMT}^{[m]}, t^{[m]}, x^{[m]}\right)\left(1 - \frac{r_{RS}}{1 + r_{RS}}\right)$$ [F.39]	
Variables	$c_{P\ AGMT}^{[m=0]}$, $C_{P\ BGMT}^{[m=0]}$, $c_{B\ AGMT}^{[m]}$, $C_{B\ BGMT}^{[m]}$, $t^{[m]}$, $x^{[m]}$, r_{RS}
Section References	8.1.6.3
Comments	cumulative emissions from AGMT, Types F-U1 and G-U1

$$E_{B\ AGMT}^{[m]} = BEM_{U2,3}\left(c_{P\ AGMT}^{[m=0]} + c_{P\ BGMT}^{[m=0]}, c_{B\ AGMT}^{[m]} + c_{B\ BGMT}^{[m]}, t^{[m]}, x^{[m]}\right)\left(1 - \frac{r_{RS}}{1 + r_{RS}}\right)$$ [F.40]	
Variables	$c_{P\ AGMT}^{[m=0]}$, $C_{P\ BGMT}^{[m=0]}$, $c_{B\ AGMT}^{[m]}$, $C_{B\ BGMT}^{[m]}$, $t^{[m]}$, $x^{[m]}$, r_{RS}
Section References	8.1.6.3
Comments	cumulative emissions from AGMT, Type F-U2 , G-U2 and F-U3

$$E_{P\ \Delta}^{[m]} = E_{P\ \Delta\ BRN}^{[m]} + E_{P\ \Delta\ LS}^{[m]} + E_{P\ \Delta\ SF}^{[m]} + A_{PAA}\left(c_P^{[m-1]} - c_P^{[m]}\right) - C_{P\ \Delta\ WP}^{[m]}$$ [F.41]	
Variables	A_{PAA}, $E_{P\ \Delta BRN}^{[m]}$, $E_{P\ \Delta\ LS}^{[m]}$,$E_{P\ \Delta\ SF}^{[m]}$, $C_{P\ \Delta\ WP}^{[m]}$, $c_P^{[m-1]}$, $c_P^{[m]}$
Section References	8.2
Comments	project emissions

$$E_{P\ \Delta\ BRN}^{[m]} = \left(\frac{44}{12}\right) 0.66 \sum_{b \in \mathcal{W}^{[m]}} r_{CF\ b}\ B_{b^{[m]}}$$ [F.42]	
Variables	$r_{CF\ b}$, $W^{[m]}$, $B_b^{[m]}$
Section References	8.2.2

Comments	Project Emissions from Burning (1-0.33=0.66) account for the proportion of mass burned assumed to be water (Simpson & Sagoe, 1991) 44/12 is the ratio of the mass of carbon dioxide to the mass of carbon used to convert to CO2e units

$$E_{P\,\Delta\,LS}^{[m]} = \sum_{i \in T} \left(\frac{f_{LS\,i} n_{LS\,i}}{10^3} \right) \times 21$$ [F.43]	
Variables	$E_{P\,\Delta\,LS}^{[m]}$, $f_{LS\,i}$, $n_{LS\,i}$, T
Section References	8.2.4
Comments	Project Emissions from Livestock Grazing 21 = conversion from tCH4 to tCO2e

$$E_{L\,\Delta}^{[m]} = E_{L}^{[m]} - E_{L}^{[m-1]}$$ [F.44]	
Variables	$E_{L}^{[m]}$, $E_{L}^{[m-1]}$
Section References	8.3
Comments	Total emissions from leakage for the current monitoring period. $E_{L\,\Delta}^{[m]}$ cannot be less than zero.

$$E_{L}^{[m]} = E_{L\,ASF}^{[m]} + E_{L\,ASG}^{[m]} + E_{L\,ME}^{[m]}$$ [F.45]	
Variables	$E_{L\,ASF}^{[m]}$, $E_{L\,ME}^{[m]}$, $E_{L\,ASG}^{[m]}$
Section References	8.3
Comments	cumulative emissions from leakage

$$E_{L\ ASF}^{[m]} = LEM\left(c_P^{[m]}, c_B^{[m]}, p_{L\ DEG}^{[m]}, t^{[m]}, x^{[m]}\right)$$	[F.46]
Variables	$t^{[m]}$, $c_B^{[m]}$, $c_P^{[m]}$, $p_{L\ DEG}^{[m]}$, $x^{[m]}$
Section References	8.3.2
Comments	Cumulative emissions from activity-shifting leakage in forested areas

$$E_{L\ ASG}^{[m]} = LEM\left(c_P^{[m]}, c_B^{[m]}, p_{L\ CON\ G}^{[m]}, t^{[m]}, x^{[m]}\right)$$	[F.47]
Variables	$t^{[m]}$, $c_B^{[m]}$, $c_P^{[m]}$, $p_{L\ DEG}^{[m]}$, $x^{[m]}$
Section References	8.3.2
Comments	Cumulative emissions from activity-shifting leakage in grassland project accounting areas

$$LEM_F(c_P, c_B, p_{L\ DEG}, t, x) = p_{L\ DEG}^{[m]} A_{AS}(c_P - c_B) - \frac{A_{AS}(c_P - c_B)}{1 + e^{\ln\left(\frac{1}{p_{L\ DEG}^{[m=0]}} - 1\right) - \beta t - \theta (x_0 - x)^T}}$$	[F.48]
Variables	β, θ, t, x, x_o, $c_B^{[m]}$, $c_P^{[m]}$, $p_{L\ DEG}^{[m]}$, $p_{L\ DEG}^{[m=0]}$
Section References	8.3.2.2
Comments	Leakage Emissions Model for activity shifting leakage in forested project accounting areas

$$LEM_G(c_P, c_B, p_{L\ DEG}, t, x) = p_{L\ CON\ G}^{[m]} A_{AS}(c_P - c_B) - \frac{A_{AS}(c_P - c_B)}{1 + e^{\ln\left(\frac{1}{p_{L\ CON\ G}^{[m=0]}} - 1\right) - \beta t - \theta (x_0 - x)^T}}$$	[F.49]
Variables	β, θ, t, x, x_o, $c_B^{[m]}$, $c_P^{[m]}$, $p_{L\ DEG}^{[m]}$, $p_{L\ DEG}^{[m=0]}$

Section References	8.3.2.2
Comments	Leakage Emissions Model for activity shifting leakage in grassland project accounting areas

$$c_{L\,BM} = \sum_{p \in \mathcal{B}} c_{L\,p}$$	[F.50]
Variables	$c_{L\,p}$, B
Section References	8.3.3.3
Comments	Used to determine the discount factor in Table 7

$$E_{L\,ME}^{[m]} = p_{L\,ME} E_{B\,AGMT}^{[m]}$$	[F.51]
Variables	$p_{L\,ME}$, $E_{B\,AGMT}^{[m]}$
Section References	8.3.3.3, 8.1.6
Comments	Cumulative emissions from market leakage of wood products under the discount approach

$$A_{B\,\Delta\,PAA}^{[m]} = \frac{E_{B\,BM}^{[m]}}{c_{P\,BM}^{[m]} - c_{B\,BM}^{[m]}} - \frac{E_{B\,BM}^{[m-1]}}{c_{P\,BM}^{[m-1]} - c_{B\,BM}^{[m-1]}}$$	[F.52]
Variables	$c_{P\,BM}^{[m]}$, $c_{B\,BM}^{[m]}$, $E_{B\,BM}^{[m]}$, $A_{B\,\Delta\,PAA}^{[m]}$, A_{PAA}
Section References	8.3.3.4, 8.3.3

Comments	"Area of avoided conversion" under the production approach. For the first monitoring period, the term $\frac{E_{B\,BM}^{[m-1]}}{c_{P\,BM}^{[m-1]}-c_{B\,BM}^{[m-1]}} = 0$. This equation conservatively over estimates baseline conversion in the project accounting area because $E_{B\,BM}^{[m]}$ may include emissions from degradation.

$$E_{\Delta\,GER}^{[m]} = E_{\mathrm{B}\,\Delta}^{[m]} - E_{\mathrm{P}\,\Delta}^{[m]} - E_{\mathrm{L}\,\Delta}^{[m]} - E_{U}^{[m]}$$	[F.53]
Variables	$\mathrm{E}_{\mathrm{B}\,\Delta}^{[\mathrm{m}]}$, $\mathrm{E}_{\mathrm{P}\,\Delta}^{[\mathrm{m}]}$, $\mathrm{E}_{\mathrm{L}\,\Delta}^{[\mathrm{m}]}$, $E_{U}^{[m]}$
Section References	8.4.1, 8.4.1.2, 8.4.2, 8.4.2.1
Comments	GERs for the current monitoring period

$$E_{GER}^{[m]} = \sum_{i \in \mathcal{M}} E_{\Delta\,GER}^{[i]}$$	[F.54]
Variables	M, $\mathrm{E}_{\Delta\,\mathrm{GER}}^{[\mathrm{m}]}$
Section References	8.4.2.1
Comments	Cumulative GERs to-date

$$E_{\Delta\,NER}^{[m]} = E_{\Delta\,GER}^{[m]} - E_{BA}^{[m]}$$	[F.55]
Variables	$\mathrm{E}_{\Delta\,\mathrm{GER}}^{[\mathrm{m}]}$, $E_{\Delta\,NER}^{[m]}$, $\mathrm{E}_{\mathrm{BA}}^{[\mathrm{m}]}$
Section References	8.4.3, 8.4.7
Comments	NERs for the current monitoring period

$$E_{NER}^{[m]} = \sum_{i \in \mathcal{M}} E_{\Delta\,NER}^{[i]}$$ [F.56]	
Variables	$\mathcal{M}$, $E_{\Delta\,NER}^{[i]}$
Section References	8.4.7
Comments	Cumulative NERs to-date

$$E_{U}^{[m]} = E_{B\,\Delta}^{[m]} \left[\frac{1.64}{E_{B\,\Delta}^{[m]} + A_{PAA} c_{P}^{[m]} + A_{PX} c_{B}^{[m]}} \sqrt{\left(U_{EM}^{[M]}\right)^2 + \left(U_{P}^{[m]}\right)^2 + \left(U_{B}^{[m]}\right)^2} - 0.15 \right]$$ [F.57]	
Variables	$c_{P}^{[m]}$, $c_{B}^{[m]}$, $E_{B\,\Delta}^{[m]}$, $U_{EM}^{[M]}$, $U_{B}^{[m]}$, $U_{P}^{[m]}$, A_{PX}, A_{PAA}, $E_{U}^{[m]}$, $E_{B\,\Delta}^{[m]}$
Section References	8.4.1.1
Comments	Confidence deduction based on uncertainty in emissions models, carbon stock estimates in the project accounting area and carbon stock estimates in the proxy area. $E_{U}^{[m]}$ must be greater than zero; otherwise $E_{U}^{[m]} = 0$. Constant 1.64 is the Z value at the 90% confidence level.

APPENDIX G: VALIDATION VARIABLES

Data / Parameter	Unit	Description	Source of Data	Used in Equations	Justification	Comment
$\boldsymbol{\alpha}$	unitless	Combined effects of β and θ at the start of the historic reference period	Reference area and historic reference period	[F.3], [F.5], [F.6], [F.8]	Time and place in which the logistic model is fit	
$\boldsymbol{\beta}$	unitless	Effect of time on the cumulative proportion of conversion over time	Reference area and historic reference period	[F.2], [F.3], [F.4], [F.5], [F.6], [F.7], [F.8],	Time and place in which the logistic model is fit	
$\boldsymbol{\gamma}$	days	Time shift from beginning of historic reference period to project start date	Historic reference period	[F.3], [F.6]	Time in which the logistic model is fit	
$\boldsymbol{\theta}$	unitless	Effect of certain covariates on the cumulative proportion of conversion over time	Reference area and historic reference period	[F.2], [F.3], [F.4], [F.5], [F.6], [F.7], [F.8]	Time and place in which the logistic model is fit	
$\boldsymbol{\lambda_{SOC}}$	proportion (unitless)	Exponential soil carbon decay parameter	Default values, literature estimates or empirical estimation based on reference area sampling	[F.9], [F.33]	A conservative default or values derived from direct measurement by the project proponent or from the literature are acceptable	
$\boldsymbol{\hat{\sigma}_{EM}}$	standard deviation (unitless)	The estimated standard deviation of the state observations used to fit the logistic function	Remote sensing image interpretation	[F.12], [F.14], [B.31]	-	
$\boldsymbol{\mathcal{B}}$	set	The set of all selected carbon pools in biomass. Is a subset of $\mathcal{C}$	PDD	[F.17], [F.18], [F.23], [F.50]	-	

Data / Parameter	Unit	Description	Source of Data	Used in Equations	Justification	Comment
$\mathcal{C}$	set	The set of all selected carbon pools	Monitoring records		-	
$\mathcal{I}$	set	The set of all observations of conversion. When superscripted with a monitoring period, the conversion observations are taken for leakage analysis.	Remote sensing image interpretation or field observations in the leakage area.	[F.13]	-	
$\mathcal{M}$	set	The set of all monitoring periods	Monitoring records	[F.32], [F.33], [F.36], [F.54], [F.56]	-	
$\mathcal{T}$	set	The set of all species/categories of livestock	Monitoring records	[F.43]	-	
A_{PAA}	ha	Area of project accounting area	GIS analysis prior to sampling	[F.2], [F.3], [F.4], [F.5], [F.6], [F.7], [F.8], [F.41], [F.52], [F.57],	-	
A_{PX}	ha	Area of proxy area	GIS analysis prior to sampling	[F.57]	-	
$c_{L\,p}$	tCO2e/ha	Carbon stocks in project leakage area	Leakage area sampling	[F.50]	Direct measurement	
$f_{LS\,i}$	kg CH_4 head^{-1} yr^{-1}	Emission factor for the defined livestock population, i	IPCC default values	[F.43]	Obtained directly from IPCC default values	

Data / Parameter	Unit	Description	Source of Data	Used in Equations	Justification	Comment
$\boldsymbol{m}$	tCO2e/yr	Average carbon in merchantable trees cut each year as a result of legally-sanctioned commercial logging	Timber harvest plans or measurement of carbon stocks in merchantable trees in the *project accounting area*	[F.2]	Should use the most accurate of the two data sources if both are available	
$\boldsymbol{n_d}$		Number of spatial points in the reference area	Remote sensing image interpretation	[F.14]	-	
$\boldsymbol{o_i}$	binary	State observation for the i^{th} sample point in the reference area	Remote sensing image interpretation	[F.13]	-	
$\boldsymbol{p_{L\,ME}}$	unitless	Portion of leakage related to market	8.3.3	[F.51]	-	
$\boldsymbol{q}$	days	Lag between start of degradation and conversion	Expert knowledge, results from the PRA or reports from peer-reviewed literature	[F.3], [F.4], [F.5],	Commonly accepted methods in the social sciences, choice determined and justified by project proponent	
$\boldsymbol{r_{CF\,b}}$	unitless	Carbon fraction of biomass for burned wood or herbaceous material b	Literature estimates or direct measurement	[F.42]	-	
$\boldsymbol{r_{RS}}$	unitless	Expansion factor for above-ground biomass to below-ground biomass (root/shoot ratio)	Reviewed literature, allometry, or IPCC default values	[F.30]	-	
$\boldsymbol{r_U}$	unitless	Onset proportion of conversion immediately adjacent to project area	GIS analysis and image interpretation	[F.4]	Positions the baseline emissions models relative to the instantaneous rate of conversion	

Data / Parameter	Unit	Description	Source of Data	Used in Equations	Justification	Comment
t	days	Time since project start date	Monitoring records	[F.2], [F.3], [F.4], [F.5], [F.6], [F.7], [F.8],[F.10],	-	
t_i	days	The point in time of the observation made at point i	Remote sensing image interpretation	[F.11], [A.6]	-	
t_{PA}	days	Time prior to the project start date when the primary agent began commercial logging in the *project accounting area*	Harvest plans prepared for the *project accounting area*, or by public record	[F.1], [F.2], [F.3], [F.6]	Should use the most accurate of the two data sources if both are available	
t_m	days	Length of project or logging in baseline scenario	PD	[F.1]		
t_{PL}	days	Length of project crediting period	PD	[F.5]		
t_{PAI}	days	Number of days after the project start date for the start of a project activity instance in a grouped project	PD	[F.2], [F.3], [F.4], [F.5], [F.6], [F.7], [F.8]		
t_{SA}	days	Arrival time of secondary agents after start of commercial logging	Participatory rural appraisal, or expert knowledge	[F.2]	Should use the most accurate of the two data sources if both are available	
w_i	unitless	weight applied to the i^{th} sample point in the reference area	Remote sensing image interpretation	[A.6], [F.13]		

Data / Parameter	Unit	Description	Source of Data	Used in Equations	Justification	Comment
$\boldsymbol{x}$	unitless	Covariate values	Participatory Rural Appraisal, analysis of public records, and/or expert interpretation of inventory data or remotely sensed imagery	[F.2], [F.3], [F.4], [F.5], [F.6], [F.7], [F.8],	Should use the most accurate of the data sources if both are available	
$\boldsymbol{x_i}$	geographic coordinates	Latitude of the i^{th} sample point	Remote sensing image interpretation	[F.11], [A.6]	-	
$\boldsymbol{x_o}$	unitless	Covariate values as of the project start date	Participatory Rural Appraisal, analysis of public records, and/or expert interpretation of inventory data or remotely sensed imagery	[F.4], [F.5], [F.6], [F.7], [F.8],	Should use the most accurate of the data sources if both are available	
$\boldsymbol{x_{SA}}$	unitless	Covariate values as of the arrival of the secondary agents	Participatory Rural Appraisal, analysis of public records, and/or expert interpretation of inventory data or remotely sensed imagery	[F.2]	Should use the most accurate of the data sources if both are available	
$\boldsymbol{y_i}$	geographic coordinates	Longitude of the i^{th} sample point	Remote sensing image interpretation	[F.11], [A.6]	-	

APPENDIX H: MONITORING VARIABLES

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC	Comment
$\mathcal{W}^{[m]}$	set	The set of all burned wood or herbaceous material	Monitoring records	N/A	[F.42]	Every monitoring period	Review of monitoring records	
$A_{B\,\Delta\,PAA}^{[m]}$	ha	Area of avoided conversion	Generated from equation	8.3.3.4	[F.52]	Every monitoring period	Review of monitoring records	
$A_{P\,1}^{[m=0]}$	ha	Area of project accounting area stratum 1 prior to first verification event	GIS analysis prior to sampling	GIS analysis of best available data B.1.1	[F.24]	First monitoring period	Cross-check of GIS analysis	
$A_{P\,2}^{[m=0]}$	ha	Area of project accounting area stratum 2 prior to first verification event	GIS analysis prior to sampling	GIS analysis of best available data B.1.1	[F.24]	First monitoring period	Cross-check of GIS analysis	
$A_{P\,n}^{[m=0]}$	ha	Area of project accounting area stratum n prior to first verification event	GIS analysis prior to sampling	GIS analysis of best available data B.1.1	[F.24]	First monitoring period	Cross-check of GIS analysis	
$B_{b}^{[m]}$	tonnes	Biomass in burned wood or herbaceous material b	Measurements of biomass	Scale	[F.42]	Every monitoring period	Review of monitoring records	
$c_{B}^{[m]}$	tCO2e/ha	Baseline carbon stocks at the end of the current monitoring period	Proxy area sampling	Appendix B.2,6.4	[F.2], [F.3], [F.4], [F.5], [F.6], [F.7], [F.57]	Every time measured (≤ 5 yrs)	Review of monitoring records	

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC	Comment
$C_{B\ BGB}^{[m]}$	tCO2e	Carbon not decayed in BGB at the end of the current monitoring period	Proxy area sampling	8.1.4	[F.16]	Every monitoring period	Review of monitoring records	
$C_{B\ DW}^{[m]}$	tCO2e	Carbon not decayed in DW at the end of the current monitoring period	Proxy area sampling	8.1.3	[F.16]	Every monitoring period	Review of monitoring records	
$C_{B\ SOC}^{[m]}$	tCO2e	Carbon not decayed in SOC at the end of the current monitoring period	Proxy area sampling	8.1.5	[F.16]	Every monitoring period	Review of monitoring records	
$C_{B\ WP}^{[m]}$	tCO2e	Carbon not decayed in WP at the end of the current monitoring period	Proxy area sampling	Appendix C	[F.16]	Every monitoring period	Review of monitoring records	
$c_{B\ AGMT}^{[m]}$	tCO2e/ha	Baseline carbon stocks in above-ground merchantable trees at the end of the current monitoring period	Proxy area sampling	Appendix B.2.1	[F.37], [F.38], [F.39], [F.40]	Every time measured (≤ 5 yrs)	Review of monitoring records	
$C_{B\ BGMT}^{[m]}$	tCO2e/ha	Baseline carbon stocks in below-ground merchantable trees at the end of the current monitoring period	Proxy area sampling	Appendix B.2.1	[F.37], [F.38], [F.39], [F.40]	Every time measured (≤ 5 yrs)	Review of monitoring records	

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC	Comment
$C_{P\ AGMT}^{[m=0]}$	tCO2e	Project carbon stocks in above-ground merchantable trees at project start	Project accounting area sampling	Appendix B.2.1	[F.1]	First monitoring period	Review of monitoring records	
$C_{P\ BGMT}^{[m=0]}$	tCO2e	Project carbon stocks in below-ground merchantable trees at project start	Project accounting area sampling	Appendix B.2.3	[F.1]	First monitoring period	Review of monitoring records	
$c_{B\ b}^{[m]}$	tCO2e/ha	Baseline scenario average carbon stock in selected carbon pools	Proxy area sampling	Appendix B.1.5	[F.18] [F.24]	Every time measured (≤ 5 yrs)	Review of monitoring records	
$c_{B\ BM}^{[m]}$	tCO2e/ha	Baseline carbon stocks in biomass at the end of the current monitoring period	Proxy area sampling	Appendix B.2	[F.19], [F.20], [F.21], [F.24], [F.52]	Every time measured (≤ 5 yrs)	Review of monitoring records	
$c_{B\ SOC}^{[m]}$	tCO2e/ha	Baseline soil carbon stocks at the end of the current monitoring period	Proxy area sampling	Appendix B.2.6	[F.25], [F.27], [F.28]	Every time measured (≤ 5 yrs)	Review of monitoring records	
$c_{P}^{[m]}$	tCO2e/ha	Project carbon stocks at the end of the current monitoring period	Project accounting area sampling	Appendix B.2	[F.41], [F.57]	Every time measured (≤ 5 yrs)	Review of monitoring records	
$c_{P}^{[m-1]}$	tCO2e/ha	Project carbon stocks at the beginning of the current monitoring period	Project accounting area sampling	Appendix B.2	[F.41]	Prior monitoring period	Already reviewed	

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC	Comment
$c_{P}^{[m=0]}$	tCO2e/ha	Project carbon stocks prior to first verification event	Project accounting area sampling	Appendix B.2	[F.7]	First monitoring period	Review of monitoring records	
$c_{P\ 1\ BM}^{[m=0]}$	tCO2e/ha	Project carbon stocks in biomass in stratum 1 prior to first verification event	Project accounting area sampling	Appendix B.2	[F.24]	First monitoring period	Review of monitoring records	
$c_{P\ 2\ BM}^{[m=0]}$	tCO2e/ha	Project carbon stocks in biomass in stratum 2 prior to first verification event	Project accounting area sampling	Appendix B.2	[F.24]	First monitoring period	Review of monitoring records	
$c_{P\ 3\ BM}^{[m=0]}$	tCO2e/ha	Project carbon stocks in biomass in stratum 3 prior to first verification event	Project accounting area sampling	Appendix B.2	[F.24]	First monitoring period	Review of monitoring records	
$c_{P\ n\ BM}^{[m=0]}$	tCO2e/ha	Project carbon stocks in biomass in stratum n prior to first verification event	Project accounting area sampling	Appendix B.2	[F.24]	First monitoring period	Review of monitoring records	
$c_{P\ AGMT}^{[m=0]}$	tCO2e/ha	Project carbon stocks in above-ground merchantable trees prior to first verification event	Project accounting area sampling	Appendix B.2.1	[F.37], [F.38], [F.39], [F.40]	First monitoring period	Review of monitoring records	
$c_{P\ BM}^{[m=0]}$	tCO2e	Project carbon stocks in biomass prior to first verification event	Project accounting area sampling	Appendix B.2	[F.19], [F.20], [F.21], [F.52]	First monitoring period	Review of monitoring records	

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC	Comment
$c_{P\,b}^{[m]}$	tCO2e/ha	Average carbon in biomass in the project accounting area	Project accounting area sampling	Appendix B.2	[F.17]	Every time measured (≤ 5 yrs)	Review of monitoring records	
$c_{P\,s\,b}^{[m]}$	tCO2e/ha	Average carbon in biomass for each project accounting area stratum s	Project accounting area sampling	Appendix B.2	[F.23]	Every time measured (≤ 5 yrs)	Review of monitoring records	
$c_{P\,SOC}^{[m=0]}$	tCO2e/ha	Project soil carbon stocks prior to first verification event	Project accounting area sampling	Appendix B.2.6	[F.25], [F.27], [F.28]	First monitoring period	Review of monitoring records	
$C_{P\,\Delta\,WP}^{[m]}$	tCO2e	Project carbon stocks in wood products at the end of the current monitoring period	Project accounting area sampling	Appendix C	[F.41]	Every monitoring period	Review of monitoring records	
$E_{\Delta\,GER}^{[m]}$	tCO2e	GERs for the current monitoring period	Area measurements	8.4.1	[F.55], [F.57]	Every monitoring period	Review of GER calculations	
$E_{\Delta\,GER}^{[i]}$	tCO2e	GERs for monitoring period i	Area measurements	8.4.1	[F.54]	Prior monitoring period	Review of GER calculations	
$E_{\Delta\,NER}^{[i]}$	tCO2e	NERs for monitoring period i	Area measurements	8.4.3	[F.56]	Prior monitoring period	Review of NER calculations	
$E_{B}^{[m]}$	tCO2e	Cumulative baseline emissions at the end of the current monitoring period	Proxy area measurements	8.1	[F.15]	Every monitoring period	Review of monitoring records	

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC	Comment
$E_{B}^{[m-1]}$	tCO2e	Cumulative baseline emissions at the beginning of the current monitoring period	Proxy area measurements	8.1	[F.15]	Prior monitoring period	Review of monitoring records	
$E_{B\,\Delta}^{[m]}$	tCO2e	Change in baseline emissions	Proxy area measurements	8.1	[F.9], [F.10], [F.14], [F.53], [F.57]	Every monitoring period	Review of monitoring records	
$E_{B\,\Delta\,BGB}^{[i]}$	tCO2e	Change in baseline emissions from below-ground biomass during monitoring period i	Monitoring the proxy area	Appendix B.2.3	[F.32]	Prior monitoring period	Review of monitoring records	
$E_{B\,\Delta\,DW}^{[i]}$	tCO2e	Baseline emissions from dead wood in monitoring period i	Measurements in the proxy area	Appendix B.2.4 and B.2.5	[F.36]	Prior monitoring period	Review of monitoring records	
$E_{B\,\Delta\,SOC}^{[m]}$	tCO2e	Baseline change in emissions from soil carbon	Measurements in the proxy area	8.1.2.1, 8.1.2.2, 8.1.2.3, Appendix B.2.6	[F.15],[F.33]	Every monitoring period	Review of monitoring records	
$E_{B\,\Delta\,SOC}^{[i]}$	tCO2e	Baseline emissions from soil carbon in monitoring period i	Measurements in the proxy area	8.1.2.1, 8.1.2.2, 8.1.2.3, Appendix B.2.6	[F.33]	Prior monitoring period	Review of monitoring records	

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC	Comment
$E_{B\ AGMT}^{[m]}$	tCO2e	Cumulative baseline emissions from above-ground commercial trees at the end of the current monitoring period	Measurements in the proxy area	8.1.6.1, 8.1.6.2, 8.1.6.3	[F.34], [F.51]	Every monitoring period	Review of monitoring records	
$E_{B\ BGB}^{[m]}$	tCO2e	Cumulative baseline emissions from below-ground biomass at the end of the current monitoring period	Measurements in the proxy area	8.1.4	[F.31]	Every monitoring period	Review of monitoring records	
$E_{B\ BGB}^{[m-1]}$	tCO2e	Cumulative baseline emissions from below-ground biomass at the beginning of the current monitoring period	Measurements in the proxy area	8.1.4	[F.31]	Prior monitoring period	N/A	
$E_{B\ BM}^{[m]}$	tCO2e	Cumulative baseline emissions from biomass at the end of the current monitoring period	Measurements in the proxy area	8.1.1, 8.1.1.5.1	[F.16], [F.30], [F.52]	Every monitoring period	Review of monitoring records	
$E_{B\ DW}^{[m]}$	tCO2e	Cumulative baseline emissions from dead wood at the end of the current monitoring period	Measurements in the proxy area	8.1.3	[F.35]	Every monitoring period	Review of monitoring records	

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC	Comment
$E_{B\ DW}^{[m-1]}$	tCO2e	Cumulative baseline emissions from dead wood at the beginning of the current monitoring period	Measurements in the proxy area	8.1.3	[F.35]	Prior monitoring period	N/A	
$E_{B\ SOC}^{[m]}$	tCO2e	Cumulative baseline emissions from soil carbon at the end of the current monitoring period	Measurements in the proxy area	8.1.2.1, 8.1.2.2, 8.1.2.3	[F.16], [F.26]	Every monitoring period	Review of monitoring records	
$E_{B\ SOC}^{[m-1]}$	tCO2e	Cumulative baseline emissions from soil carbon at the beginning of the current monitoring period	Measurements in the proxy area	8.1.2.1, 8.1.2.2, 8.1.2.3	[F.26]	Prior monitoring period	N/A	
$E_{BA}^{[m]}$	tCO2e	Cumulative emissions allocated to the buffer account at the end of the current monitoring period	N/A	8.4.4	[F.55]	Every monitoring period	Review of monitoring records	
$E_{L}^{[m]}$	tCO2e	Cumulative emissions from leakage at the end of the current monitoring period	Measurements in the leakage area(s)	8.3	[F.44]	Every monitoring period	Review of monitoring records	

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC	Comment
$E_{L}^{[m-1]}$	tCO2e	Cumulative emissions from leakage at the beginning of the current monitoring period	Measurements in the leakage area(s)	8.3	[F.44]	Prior monitoring period	N/A	
$E_{L\,\Delta}^{[m]}$	tCO2e	Change in emissions due to leakage	N/A	8.3	[F.53]	Every monitoring period	Review of monitoring records	
$E_{L\,ASF}^{[m]}$	tCO2e	Cumulative emissions from activity-shifting leakage in forested strata at the end of the current monitoring period	Measurements in the activity-shifting leakage area	8.3	[F.45]	Every monitoring period	Review of monitoring records	
$E_{L\,ASG}^{[m]}$	tCO2e	Cumulative emissions from activity-shifting leakage in native grassland strata at the end of the current monitoring period	Measurements in the activity-shifting leakage area	8.3.3.4	[F.44],[F.45]	Every monitoring period	Review of monitoring records	
$E_{L\,ME}^{[m]}$	tCO2e	Cumulative emissions from market leakage at the end of the current monitoring period	Measurements in the market leakage area	8.3	[F.45],	Every monitoring period	Review of monitoring records	

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC	Comment
$E_{P\,\Delta}^{[m]}$	tCO2e	Change in project emissions	Monitoring records for Forest Fire, Burning, logging, wood products, and natural disturbance events	8.2	[F.53]	Every monitoring period	Review of monitoring records	
$E_{P\,\Delta BRN}^{[m]}$	tCO2e	Cumulative project emissions due to burning at the end of the current monitoring period	Monitoring plots in the project	8.2.2	[F.41]	Every monitoring period	Review of monitoring records	
$E_{P\,\Delta\,LS}^{[m]}$	tCO2e	Cumulative project emissions due to livestock grazing within the project area.	Monitoring in the project area	8.2.4	[F.43]	Every time measured (≤ 5 yrs)	Review of monitoring records	
$E_{P\,\Delta\,SF}^{[m]}$	tCO2e	Cumulative project emissions due to the use of synthetic fertilizers within the project area.	Monitoring in the project area	8.2.5	[F.53]	Every time measured (≤ 5 yrs)	Review of monitoring records	*Estimation of direct and indirect (eg, leaching and runoff) nitrous oxide emission from nitrogen fertilization*

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC	Comment
$E_U^{[m]}$	tCO2e	Cumulative confidence deduction at the end of the current monitoring period	N/A	8.4.1.1	[F.55]	Every monitoring period	Review of monitoring records	
$n_{LS\ i}$	count	The number of head of livestock species/ category i in the project area	Monitoring in the project area	8.2.4	[F.43]	Every time measured (≤ 5 yrs)	Review of monitoring records	
$p_{L\ DEG}^{[m]}$	proportion (unitless)	Portion of leakage due to degradation in forest at the end of the current monitoring period	Monitoring in the leakage area	8.3.2.3	[F.46] [F.47] [F.48] [F.49]	Every time measured (≤ 5 yrs)	Review of monitoring records	
$p_{L\ DEG}^{[m=0]}$	proportion (unitless)	Portion of leakage due to degradation prior to first verification event	Monitoring in the leakage area	8.3.2.3	[F.48]	First monitoring period	Project verification	
$p_{L\ CON\ G}^{[m=0]}$	proportion (unitless)	Portion of leakage due to native grasslands prior to the first verification event	Monitoring in the leakage area	8.3.2.4	[F.47][F.49]	First monitoring period	Review of monitoring records	
$p_{L\ CON\ G}^{[m]}$	proportion (unitless)	Portion of leakage due to native grasslands conversion at the beginning of the current monitoring period	Monitoring in the leakage area	8.3.2.4	[F.47][F.49]	Every time measured (≤ 5 yrs)	Review of monitoring records	

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC	Comment
$p_{L\ CON\ G}^{[m-1]}$	proportion (unitless)	Portion of leakage due to native grasslands conversion at the end of the current monitoring period	Monitoring in the leakage area	8.3.2.4	[F.47][F.49]	Every time measured (≤ 5 yrs)	Review of monitoring records	
$p_{SL}^{[m]}$	proportion (unitless)	Proportion of AGMT that is not merchantable and goes into slash estimated from inventory	Estimated from inventory	8.1.6.3	[F.34]	Every time measured (≤ 5 yrs)	Review of monitoring records	
$t^{[i-1]}$	days	Time from project start date to beginning of monitoring period i	Monitoring records	N/A	[F.32], [F.33]	Prior monitoring period	N/A	
$t^{[m]}$	days	Time from project start date to end of current monitoring period	Monitoring records	N/A	[F.19], [F.20], [F.24], [F.21], [F.25], [F.27], [F.28], [F.32], [F.33], [F.36], [F.37], [F.38], [F.39], [F.40],	Every monitoring period	Review of monitoring records	
$t^{[m-1]}$	days	Time from project start date to beginning of current monitoring period	Monitoring records	N/A	[F.10], [F.36]	Prior monitoring period	N/A	
$U_B^{[m]}$	tCO2e	Total uncertainty in proxy area carbon stock estimate	N/A	N/A	[F.57]	Every monitoring period	Review of monitoring records	

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC	Comment
$U_{EM}^{[M]}$	tCO2e	Total uncertainty in Baseline Emissions Models	N/A	N/A	[F.57]	Every monitoring period	Review of monitoring records	
$U_{P}^{[m]}$	tCO2e	Total uncertainty in project accounting area carbon stock estimate	N/A	N/A	[F.57]	Every monitoring period	Review of monitoring records	
$wc_{Pi}^{[m=o]}$	tCO2e	Weighted average carbon stocks for biomass or SOC in the project for the set of selected strata	Inventory	Inventory, GIS	[F.29] [F.24]	Every monitoring period	Review of monitoring records	
$x^{[m]}$	varies	Covariate values	Participatory Rural Appraisal, analysis of public records, and/or expert interpretation of inventory data or remotely sensed imagery	N/A	[F.19], [F.20], [F.21], [F.24], [F.25], [F.27], [F.28], [F.37], [F.38], [F.39], [F.40],	Every time measured (≤ 5 yrs)	Review of monitoring records	

APPENDIX I: PROJECT DOCUMENT REQUIREMENTS BY BASELINE TYPE

PDR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
PDR.1	Applicability Conditions	For each applicability condition, a statement of whether it applies to the project. If the applicability condition does not apply to the project, justification for this conclusion.	x	x	x	x	x	x	x	x	x
PDR.2	Applicability Conditions	Where applicability conditions apply, credible evidence in the forms of analysis, documentation or third-party reports to satisfy the condition.	x	x	x	x	x	x	x	x	x
PDR.3	Applicability Conditions	Definition of forest used by the project proponent and its source.	x	x	x	x	x	x	x	x	x
PDR.4	Spatial Project Boundaries	A digital (GIS-based) map of the project area with at least the above minimum requirements for delineation of the geographic boundaries.	x	x	x	x	x	x	x	x	x
PDR.5	Spatial Project Boundaries	Credible documentation demonstrating control of the project area, or documentation that the provisos listed in the case of less than 80% project control at the time of validation delineated in section 5.1 of the methodology are met.	x	x	x	x	x	x	x	x	x
PDR.6	Temporal Project Boundaries	The project start date.	x	x	x	x	x	x	x	x	x
PDR.7	Temporal Project Boundaries	The project crediting period start date and length.	x	x	x	x	x	x	x	x	x
PDR.8	Temporal Project Boundaries	The dates for mandatory baseline reevaluation after the project start date.	x	x	x	x	x	x	x	x	x
PDR.9	Temporal Project Boundaries	A timeline including the first anticipated monitoring period showing when project activities will be implemented.	x	x	x	x	x	x	x	x	x
PDR.10	Temporal Project Boundaries	A timeline for anticipated subsequent monitoring periods.	x	x	x	x	x	x	x	x	x

PDR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
PDR.11	Carbon Pools	A list of the greenhouse gases considered.	x	x	x	x	x	x	x	x	x
PDR.12	Carbon Pools	A list of the selected carbon pools and evidence for the conservative exclusion of any optional pools.	x	x	x	x	x	x	x	x	x
PDR.13	Carbon Pools	The definition and evidence to support the definition of a merchantable tree if the baseline scenario or project activities include logging.	x	x	x	x	x	x	x	x	x
PDR.14	Grouped Projects	A list and descriptions of all enrolled project activity instances in the group at the time of validation.	x	x	x	x	x	x	x	x	x
PDR.15	Grouped Projects	A map of the designated geographic area within which all project activity instances in the group will be located, indicating that all instances are in the same region.	x	x	x	x	x	x	x	x	x
PDR.16	Grouped Projects	A map of the common reference area, proxy area, activity-shifting leakage area, and market leakage area.	x	x	x	x	x	x	x	x	x
PDR.17	Determining the Baseline Scenario	Show that the identified baseline type is the most plausible baseline scenario identified in section 7	x	x	x	x	x	x	x	x	x
PDR.18	Agents and Drivers of Conversion	A list of the agents and drivers of conversion, including quantitative descriptions of agent mobilities.	x	x	x	x	x	x	x	x	x
PDR.19	Agents and Drivers of Conversion	A narrative describing the agents and drivers of conversion.	x	x	x	x	x	x	x	x	x
PDR.20	Agents and Drivers of Conversion	Descriptions of agents and drivers including any useful statistics and their sources.	x	x	x	x	x	x	x	x	x
PDR.21	Agents and Drivers of Conversion	A list of external drivers (covariates) of conversion used in the model, if any, that may be identified as part of a PRA, expert knowledge or literature (eg, median household income, road density, rainfall).	x	x	x	x	x	x	x	x	x

PDR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
PDR.22	Project Accounting Areas	A digital (GIS-based) map of the project accounting areas, including aerial or satellite imagery showing that they are forested as of the project start date and 10 years prior to the project start date.	x	x	x	x	x	x	x	x	x
PDR.23	Project Accounting Areas	Justify the project accounting areas using the identified agents and drivers of conversion, constraints to conversion, and attributes listed above in section 6.2.	x	x	x	x	x	x	x	x	x
PDR.24	Project Accounting Areas	Selection of patch size at which land conversion typically occurs.								x	x
PDR.25	Project Accounting Areas	Justification of selection of patch size for delineation of project accounting area.								x	x
PDR.26	Identifying the Baseline Type - Forest	If Types F-P1.a, F-P1.b or F-P2 are selected, justification for meeting the definition of APD in the current VCS-approved AFOLU Requirements.	x	x	x						
PDR.27	Identifying the Baseline Type - Forest	If Type F-P1.a or F-P1.b is selected, evidence of legally-sanctioned commercial harvest in the baseline scenario.	x	x							
PDR.28	Identifying the Baseline Type - Forest	If Type F-P1.a is selected, evidence of legally-sanctioned deforestation in the baseline scenario	x								

PDR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
PDR.29	Identifying the Baseline Type - Forest	If Type F-P1.b is selected, evidence of frontier configuration: a. Projects must demonstrate that the agent of degradation had access to the project area AND that comparable agents create roads for extraction of timber AND/OR b. Projects may produce permits, construction plans, contracts or tenders, budgets, or other evidence of the intent to construct roads.		x							
PDR.30	Identifying the Baseline Type - Forest	If Type F-U1 is selected, a spatial analysis of the project area showing that at least 25% of the perimeter is within 120 meters of deforestation that occurred within 10 years prior to the project start date and showing that the reference area is adjacent to at least 25% of the project area.				x					
PDR.31	Identifying the Baseline Type - Forest	If Type F-U2 is selected, a spatial analysis of the project area showing that at least 25% of the perimeter is within 120 meters of deforestation that occurred within 10 years prior to the project start date.					x				
PDR.32	Identifying the Baseline Type - Forest	If Types F-U1, F-U2 or F-U3 is selected, a spatial analysis of the project area showing that it is within 120 meters of deforestation that occurred within 10 years prior to the project start date.				x	x	x			

PDR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
PDR.33	Identifying the Baseline Type - Grassland	If Type G-P2 is selected, justification for meeting the definition of APC in the current VCS-approved AFOLU Requirements. Justification must include evidence of intent to convert the project area and that the converted land-use category would meet the definition of native grassland / shrubland conversion.							x		
PDR.34	Identifying the Baseline Type - Grassland	If Type G-U1 is selected, a spatial analysis of the project area showing that the reference area is adjacent to at least 25% of the project area.								x	
PDR.35	Delineation of the Proxy Areas	A map of the delineated boundaries.	x	x	x	x	x	x	x		
PDR.36	Delineation of the Proxy Areas	Maps or other evidence that the proxy area’s site characteristics and landscape configuration is similar to its respective project accounting area, including: Vegetation; Climatic conditions (eg, mean temperature, rainfall, etc.); Topographic constraints to conversion (slope, aspect, elevation); Land use and/or land cover; Soil map (if available) or other soil information; Applicable infrastructure (eg, water ways, roads, railroad, airports, provision of electricity, and other access points); and Ownership/tenure boundaries that influence conversion (eg, government holdings, private holdings and reserves).	x	x	x	x	x	x	x		

PDR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
PDR.37	Delineation of the Proxy Areas	A narrative describing the rationale for selection of proxy area boundaries, including the proxy area's similarity to the corresponding project accounting area with respect to vegetation, soil and climatic conditions.	x	x	x	x	x	x	x	x	x
PDR.38	Delineation of the Proxy Areas	Results of a spatial analysis to demonstrate the proxy area is converted, on average, as of the project start date.	x	x	x	x	x	x	x	x	x
PDR.39	Describing the Baseline Scenarios for Selected Carbon Pools	A qualitative description of the baseline scenario for each selected carbon pool.	x	x	x	x	x	x	x	x	x
PDR.40	Delineation of the Reference Area for Planned and Unplanned Types	A map of the delineated boundaries, demonstrating that the reference area was held by the identified baseline agent or agents and does not include the project area.	x	x	x	x	x	x	x	x	x
PDR.41	Delineation of the Reference Area for Planned and Unplanned Types	Results of a spatial analysis to demonstrate the reference area had as much forest or native grassland as the project accounting area at some point in time during the historic reference period.	x	x	x	x	x	x	x	x	x
PDR.42	Delineation of the Reference Area for Planned and Unplanned Types	Evidence that the management practices of the baseline agent in the reference area are similar to those that would have been applied to the project accounting area or areas in the baseline.	x	x	x	x	x	x	x	x	x
PDR.43	Delineation of the Reference Area for Planned and Unplanned Types	A description of the rationale for selection of reference area boundaries.	x	x	x	x	x	x	x	x	x
PDR.44	Delineation of the Reference Area for Planned and Unplanned Types	The documentation required in the reference area selection requirements that the selected reference area meets the Reference Area Selection Requirements.	x	x	x	x	x	x	x	x	x

PDR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
PDR.45	Defining the Reference Area for Planned Baseline Types	Evidence that secondary agents have been considered in the delineation of the reference area for baseline types F-P1.a and F-P1.b.	x	x							
PDR.46	Defining the Reference Period for Planned Types	Established reference period boundaries.	x	x	x				x		
PDR.47	Defining the Reference Period for Planned Types	The date when the agent acquired control of the reference area or when the land management practices employed in the reference area changed.	x	x	x				x		
PDR.48	Defining the Reference Period for Unplanned Types	Established reference period boundaries.				x	x	x		x	x
PDR.49	Defining the Reference Period for Unplanned Types	A list of available historic imagery for the reference area.				x	x	x		x	x
PDR.50	Defining the Reference Period for Unplanned Types	A timeline of important events as they relate to the agents and drivers of conversion.				x	x	x		x	x
PDR.51	Defining the Reference Period for Unplanned Types	Narrative rationale for the selection of the reference period.				x	x	x		x	x
PDR.52	Historic Imagery to Parameterize α, β and θ	A map of the reference area showing the area of "double-coverage".	x	x	x	x	x	x	x	x	x
PDR.53	Historic Imagery to Parameterize α, β and θ	Quantification of "double coverage"(greater than 90%).	x	x	x	x	x	x	x	x	x
PDR.54	Historic Imagery to Parameterize α, β and θ	A line plot of the historic image dates to confirm stationarity.	x	x	x	x	x	x	x	x	x
PDR.55	Historic Imagery to Parameterize α, β and θ	Evidence that all image pixels are not more than 30m x 30m.	x	x	x	x	x	x	x	x	x

PDR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
PDR.56	Historic Imagery to Parameterize α, β and θ	Empirical evidence that imagery is registered to within 10% RMSE, on average.	x	x	x	x	x	x	x	x	x
PDR.57	Sampling Conversion to Parameterize α, β and θ	The sample size.	x	x	x	x	x	x	x	x	x
PDR.58	Sampling Conversion to Parameterize α, β and θ	A map of the reference area showing the sample point locations.	x	x	x	x	x	x	x	x	x
PDR.59	Parameterizing α, β and θ	The covariates that were considered and their data sources.	x	x	x	x	x	x	x	x	x
PDR.60	Parameterizing α, β and θ	The parameters in θ that were evaluated during model selection.	x	x	x	x	x	x	x	x	x
PDR.61	Parameterizing α, β and θ	The parameters in θ of the selected model.	x	x	x	x	x	x	x	x	x
PDR.62	Parameterizing α, β and θ	The rationale used for selecting θ including comparisons of AIC.	x	x	x	x	x	x	x	x	x
PDR.63	Minimizing Uncertainty in Parameters $\hat{\alpha}$, $\hat{\beta}$ and $\hat{\theta}$	A protocol for interpreting land cover state from imagery, which must include guidance for interpreting the following: Discerning conversion features using shape, texture and context in the reference area landscape Addressing seasonal variation of vegetation (phenology) within imagery Identifying and addressing the characteristics of specific landscape configurations (ie, mosaic forest, grassland, etc.)	x	x	x	x	x	x	x	x	x
PDR.64	Minimizing Uncertainty in Parameters $\hat{\alpha}$, $\hat{\beta}$ and $\hat{\theta}$	The results of an independent check of the interpretation.	x	x	x	x	x	x	x	x	x
PDR.65	Minimizing Uncertainty in Parameters $\hat{\alpha}$, $\hat{\beta}$ and $\hat{\theta}$	Evidence that systematic errors, if any, from the independent check of the interpretation were corrected.	x	x	x	x	x	x	x	x	x

PDR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
PDR.66	Estimating Uncertainty in Parameters $\hat{\alpha}$, $\hat{\beta}$ and $\hat{\theta}$	The estimated uncertainty σEM from [F.13] and statistical summaries from model fitting software, if available.	x	x	x	x	x	x	x	x	x
PDR.67	Estimating Uncertainty in Parameters $\hat{\alpha}$, $\hat{\beta}$ and $\hat{\theta}$	Reference to uncertainty calculations.	x	x	x	x	x	x	x	x	x
PDR.68	Parameterizing t_{SA}	The parameter tSA as the number of days after the primary agent begins commercial logging until when the secondary agent of deforestation is likely to begin degrading the project accounting area.	x	x							
PDR.69	Parameterizing t_{SA}	A description of how tSA was obtained.	x	x							
PDR.70	Parameterizing t_{SA}	Harvest plans for the project accounting area under the baseline scenario, results from the PRA or analysis of the reference area to determine the parameter.	x	x							
PDR.71	Parameterizing t_{SA}	The parameter tPA as the number of days relative to the project start date when the primary agent began or would have begun legally-sanctioned commercial logging in the project accounting area.	x	x							
PDR.72	Parameterizing t_{SA}	A description of how tPA was obtained.	x	x							
PDR.73	Parameterizing t_{SA}	Harvest plans for the project accounting area under the baseline scenario or public records to support the determination of the parameter.	x	x							
PDR.74	Determining x_0	A table of covariate values as of the project start date and a description of how the values were determined including any interpolation or extrapolation methods.	x	x	x	x	x	x	x	x	x

PDR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
PDR.75	Determining x_0	Justification for why the rate of conversion predicted by covariates exceeds the rate indicated from historical conversion patterns.	x	x	x	x	x	x	x	x	x
PDR.76	Parameterizing *m*	The parameter m as the average carbon in merchantable trees cut each year as a result of legally-sanctioned commercial logging.	x	x							
PDR.77	Parameterizing *m*	Documentation of how m was determined. This may include an analysis of carbon stocks in merchantable trees in the project accounting area, timber harvest plans for the project accounting area or reference to a publication containing the maximum allowable cut applicable to the project area. The parameter must be greater than zero.	x	x							
PDR.78	Determining γ	The project shift parameter γ as the number of days between the beginning of the historical reference period and the project start date.	x	x	x				x		
PDR.79	Parameterizing *q*	The parameter q as the number of days between the onset of degradation and the beginning of conversion.	x	x	x	x	x	x	x	x	x
PDR.80	Parameterizing *q*	If the default of zero is not selected for q, then a justification for the determination of q.	x	x	x	x	x	x	x	x	x
PDR.81	Parameterizing r_U	The parameter rU as the ratio of converted perimeter to total threatened perimeter, or the ratio of converted area to total project accounting area(s), as of the project start date.					x	x			x
PDR.82	Parameterizing r_U	Description of how rU was obtained.					x	x			x

PDR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
PDR.83	Parameterizing r_U	Results of GIS analysis to determine or measure rU in the project area including the dates of images used to identify conversion.					x	x			x
PDR.84	Empirically Estimating λ_{SOC}	Description of how samples from the reference area were selected including stratification, if any.	x	x	x	x	x	x	x	x	x
PDR.85	Empirically Estimating λ_{SOC}	A map of sample locations in the reference area.	x	x	x	x	x	x	x	x	x
PDR.86	Empirically Estimating λ_{SOC}	A table showing the conversion time for each area (farm or otherwise) from which samples were taken.	x	x	x	x	x	x	x	x	x
PDR.87	Empirically Estimating λ_{SOC}	Description of and statistics for the method applied to estimate λSOC.	x	x	x	x	x	x	x	x	x
PDR.88	Empirically Estimating λ_{SOC}	Graph of projected decay model over project lifetime.	x	x	x	x	x	x	x	x	x
PDR.89	Literature Estimates for λ_{SOC}	Inclusion of decay model on which parameter is based.	x	x	x	x	x	x	x	x	x
PDR.90	Literature Estimates for λ_{SOC}	Explicit description of referenced literature, including project location, sampling methodology, included species, sample size, duration of field experiments, and decay parameter upon which decay is based.	x	x	x	x	x	x	x	x	x
PDR.91	Literature Estimates for λ_{SOC}	Graph of projected decay model over project lifetime.	x	x	x	x	x	x	x	x	x
PDR.92	Literature Estimates for λ_{SOC}	If decay model is based on any other element besides carbon, defense of ability to predict carbon decay must be provided.	x	x	x	x	x	x	x	x	x
PDR.93	Baseline Reevaluation	All required documentation as specified in section 6 for the project prior to the baseline reevaluation.	x	x	x	x	x	x	x	x	x

PDR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
PDR.94	Baseline Reevaluation	All required documentation as specified in section 6 for the project after the baseline reevaluation including the reevaluation period.	x	x	x	x	x	x	x	x	x
PDR.95	Baseline Reevaluation	A narrative of the reevaluation including any obstacles and how they were overcome.	x	x	x	x	x	x	x	x	x
PDR.96	Reevaluation of the Reference Area and Period	A map of the new reference area.	x	x	x	x	x	x	x	x	x
PDR.97	Re-parameterization of α, β and θ	Summary of new data observed in the new reference area.	x	x	x	x	x	x	x	x	x
PDR.98	Re-parameterization of α, β and θ	The re-parameterized values $\hat{\alpha}$, $\hat{\beta}$ and $\hat{\theta}$.	x	x	x	x	x	x	x	x	x
PDR.99	Demonstration of Project Additionality	A list of alternative land use scenarios to the project.	x	x	x	x	x	x	x	x	x
PDR.100	Demonstration of Project Additionality	Justification for the selected baseline scenario. This justification can include expert knowledge, results from the participatory rural appraisal and ex-ante estimates of avoided emissions (see sections 6.1 and 8.4.7).	x	x	x	x	x	x	x	x	x
PDR.101	Demonstration of Project Additionality	An investment or barriers analysis proving that the project is not the most economical option.	x	x	x	x	x	x	x	x	x
PDR.102	Demonstration of Project Additionality	A common practice analysis including a list of project activities and the drivers of conversion that they address.	x	x	x	x	x	x	x	x	x
PDR.103	Demonstration of Project Additionality	Evident compliance with the minimum requirements of the aforementioned VCS tool. This evidence may be the same as the evidence provided to meet reporting requirements listed in section 4.	x	x	x	x	x	x	x	x	x

PDR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
PDR.104	Leakage Mitigation Strategies	A list of project activities designed to mitigate leakage.	x	x	x	x	x	x	x	x	x
PDR.105	Delineation of the Activity-Shifting Leakage Area	A map of the delineated boundaries.	x	x	x	x	x	x	x	x	x
PDR.106	Delineation of the Activity-Shifting Leakage Area	Maps of the landscape configuration, including: a. Topography (elevation, slope, aspect); b. Recent land use and land cover (either a thematic map created by the project proponent or publicly available map); c. Access points; d. Soil class maps (if available); e. Locations of important markets; f. Locations of important resources like waterways or roads; and g. Land ownership/tenure boundaries.	x	x	x	x	x	x	x	x	x
PDR.107	Delineation of the Activity-Shifting Leakage Area	A narrative describing the rationale for selection of activity-shifting leakage area boundaries. If the activity-shifting leakage area is smaller than the project accounting area or cannot be defined, justification for the size of the area. If foreign agents have been identified as an agent of conversion, justification that they are unlikely to shift their activities outside the activity-shifting leakage area.	x	x	x	x	x	x	x	x	x
PDR.108	Delineation of the Activity-Shifting Leakage Area	Results of a spatial analysis to demonstrate the activity-shifting leakage area is entirely forested as of the project start date.	x	x	x	x	x	x	x	x	x

PDR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
PDR.109	Delineation of the Activity-Shifting Leakage Area	Results of a spatial analysis to demonstrate the activity-shifting leakage area is no larger than the project accounting area.	x	x	x	x	x	x	x	x	x
PDR.110	Determining the Market Discount Factor	The selected discount factor pL ME.	x	x	x	x	x	x	x	x	x
PDR.111	Determining the Market Discount Factor	Calculations of cL AGMT in the market leakage area, including references to literature if cited.	x	x	x	x	x	x	x	x	x
PDR.112	Determining the Market Discount Factor	Justification for the selection of the discount factor.	x	x	x	x	x	x	x	x	x
PDR.113	Delineation of the Market Leakage Area	A map of the delineated boundaries.	x	x	x	x	x	x	x	x	x
PDR.114	Delineation of the Market Leakage Area	Maps of the landscape configuration, including: a. Topography (elevation, slope, aspect); b. Recent land use and land cover (either a thematic map created by the project proponent or publicly available map); c. Access points; d. Soil class maps (if available); e. Locations of important markets; f. Locations of important resources like waterways or roads; and g. Land ownership/tenure boundaries.	x	x	x	x	x	x	x	x	x
PDR.115	Delineation of the Market Leakage Area	A narrative describing the rationale for selection of market leakage area boundaries.	x	x	x	x	x	x	x	x	x

PDR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
PDR.116	Delineation of the Market Leakage Area	Results of a spatial analysis to demonstrate the market leakage area is entirely forested as of the project start date.	x	x	x	x	x	x	x	x	x
PDR.117	Delineation of the Market Leakage Area	Results of a spatial analysis to demonstrate the market leakage area is as large or larger than the project accounting area.	x	x	x	x	x	x	x	x	x
PDR.118	*Ex-Ante* Estimation of NERs	The projected avoided baseline emissions, project emissions and leakage for each monitoring period and vintage year over the lifetime of the project.	x	x	x	x	x	x	x	x	x
PDR.119	*Ex-Ante* Estimation of NERs	A narrative description of sources used to estimate the leakage rate and demonstration that the estimated rate is conservative.	x	x	x	x	x	x	x	x	x
PDR.120	*Ex-Ante* Estimation of NERs	If included in project activities, a description of procedures used to estimate the rate of biomass burning, charcoal production or logging and demonstration that these estimates are conservative.	x	x	x	x	x	x	x	x	x
PDR.121	Data and Parameters Available at Validation	The value for each variable in Appendix G.	x	x	x	x	x	x	x	x	x
PDR.122	Description of the Monitoring Plan	Summary of sampling procedures for the project accounting areas, with a copy of a sampling protocol used to carry out measurements.	x	x	x	x	x	x	x	x	x
PDR.123	Description of the Monitoring Plan	Summary of sampling procedures for the proxy areas, with a copy of a sampling protocol used to carry out measurements.	x	x	x	x	x	x	x	x	x
PDR.124	Description of the Monitoring Plan	Summary of sampling procedures for the activity-shifting leakage areas, with a copy of a sampling protocol used to carry out measurements.	x	x	x	x	x	x	x	x	x

APPENDIX J: MONITORING REPORT REQUIREMENTS BY BASELINE TYPE

MR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
MR.1	Spatial Project Boundaries	A digital (GIS-based) map of the project area with at least the above minimum requirements for delineation of the geographic boundaries.	x	x	x	x	x	x	x	x	x
MR.2	Temporal Project Boundaries	The project start date.	x	x	x	x	x	x	x	x	x
MR.3	Temporal Project Boundaries	The project crediting period start date, end date and length.	x	x	x	x	x	x	x	x	x
MR.4	Grouped Projects	A list and descriptions of all instances in the group.	x	x	x	x	x	x	x	x	x
MR.5	Grouped Projects	A map of the locations or boundaries of all instances in the group indicating that all instances are in the same region.	x	x	x	x	x	x	x	x	x
MR.6	Project Accounting Areas	A digital (GIS-based) map of the project accounting areas with at least the above minimum requirements for delineation of the geographic boundaries.	x	x	x	x	x	x	x	x	x
MR.7	Determining t_{PAI}	For each project activity instance in the group, its project activity instance start date.	x	x	x	x	x	x	x	x	x
MR.8	Determining t_{PAI}	For each project accounting area, the value of tPAI.	x	x	x	x	x	x	x	x	x
MR.9	Determining x_{PAI}	A table of covariate values as of the project activity instance start dates and a description of how the values were determined including any interpolation or extrapolation methods.	x	x	x	x	x	x	x	x	x
MR.10	Baseline Emissions	Calculations of current baseline emissions EB Δm as of the current monitoring period.	x	x	x	x	x	x	x	x	x
MR.11	Baseline Emissions	Calculations of baseline emissions EB Δm-1 from prior monitoring periods.	x	x	x	x	x	x	x	x	x
MR.12	Baseline Emissions	Calculations of cumulative baseline emissions for each selected pool (EB BMm and EB SOCm) and undecayed carbon (CB BGBm, CB DWm, CB SOCm and CB WPm), as of the current monitoring period.	x	x	x	x	x	x	x	x	x

MR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
MR.13	Baseline Emissions from Biomass	Calculations of cumulative baseline emissions from biomass EB BMm for the current monitoring period.	x	x	x	x	x		x	x	x
MR.14	Baseline Emissions from Biomass	Calculations of cumulative baseline emissions from biomass EB BMm for all prior monitoring periods.	x	x	x	x	x		x	x	x
MR.15	Applying the Spatial Algorithm	The order of strata from lowest carbon stocks to highest carbon stocks based on the average across all pools.		x				x			
MR.16	Applying the Spatial Algorithm	Calculations for each step which are carried through from monitoring period to monitoring period.		x				x			
MR.17	Applying the Spatial Algorithm	Calculations of cumulative baseline emissions from biomass EB BMm for prior monitoring periods.		x				x			
MR.18	Baseline Emissions from SOC for Types F-P1.a, F-P1.b, F-P2 and G-P2	An estimate of current baseline emissions from SOC EB Δ SOCm as of the current monitoring period.	x	x	x				x		
MR.19	Baseline Emissions from SOC for Types F-P1.a, F-P1.b, F-P2 and G-P2	An estimate of cumulative baseline emissions from SOC EB SOCm for the current monitoring period.	x	x	x				x		
MR.20	Baseline Emissions from SOC for Types F-P1.a, F-P1.b, F-P2 and G-P2	Calculations of cumulative baseline emissions from SOC EB SOCm for all prior monitoring periods.	x	x	x				x		
MR.21	Carbon Not Decayed in DW	An estimate of carbon stored in non-decayed DW CB DWm for the current monitoring period.	x	x	x	x	x	x	x	x	x

MR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
MR.22	Carbon Not Decayed in DW	An estimate of cumulative baseline emissions from DW EB DWm for the current monitoring period.	x	x	x	x	x	x	x	x	x
MR.23	Carbon Not Decayed in DW	An estimate of cumulative baseline emissions from AGMT EB AGMTm for the current monitoring period.	x	x	x	x	x	x	x	x	x
MR.24	Carbon Not Decayed in DW	Calculations of cumulative baseline emissions from DW EB DWm for all prior monitoring periods.	x	x	x	x	x	x	x	x	x
MR.25	Carbon Not Decayed in DW	Calculations of cumulative baseline emissions from AGMT EB AGMTm for all prior monitoring periods.	x	x	x	x	x	x	x	x	x
MR.26	Carbon Not Decayed in BGB	An estimate of carbon stored in non-decayed BGB CB BGBm for the current monitoring period.	x	x	x	x	x	x	x	x	x
MR.27	Carbon Not Decayed in BGB	An estimate of cumulative baseline emissions from BGB EB BGBm for the current monitoring period.	x	x	x	x	x	x	x	x	x
MR.28	Carbon Not Decayed in BGB	Calculations of cumulative baseline emissions from BGB EB BGBm for all prior monitoring periods.	x	x	x	x	x	x	x	x	x
MR.29	Carbon Not Decayed in SOC	An estimate of carbon stored in non-decayed SOC CB SOCm for the current monitoring period.	x	x	x	x	x	x	x	x	x
MR.30	Carbon Stored in Wood Products	Carbon stored in long-lived wood products CB WPm after 100 years.	x	x	x	x	x	x	x	x	x
MR.31	Carbon Stored in Wood Products	Calculations to determine CB WPm.	x	x	x	x	x	x	x	x	x
MR.32	Emissions Events in Project Area	A map of the boundaries of any significant disturbance in the project accounting areas during the monitoring period.	x	x	x	x	x	x	x	x	x
MR.33	Emissions Events in Project Area	Evidence that plots were installed into these disturbed areas and were measured per section 9.	x	x	x	x	x	x	x	x	x

MR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
MR.34	Emissions from Burning from Project Activities	A table of events when woody or herbaceous biomass was burned during the monitoring period, showing the weight of woody or herbaceous biomass in tonnes and the date consumed.	x	x	x	x	x	x	x	x	x
MR.35	Carbon Stored in Wood Products from Project Activities	Carbon stored in long-lived wood products CP Δ WPm after 100 years.	x	x	x	x	x	x	x	x	x
MR.36	Carbon Stored in Wood Products from Project Activities	Scale reports or records of carbon in log production by wood products type CP tym.	x	x	x	x	x	x	x	x	x
MR.37	Carbon Stored in Wood Products from Project Activities	Calculations to determine CP Δ WPm.	x	x	x	x	x	x	x	x	x
MR.38	Livestock Grazed in the Project Area	A report or record of the number of livestock per species of livestock $n_{LS\,i}$ being grazed within the project area $\mathrm{n}_{\mathrm{LS\,i}}$.	x	x	x	x	x	x	x	x	x
MR.39	Livestock Grazed in the Project Area	Emissions released due to livestock grazing $\mathrm{E}_{\mathrm{P\,\Delta\,LS}}^{[\mathrm{m}]}$.	x	x	x	x	x	x	x	x	x
MR.40	Livestock Grazed in the Project Area	Calculations to determine $\mathrm{E}_{\mathrm{P\,\Delta\,LS}}^{[\mathrm{m}]}$.	x	x	x	x	x	x	x	x	x
MR.41	Synthetic Fertilizer in the Project Area	A report or record of the quantity of synthetic fertilizer applied in the project area.	x	x	x	x	x	x	x	x	x
MR.42	Synthetic Fertilizer in the Project Area	Emissions released due to use of synthetic fertilizer $\mathrm{E}_{\mathrm{P\,\Delta\,LS}}^{[\mathrm{m}]}$.	x	x	x	x	x	x	x	x	x

MR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
MR.43	Synthetic Fertilizer in the Project Area	Calculations to determine $E^{[m]}_{P\,\Delta\,LS}$.	x	x	x	x	x	x	x	x	x
MR.44	Leakage Mitigation Strategies	A description of project activities that have been implemented since the project start date and the estimated effects of these activities on leakage mitigation.	x	x	x	x	x	x	x	x	x
MR.45	Commodity Production for Leakage Mitigation	A list of mitigation activities reduce demand for forgone goods and services.	x	x	x	x	x	x	x	x	x
MR.46	Commodity Production for Leakage Mitigation	Quantities for the reduction or replacement of goods and services if they are used in section 8.3.3.4.	x	x	x	x	x	x	x	x	x
MR.47	Commodity Production for Leakage Mitigation	Methods for measuring the reduction or replacement of goods and services.	x	x	x	x	x	x	x	x	x
MR.48	Estimating Emissions from Activity-Shifting Leakage	Calculated cumulative emissions from activity-shifting leakage for the current monitoring period $\boldsymbol{E^{[m]}_{L\,AS}}$ and supporting calculations.	x	x	x	x	x	x	x	x	x
MR.49	Estimating Emissions from Activity-Shifting Leakage	Calculated cumulative emissions from activity-shifting leakage for the prior monitoring periods $\boldsymbol{E^{[m]}_{L\,AS}}$. If an activity-shifting leakage area is not installed, then include results from the participatory rural appraisal and/or expert knowledge, with an analysis of the nearest suitable forest cover for activity shifting leakage.	x	x	x	x	x	x	x	x	x

MR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
MR.50	Change to the Activity-Shifting Leakage Area	A description and justification of the change to the activity-shifting leakage area.	x	x	x	x	x	x	x	x	x
MR.51	Change to the Activity-Shifting Leakage Area	A map of the delineated boundaries.	x	x	x	x	x	x	x	x	x
MR.52	Change to the Activity-Shifting Leakage Area	Maps of the landscape configuration, including: a. Topography (elevation, slope, aspect); b. Recent land use and land cover (either a thematic map created by the project proponent or publicly available map); c. Access points; d. Soil class maps (if available); e. Locations of important markets; f. Locations of important resources like waterways or roads; and g. Land ownership/tenure boundaries.	x	x	x	x	x	x	x	x	x
MR.53	Change to the Activity-Shifting Leakage Area	A narrative describing the rationale for selection of activity-shifting leakage area boundaries. If the activity-shifting leakage area is smaller than the project accounting area or cannot be defined, justification for the size of the area.	x	x	x	x	x	x	x	x	x
MR.54	Change to the Activity-Shifting Leakage Area	Results of a spatial analysis to demonstrate the activity-shifting leakage area is entirely forested as of the project start date.	x	x	x	x	x	x	x	x	x
MR.55	Change to the Activity-Shifting Leakage Area	Results of a spatial analysis to demonstrate the activity-shifting leakage area is no larger than the project accounting area.	x	x	x	x	x	x	x	x	x

MR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
MR.56	Estimating $p_{L\ DEG}$	The estimated value pL DEGm for the current monitoring period and supporting calculations.	x	x	x	x	x	x	x	x	x
MR.57	Estimating $p_{L\ DEG}$	The calculated value pL DEGm=0 calculated for the first monitoring period.	x	x	x	x	x	x	x	x	x
MR.58	Estimating $p_{L\ CON\ G}$	The estimated value pL CON Gm for the current monitoring period and supporting calculations.	x	x	x	x	x	x	x	x	x
MR.59	Estimating $p_{L\ CON\ G}$	The calculated value pL CON Gm=0 calculated for the first monitoring period.	x	x	x	x	x	x	x	x	x
MR.60	Determining Emissions from Market Leakage	The selected approach to determining emissions from market leakage.	x	x	x	x	x	x	x	x	x
MR.61	Determining Emissions from Market Leakage	Estimated cumulative emissions from market leakage for the current monitoring period EL MEm and supporting calculations.	x	x	x	x	x	x	x	x	x
MR.62	Confidence Deduction Determining Emissions from Market Leakage	Calculated cumulative emissions from market leakage for the prior monitoring periods EL MEm.	x	x	x	x	x	x	x	x	x
MR.63	Ensuring No Leakage Within Project Proponent's Ownership	Provide location-by-location evidence that management plans and land-use designations of all areas under the project proponent's control within the country have not changed as a result of the project. For entities with a conservation mission, provide evidence of the organization's policy not to change the land use of other owned and managed lands, and evidence of compliance with such a policy.	x	x	x	x	x	x	x	x	x

MR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
MR.64	Ensuring Constancy of Baseline Operator Management	Provide evidence in the form of GIS imagery, PRA evidence, or the baseline operator's management plan that management plans or land-use designations have not changed in the baseline operator's other lands.	x	x	x						
MR.65	Quantification of GERs	Quantified GERs for the current monitoring period including references to calculations.	x	x	x	x	x	x	x	x	x
MR.66	Quantification of GERs	Quantified GERs for the prior monitoring period.	x	x	x	x	x	x	x	x	x
MR.67	Quantification of GERs	A graph of GERs by monitoring period for all monitoring periods to date.	x	x	x	x	x	x	x	x	x
MR.68	Confidence Deduction	The confidence deduction EUm and estimated standard errors used to determine the confidence deduction.	x	x	x	x	x	x	x	x	x
MR.69	Confidence Deduction	Reference to calculations used to determine the confidence deduction.	x	x	x	x	x	x	x	x	x
MR.70	Quantification of NERs Using a Linear Model	The linear model used to generate GERs for the current monitoring period.	x	x	x	x	x	x	x	x	x
MR.71	Quantification of NERs Using a Linear Model	A graph of GERs from the linear model by monitoring period for all monitoring periods to date that used a linear model.	x	x	x	x	x	x	x	x	x
MR.72	Reversal Event	A description of the reversal including which pools contributed to the reversal and reasons for its occurrence.	x	x	x	x	x	x	x	x	x
MR.73	Reversal Event as a Result of Baseline Reevaluation	A description of the reversal including a summary of new data obtained in the reference area.	x	x	x	x	x	x	x	x	x

MR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
MR.74	Quantification of NERs for a PAA	Quantified NERs for the current monitoring period including references to calculations.	x	x	x	x	x	x	x	x	x
MR.75	Quantification of NERs for a PAA	Quantified NERs for the prior monitoring period.	x	x	x	x	x	x	x	x	x
MR.76	Quantification of NERs for a PAA	A graph of NERs by monitoring period for all monitoring periods to date.	x	x	x	x	x	x	x	x	x
MR.77	Buffer Account	Reference to the VCS requirements used to determine the buffer account allocation.	x	x	x	x	x	x	x	x	x
MR.78	Buffer Account	Reference to calculations used to determine the buffer account allocation.	x	x	x	x	x	x	x	x	x
MR.79	Quantification of NERs across PAAs	Quantified NERs for the current monitoring period including references to calculations.	x	x	x	x	x	x	x	x	x
MR.80	Quantification of NERs across PAAs	Quantified NERs for the prior monitoring period.	x	x	x	x	x	x	x	x	x
MR.81	Quantification of NERs across PAAs	A graph of NERs by monitoring period for all monitoring periods to date.	x	x	x	x	x	x	x	x	x
MR.82	Vintages	Quantified NERs by vintage year for the current monitoring period including references to calculations.	x	x	x	x	x	x	x	x	x
MR.83	Evaluating Project Performance	Comparison of NERs presented for verification relative to NERs from ex-ante estimates.	x	x	x	x	x	x	x	x	x
MR.84	Evaluating Project Performance	Description of the cause and effect of deviations from ex-ante estimates.	x	x	x	x	x	x	x	x	x
MR.85	Data and Parameters Monitored	List of parameters from Appendix H, their values and the time last measured.	x	x	x	x	x	x	x	x	x

MR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
MR.86	Data and Parameters Monitored	Quality assurance and quality control measures employed for each.	x	x	x	x	x	x	x	x	x
MR.87	Data and Parameters Monitored	Description of the accuracy of each.	x	x	x	x	x	x	x	x	x
MR.88	Description of the Monitoring Plan	Documentation of training for field crews.	x	x	x	x	x	x	x	x	x
MR.89	Description of the Monitoring Plan	If included in project activities, a description of procedures used to estimate the rate of biomass burning and charcoal production and demonstration that these estimates are conservative.	x	x	x	x	x	x	x	x	x
MR.90	Description of the Monitoring Plan	Documentation of data quality assessment such as a check cruise and plots of the data such as diameter distributions by strata or plot.	x	x	x	x	x	x	x	x	x
MR.91	Description of the Monitoring Plan	Maps of a stratification (if any) and references to plot allocation.	x	x	x	x	x	x	x	x	x
MR.92	Description of the Monitoring Plan	List of plot GPS coordinates.	x	x	x	x	x	x	x	x	x
MR.93	Description of the Monitoring Plan	Description of plot sizes and layout (such as the use of nests and their sizes) for each carbon pool.	x	x	x	x	x	x	x	x	x
MR.94	Description of the Monitoring Plan	If applicable, a detailed description of the process used to develop allometric equations, to include: a. Sample size b. Distribution (eg, diameter) of the sample c. Model fitting procedure d. Model selection	x	x	x	x	x	x	x	x	x

MR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
MR.95	Description of the Monitoring Plan	The estimated carbon stock, standard error of the total for each stock, and the sample size for each stratum in the area selected.	x	x	x	x	x	x	x	x	x
MR.96	Description of the Monitoring Plan	Log export monitoring records and standard operating procedure in the project area, if there is commercial harvest in the project scenario.	x	x	x	x	x	x	x	x	x
MR.97	Description of the Monitoring Plan	Deviations from the measurement methods set out in Appendix B or the monitoring plan, per current VCS requirement.	x	x	x	x	x	x	x	x	x
MR.98	Description of the Monitoring Plan	The frequency of monitoring for each plot for all plots – all plots should be measured for the first verification. All leakage plots should be measured every verification, and all proxy and project accounting area plots at least every five years, or after a significant event that changes stocks.	x	x	x	x	x	x	x	x	x
MR.99	Sources of Allometry	A list of all selected allometric equations used to estimate biomass for trees and non-trees.	x	x	x	x	x	x	x	x	x
MR.100	Sources of Allometry	For each selected allometric equation, a list of species to which it is being applied and the proportion of the total carbon stocks predicted by the equation.	x	x	x	x	x	x	x	x	x
MR.101	Sources of Allometry	For each selected allometric equation, indication of when it was first employed to estimate carbon stocks in the project area (monitoring period number and year of monitoring event).	x	x	x	x	x	x	x	x	x
MR.102	Sources of Allometry	For each selected allometric equation, indication of whether was validated per sections 9.3.1.1 or 9.3.1.2.	x	x	x	x	x	x	x	x	x
MR.103	Sources of Allometry	Documentation of the source of each selected allometric equation and justification for their applicability to the project area considering climatic, edaphic, geographical and taxonomic similarities between the project location and the location in which the equation was derived.	x	x	x	x	x	x	x	x	x

MR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
MR.104	Validating Previously Developed Allometry	A list of allometric equations validated by destructive sampling.	x	x	x	x	x	x	x	x	x
MR.105	Validating Previously Developed Allometry	For each, the number of trees (or non-trees) destructively sampled and the location where the measurement were made relative to the project area.	x	x	x	x	x	x	x	x	x
MR.106	Validating Previously Developed Allometry	A field protocol used to measure destructively sampled trees (or non-trees).	x	x	x	x	x	x	x	x	x
MR.107	Validating Previously Developed Allometry	Justification that the field protocol for the destructive measurement method conservatively estimates biomass.	x	x	x	x	x	x	x	x	x
MR.108	Validating Previously Developed Allometry	For each allometric equation in the list, a figure showing all the descriptive measurements of biomass compared to predicted values from its selected allometric equation.	x	x	x	x	x	x	x	x	x
MR.109	Validating Newly Developed Allometry	A list of allometric equations cross validated.	x	x	x	x	x	x	x	x	x
MR.110	Validating Newly Developed Allometry	For each, the number of trees (or non-trees) destructively sampled to build the equation and the location where the measurements were made relative to the project area.	x	x	x	x	x	x	x	x	x

MR #	Category	Requirement	F-P1.a	F-P1.b	F-P2	F-U1	F-U2	F-U3	G-P2	G-U1	G-U2
MR.111	Validating Newly Developed Allometry	A field protocol used to measure trees (or non-trees) when developing the equation.	x	x	x	x	x	x	x	x	x
MR.112	Validating Newly Developed Allometry	Justification that the field protocol for the measurement method to build the equation conservatively estimates biomass.	x	x	x	x	x	x	x	x	x
MR.113	Validating Newly Developed Allometry	For each allometric equation in the list, the value of E.	x	x	x	x	x	x	x	x	x

DOCUMENT HISTORY

Version	Date	Comment
v1.0	11 Feb 2011	Initial version released
v1.1	10 Nov 2011	Clarifications were made to the soil carbon loss model in section 6.5. Specifically, updates (all effective on issue date) were made to: 1. Clarify the lambda value in section 6.5.2. 2. Clarify the procedures for soil sampling in section 6.5.3.
v2.0	26 Oct 2012	Revisions were made to the methodology to accommodate a variety of baseline deforestation scenarios. The methodology now quantifies GHG removals from avoiding planned deforestation and unplanned deforestation in both the mosaic and frontier configurations. End land use carbon stocks are based on a proxy area. The decay of carbon from the belowground biomass, dead wood, and harvested wood products pools have been updated to decay over time and may not be assumed to be immediately released.
v2.1	13 Dec 2012	A correction was made to the methodology to insert Equation [F.9] to Appendix F which was also referenced in section 6.18, because the equation was inadvertently omitted.
v3.0	6 Jun 2014	1. Avoided Conversion of Grasslands and Shrublands (ACoGS) was added as an eligible project type under the methodology. 2. Clarification was provided for baseline type F-P1 by dividing it into baseline types F-P1.a and F-P1.b.

VCS Methodology

VM0010

Methodology for Improved Forest Management: Conversion from Logged to Protected Forest

Version 1.3

28 April 2016

Sectoral Scope 14

Table of Contents

This methodology was developed by:

Authors
Mark Dangerfield, Charlie Wilson, Tim Pearson and James Schultz

About GCS

GreenCollar Consulting Solutions (GCS) is an environmental markets and project services consultancy with extensive experience in the development of agriculture, forestry and other land use (AFOLU) methodologies, policy and projects throughout Asia-Pacific. Our goal is to provide the tools and support services that will help land managers realize the full commercial potential of their environmental assets. Our diverse work experience extends from agriculture and forest management methodology development and project development, to domestic and international policy advice. Our project experience includes work on some of the world's largest carbon forestry and agricultural projects and initiatives. GCS is based in Sydney and has strong strategic partnerships with firms in Europe, North America and Asia.

1 SOURCES

This methodology uses the latest versions of the following methodologies, modules and tools:

- CDM *Tool for Calculation of the Number of Sample Plots for Measurements within A/R CDM Project Activities*
- CDM *Tool for testing significance of GHG emissions in A/R CDM project activities*
- VCS methodology *VM0003 Methodology for Improved Forest Management through Extension of Rotation Age*
- VCS methodology *VM0005 Methodology for Conversion of Low-Productive Forests to High-Productive Forests*
- VCS methodology *VM0007 REDD+ Methodology Framework (REDD-MF)*
- VCS methodology *VM0011 Methodology for Improved Forest Management: Calculating GHG Benefits from Logged to Protected Forest*
- VCS tool *VT0001 Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities*

2 SUMMARY DESCRIPTION

Additionality	Project Method
Crediting Baseline	Project Method

This Logged to Protected Forest (LtPF) methodology provides a detailed procedure to estimate the net GHG emission reductions/removals resulting from the implementation of IFM projects aimed at the protection of forests that would be logged in the absence of the project.

The core methodological components are as follows:

- Determine Eligibility: Sets the criteria for eligibility of projects under the methodology
- Set Project Boundaries and Scope: Provides guidelines for defining the geographical and temporal boundaries of the project and lists the GHG emissions sources and carbon pools to be included in the project
- Assess Baseline Scenario, Additionality and Baseline Modelling: Provides guidelines to select the most conservative baseline scenario and to determine the additionality of the project

- Quantify Baseline Emissions: Provides the detailed procedure to develop conservative estimates of net greenhouse gas emissions resulting from changes in carbon stocks as a result of planned timber harvest in the baseline scenario

- Quantify Project Emissions: Provides the detailed procedure to develop conservative estimates of net greenhouse gas emissions resulting from changes in carbon stocks in the project scenario

- Quantify Leakage: Describes the approach to account for leakage arising from the implementation of project activities

- Quantify Net Emission Reductions: Provides the approach to determine the amount of net greenhouse gas emission reductions/removals at the end of each year for both the baseline and project scenarios

- Quantify Verified Carbon Units: Provides the approach to determine, on the basis of the amount of net greenhouse gas emission reductions/removals, and deductions to account for risk and uncertainty, the amount of Verified Carbon Units (VCUs) that should be credited to the project each year over the project crediting period

- Perform Ongoing Monitoring: Provides guidelines for the implementation of a monitoring plan and identifies monitored parameters to assess carbon stock change and disturbance in the project scenario.

3 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions*, the below definitions apply to this methodology.

Commercial Timber Harvest
Removal of merchantable trees from a forest to obtain income from the wood products

Diameter at Breast Height (DBH)
A common dendrometric measurement to determine the diameter of the bole of a tree at 1.3 meters

Forestry Infrastructure
Physical infrastructure needed to carry out forestry operations, including (but not restricted to) roads, skid trails and log landings in the project area

Forest Inventory
A system for measuring the extent, quantity and condition of a forest by sampling through:

- A set of objective sampling methods designed to quantify the spatial distribution, composition and rates of change of forest parameters within specified levels of precision for the purpose of management; and
- Listing of data from such a survey

Land Parcel
The area of land within a forest specified for annual logging and timber extraction operations as defined in a timber harvest plan

Logging Slash
A component of the deadwood pool, representing the woody debris left in the forest estate that is generated during a timber harvest event

Planned Timber Harvest
Planned removal of merchantable trees from a forest to obtain income from the wood products under legal conditions for harvest and documented under a timber harvest plan

Timber Harvest Plan
Description of the methods and operations needed to harvest timber from a forest under a given set of legal conditions for harvest that includes:

- Demarcation of non-harvest areas within the forest
- Division of the harvestable forest into annual operating areas (land parcels) presented as descriptions and maps
- Design and presentation of the transport system for the removal of harvested timber products; and a description of the harvest and transport machinery used for timber harvest

3.1 Symbols and Notations

3.1.1 Physical quantities

This section presents the symbols that are used throughout the methodology to represent physical quantities used in the accounting equations.

Flows of greenhouse gas(es)

The symbol GHG is the common identifier used throughout this methodology to represent flows of greenhouse gas(es) to/from the atmosphere.

For these flows, the absolute value represents the intensity of the flow, in tCO_2e year-1, or the total amounts exchanged with the atmosphere, in tCO_2e.

Carbon stocks

The symbol C is the common identifier used throughout this methodology to represent carbon stocks. The values presented are either carbon stocks (in tC), or carbon stocks per unit area (in tC·ha-1) as indicated in the methodology described under Section 2.

Carbon stock changes

The symbol ∆C is the common identifier used throughout this methodology to represent changes in carbon stocks. The values presented could be either total changes in carbon stocks (in tC), annual changes in carbon stocks (in tC·year-1), or annual changes in carbon stocks per unit area (in tC·ha-1·year-1), as indicated in the methodology described under Section 2.

3.1.2 Scenario qualifiers

This section presents the symbols that are used throughout the methodology as scenario qualifiers, for the physical quantities used in the accounting equations as follows:

- Physical quantities referring to the baseline scenario feature the suffix (BSL)
- Physical quantities referring to the project scenario feature the suffix (PRJ)
- Physical quantities derived from baseline and project scenario accounting feature the suffix (LtPF)

4 APPLICABILITY CONDITIONS

Projects must fall within the VCS AFOLU project category “IFM: Logged to Protected Forest” as defined in the most recent version of the VCS *AFOLU Requirements* document.

Specific conditions under which this methodology is applicable are:

- Forest management in the baseline scenario must be planned timber harvest
- Under the project scenario, forest use must be limited to activities that do not result in commercial timber harvest or forest degradation
- Planned timber harvest must be estimated using forest inventory methods that determine allowable off take as volume of timber (m^3 ha-1)
- The boundaries of the forest land must be clearly defined and documented
- The baseline scenario cannot include conversion to managed plantations

- The baseline scenario, project scenario and project case cannot include wetland or peatland

- All applicability conditions of VCS and CDM tools used in conjunction with this methodology must be met.

4.1 Eligibility

Legal Right to Harvest

The legal right to harvest must pre-exist the implementation of the project.

The legal right to harvest must be issued by a relevant government body, define a legal allocation of rights to a forest timber resource, and include a plan for forest management that includes a definition of the spatial extent of the forest, the volume of the timber resource to be extracted and a description of harvesting practices.

Rights to forest management must be demonstrated by documentary proof of legal permissibility for timber harvest, intent to harvest and a description of the timber resource. This proof must be issued by the relevant (governmental) regulatory body that has designated, sanctioned or approved the project area (or areas) for forest management.

Intent to Harvest

The project proponent must demonstrate intent to harvest through the following forms of evidence originating prior to the date of all evidence in pursuit of carbon finance/consideration of IFM.

Projects must provide either:

- Documented evidence demonstrating that:

    - The project site is representative of other forestlands harvested in the country within the past two years; and,

    - The project site is within commercially viable distance to existing transport networks and a port for timber export or a mill for timber processing; or,

- A valid and verifiable government-approved timber management plan for harvesting the project area.

5 PROJECT BOUNDARY

5.1 Geographical Boundaries

The project proponent must clearly define the spatial boundaries of the project so as to facilitate accurate measuring, monitoring, accounting and verifying of the project's emission reductions and removals.

The IFM project activity may contain more than one discrete area of land.

When describing physical project boundaries, the following information must be provided per discrete area:

- Name of the project area (including compartment number, allotment number, local name)
- Unique identifier for each discrete land parcel used in the timber harvest plan
- Map(s) of the area (preferably in digital format)
- Geographic coordinates of each polygon vertex (preferably obtained from a geodetic coordinate or from a geo-referenced digital map)
- Total land area
- Details of forest land rights holder and user rights

The geographic boundaries of an IFM project are fixed and thus do not change over the project crediting period.

The geographic boundaries for leakage from market effects are those of the country in which the project area is located.

5.2 Temporal Boundaries

The temporal boundaries are defined by the project start date and length of the project crediting period.

The minimum duration of a monitoring period is one year and the maximum duration is 10 years.

5.3 Carbon Pools

The carbon pools included or excluded from the project boundary are shown in Table 1 below.

Table 1: Carbon Pools

Carbon pools	Included?	Justification / Explanation of choice
Aboveground trees	Included	The stock change in the above ground tree biomass must be estimated
Above ground non-tree	Excluded	Exclusion is always conservative when forests remains as forest
Belowground	Excluded	Unlikely to change significantly in forests remaining as forests and is difficult to measure-omission is conservative
Deadwood (logging slash)	Included in the baseline	The dead wood (logging slash) carbon pool is expected to be larger in the baseline than in the project scenario, and therefore this pool must be included
Dead wood (naturally accumulated)	Excluded	Following IPCC guidelines[1], it is assumed that carbon stocks in the naturally occurring dead wood pool (both standing and lying) are equivalent in both the project and baseline scenario, and therefore this pool is conservatively excluded. It is not conservative to account for this pool in the baseline scenario only.
Harvested wood products	Included	Will be greater in baseline than project scenario and significant
Litter	Excluded	Insignificant and exclusion is conservative
Soil organic carbon	Excluded	Exclusion is always conservative when forests remains as forest

[1]IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories; Volume 4 AFOLU, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

5.4 Greenhouse Gases

The emission sources included in or excluded from the project boundary are shown in Table 2 below.

The project proponent may choose to exclude to account for GHG emissions related to the combustion of fossil fuels (please refer to Section 8.1.5), which is conservative. If the project proponent decides to include accounting for GHG emissions related to fossil fuel combustion, then the specific GHGs must be tested for significance, using the most recent version of the CDM *Tool for testing significance of GHG emissions in A/R CDM project activities.*

If the application of the tool leads to the conclusion that the emission source is insignificant[2], then this GHG must be neglected. In addition, the sum of decreases in carbon pools and increases in emissions that may be neglected must be less than 5% of the total project GHG benefits.

Table 2: Emission Sources

Gas	Sources	Included?	Justification
CO_2	Combustion of fossil fuels (in vehicles, machinery and equipment)	Included, if significant	Only included if tested as significant. Otherwise excluded, which is deemed conservative, as emissions will be greater in the baseline scenario than in the project scenario.
	Removal of herbaceous vegetation	Excluded	Based on CDM EB decision reflected in paragraph11ofthe report of the23rdsessionoftheboard: cdm.unfccc.int/Panels/ar/023/ar_023_rep.pdf
CH_4	Combustion of fossil fuels (in vehicles, machinery and equipment)	Included, if significant	Only included if tested as significant. Otherwise excluded, which is deemed conservative, as emissions will be greater in the baseline scenario than in the project scenario.
	Burning of Biomass	Included	Included as CO_2 equivalent emissions
N_2O	Combustion of fossil fuels (in vehicles, machinery and equipment)	Included, if significant	Only included if tested as significant. Otherwise excluded, which is deemed conservative, as emissions will be greater in the baseline scenario than in the project

[2]http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html

			scenario.
	Nitrogen based fertilizer	Excluded	Potential emissions are negligible. Following the VCS update to the *Tool for AFOLU Methodological Issues and Guidance for AFOLU Projects*, emissions through the use of fertilizer are considered insignificant and are not considered here.
	Burning of Biomass	Excluded	Potential emissions are negligible

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

6.1 Selection of baseline

The project proponent must use the most recent version of the VCS tool, *VT0001 Tool for the Demonstration and Assessment of Additionality in AFOLU Project Activities* to assess which of the baseline alternatives must be excluded from further consideration.

As per the applicability conditions of this methodology, the project must demonstrate a baseline scenario of planned timber harvest. If such a baseline cannot be demonstrated, then this methodology cannot be applied.

Planned timber harvest events in the baseline scenario can occur in any year of the project activity, not just year *0*.

6.2 Modeling the baseline scenario

Once the baseline scenario of planned timber harvest is demonstrated, the project proponent must determine how to model the baseline management scenario. A Historical Baseline Scenario (Section 6.2.1) must be used where data is available, otherwise a Common Practice Baseline Scenario (Section 6.2.2) must be used.

Irrespective of which baseline scenario is used, the same formulas (as set out in Sections 8.1.1 to 8.1.6) for the quantification of baseline emissions are applied. The major difference between the historical and common practice baseline scenarios is the source of data for the majority of parameters (see Section 9.1) which are used in Sections 8.1.1 to 8.1.6 to calculate baseline emissions.

Where the historical baseline scenario is applied, the historical data pathway must be followed with regard to data sources for the majority of parameters available at validation.

Where the common practice scenario is applied, the common practice data pathway must be followed with regard to data sources for the majority of parameters available at validation.

In principle, under the historical baseline scenario, historical records of timber harvesting from the baseline agent are used to determine the values of many of the parameters available at validation, whereas under the common practice scenario other sources (eg, data from other forestry companies in the region, regional default values, legal requirements, etc.) must be used. See Sections 8 and 9.1 for further detail.

6.2.1 Historical Baseline Scenario

A baseline scenario and timber harvest plan (see Box 1 below) derived from the historical practices of the baseline agent of timber harvest must be modelled as the baseline if the following documents exist for the project proponent

1) Historical records of forest management exist for a minimum of 5 or more years preceding the project start date.
2) Historical records indicate that the management practices have surpassed the legal requirements (provided by conforming to all local and regional forest legislation).
3) Historical records that indicate that the historical management surpasses financial barriers by providing above average financial returns.

6.2.2 Common Practice Baseline Scenario

All other cases must model baseline harvest based on common practice.

Common practice is defined as timber harvest under the legal requirements for forest management and will be determined from a timber harvest plan (see Box 1 below) developed from:

1) The project area through scenario modeling as though the legal requirements were implemented in the project area; and
2) A reference area[3] (or multiple reference areas) already under timber harvest management that complies with legal requirements for forest management and selected to be representative of local common practice for timber harvest.

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[3] Reference areas must be in the same region as the project area and must match the project area in terms of forest types, climate and elevation (identical mix of forest types ±20%; identical annual precipitation ±20%; elevation classes (500 m classes) in the reference region shall be in the same proportion as in the project area (+/-20%))
For forest types, a de minimis rule may be applied if not suitable reference area can be found. Forest types that cover less than 1% of the project area may be excluded for the purpose of finding a suitable reference area. However, in total, no more than 5% of the project area forest cover may be excluded in this way.

Common practice cannot contradict management of the baseline agent except where common practice represents a lower harvest intensity (in m^3/ha) than management by the baseline agent.

Where there is limited capacity to generate the baseline scenario using a reference site in the region of the project area, multiple reference areas may be selected to cover a country so long as the reference area criteria regarding forest types, climate and elevation are met.

Box 1: Timber Harvest Plan

The description of harvesting in the form of a timber harvest plan forms the basis of the baseline scenario for greenhouse gas accounting.

The timber harvest plan describes the harvest of timber products and must:

1) Reference the forest volume inventory (see Section 8.1.1 – parameter $V_{j,i|BSL}$) to identify the relative number of trees per hectare potentially available for harvest by species in each stratum
2) Demarcate all non-harvest areas within the forest based on legally required exclusions for environmental features such as slope, swamp areas or conservation buffers
3) Divide the harvestable forest into annual operating areas (referred to throughout this methodology as land parcels) using common practice
4) Include a design and presentation of the forestry infrastructure to harvest, skid/haul, store and move harvested timber products from the land parcels to downstream processing or market entry points. Where the project proponent accounts for emissions from forestry infrastructure, the design and presentation must include all forest roads, skidtrails and log landings that would be established under the baseline scenario as a georeferenced layer (shapefile or equivalent), and must list necessary harvest and transport machinery.
5) The timber harvest plan must follow local best practice for timber harvest practices, including planning of roads, skidtrails and log landings-and the timber resource volume and extraction quotas defined in any legal requirements.

For the purpose of estimating the net annual changes in carbon stocks resulting from planned timber harvest in the baseline scenario, a detailed planned timber harvesting schedule will be developed from the timber harvest plan, setting out details of harvest and forestry infrastructure establishment for each land parcel in the project area in terms of the following:

1) The species to be harvested[5]

2) The year(1,2,3...) in which timber harvest and/or forestry infrastructure establishment in of each land parcel is scheduled to occur

3) The number of years each land parcel is in a post-harvest and/or post forestry infrastructure establishment state during the project crediting period

4) The maximum and minimum diameters at breast height (DBH), at stump and at top for tree harvesting

5) The planned harvesting regime (clearfelling, specie/stratum-selective logging, area- selective logging)

6) The fraction of merchantable timber volume from clearing of forest roads, skidtrails and log landings that is to be processed into wood products ($F_{V,INF,HWP}$). Based on this fraction, as well as forest inventory and forestry infrastructure data, $V_{EX,INF,j,i|BSL}$ and $V_{notEX,INF,j,i|BSL}$ (see points 2 and 3 below) will be calculated.

7) The technical specifications for the categories of wood products to be harvested

8) The total volumes or fractions to be harvested, broken down by categories of wood products defined as sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other.

The planned timber harvest schedule is determined *ex ante* to reflect the timber harvesting plan as stipulated in the legal right to harvest. The *planned timber harvesting schedule* will be developed for the project area to include all land parcels within the project boundary for the proposed IFM activity.

The output of the timber harvest plan and timber harvesting schedule must be:

1) The mean extracted volume of extracted merchantable timber per unit area by species in each stratum in each year ($V_{EX,j,i|BSL}$).

2) Where the project proponent accounts for forestry infrastructure, the mean volume of merchantable timber extracted for wood processing that is harvested during the process of forestry infrastructure establishment per unit area by species in each stratum in each year ($V_{EX,INF,j,i|BSL}$).

3) Where the project proponent accounts for forestry infrastructure, the mean volume of merchantable timber that is cleared during the process of forestry infrastructure establishment and NOT extracted for wood processing per unit area by species in each stratum in each year ($V_{notEX,INF,j,i|BSL}$).

The planned timber harvesting schedule will be submitted by the project proponent as part of the project documents.

6.3 Stratification

If the proposed project area contains different forest types or forests with different carbon density, stratification must be carried out in order to improve the accuracy and precision of carbon stock estimates.

For estimation of base year carbon stocks, strata must be defined on the basis of parameters that are key variables in any method used to estimate changes in managed forest carbon stocks. Strata will include either forest type, vegetation type and/or target timber species.

Based on the availability of data regarding the nature and composition of forest stocks in the project area, stratification will be developed on the basis of either:

a) Existing vegetation mapping or stratification, where these are documented in the legal right to harvest; or,

b) Estimates developed from sampling the project area using standard forest assessment protocols specific to the forest region where the project area is located.

Baseline stratification is developed *ex ante*.

The project proponent must submit as part of the project documents a detailed description of the stratification adopted for the project area.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

The project proponent must demonstrate the additionality of the project using the most recent version of VCS tool, *VT0001 VCS Tool for the Demonstration and Assessment of Additionality in AFOLU Project Activities*.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

Calculation of baseline emissions for all land parcels under both the historical and common practice baseline scenarios requires the application of the equations presented in Sections 8.1.1 to Section 8.1.6.

Table 3 lists the baseline emissions modeled by this methodology.

Table 3: Emission Included in Baseline Modeling

Included in modelling
All projects: 1. Emission from wood product conversion 2. Decomposition of deadwood from harvested trees 3. Emissions from wood product retirement 4. Stock change due to regrowth following timber harvest 5. Decomposition of trees incidentally killed during tree felling Where project proponent accounts for forestry infrastructure: 6. Decomposition of trees killed through skid trail creation 7. Decomposition of trees killed through road construction Optional (as omission is conservative): 8. Emissions from fossil fuels burned in baseline harvesting practices
Conservatively excluded from modeling

1. Emissions through subsequent forest re-entry

Baseline projections are calculated ex-ante and are not adjusted throughout the project crediting period.

Section 8.1.1 serves to calculate carbon stocks in commercial timber volumes. Next, baseline emissions are estimated based on the calculation of deadwood (logging slash) generated in the process of timber harvest and establishment of forestry infrastructure (Section 8.1.2), the emissions resulting from production and subsequent retirement of wood products derived from timber harvesting (including timber harvesting from the establishment of forestry infrastructure (Section 8.1.3)), the combustion of fossil fuels in forestry machinery including mechanized felling, skidding / forwarding /hauling, loading and transporting inside the project area, and processing (Section 8.1.5), minus the rates of forest regrowth post-timber harvest (Section 8.1.6).

Baseline commercial timber volumes must be derived for development of the timber harvest plan and for ex-post accounting of emissions resulting from natural forest disturbance.

The equations below calculate the total emissions across the project crediting period for each emission source. Total emissions are averaged across the project crediting period to give annual emissions and are multiplied by t*, time elapsed since the start of project activity. Ex-post, t* is updated so baseline projections are available for each proposed future verification date.

Data for input into these carbon stock change calculations for the baseline scenario must be established from the same data used to create the timber harvesting plan.

Depending on which baseline scenario is applied (ie, historical or common practice), the project proponent must follow either the ‘historical data pathway’ (for historical baseline scenario) or the ‘common practice data pathway’ (for the common practice baseline scenario) when applying the formulas in Sections 8.1.1 to 8.1.6.

As a result, the sources for the majority of parameters described in Section 9.1 must be chosen accordingly:

- Under the historic data pathway: Where applicable, parameters must be based on the historical logging practices of the baseline agent.

- Under the common practice pathway: Where applicable, parameters must be based on data that reflects common practice in the region (data from other forestry companies in the region, forest management according to the legal requirements, regional default values that, in quantitative terms, reflect average values with regard to forest management. Where data is not readily identifiable as reflecting common practice, the responsible forest department, or another equivalent institution, must confirm that the value in question is considered as being common practice in the region.

8.1.1 Calculation of carbon stocks in commercial timber volumes

This section calculates $C_{HB,j,i|BSL}$, the mean carbon stock in total harvested biomass in tC·ha-1 and $C_{EX,j,i|BSL}$, the mean carbon stock in extracted timber (merchantable timber that leaves the forest) in tC·ha-1. This includes harvested biomass from the clearing of roads, skid trails and log landings, where applicable. The following calculation of merchantable volume of timber per unit area ($V_{j,i|BSL}$) that is potentially available for harvest must be based on data from field measurements in sample plots.

It is acceptable to use pre-existing forest inventory data[4] for this purpose, provided that the pre-existing data:

a) Represents the project strata;

b) Is not more than 10 years old; and,

c) Where forest inventory data is more than 10 years old, that the volume estimate derived from the pre-existing data has been validated with limited sampling within the project area.

Validation of pre-existing forest inventory data must be carried out by field surveys. For each strata, mean volume is estimated from sample plots/points measured within the project area using standard forest inventory assessment methods. The number of sample plots will be determined from application of the most recent version of the CDM tool, *Tool for Calculation of the Number of Sample Plots for Measurements within A/R CDM Project Activities*[5].

If the validated estimate of volume is within the 90% confidence interval of the corresponding estimate or is greater than the estimate calculated from pre-existing forest inventory data, the pre-existing forest inventory data may be used. If the validation estimate is less than the corresponding estimate calculated from pre-existing forest inventory data, the estimate from pre-existing data cannot be used.

Estimation of the merchantable volume of trees must be based on locally derived allometric equations or yield tables. If locally derived equations or yield tables for each species are not available, it is acceptable to use relevant regional, national or default data.

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[4] Standard quality control / quality assurance procedures for forest inventory including field data collection and data management shall have been applied to the forest inventory assessment. Sampling data and methods shall be available for verification. Sample sizes shall have been sufficient to ensure inventory estimates are within the 95% confidence intervals with the estimated variance within +/- 15 percent from the mean.

[5]http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html

Yield tables or allometric equations must be used to convert field measurements of diameter (DBH, at typically 1.3 m [4.3 ft] aboveground level or above buttress where they exist), and total height H of each tree in the sample plots to merchantable volume, $V_{l,j,i,sp}$.

It is acceptable to combine DBH and allometric equations if field instruments (eg, a relascope) that measure the volume of each tree directly have been used.

The estimate of merchantable volume for each species *j* at the sample plot level will be calculated as:

$$\boldsymbol{V_{j,i,sp} = \sum_{l=1}^{L} V_{l,j,i,sp}} \qquad \textbf{(1)}$$

Where:

Vj,i,sp	Merchantable volume for species *j* in stratum *i* in sample plot *sp*, m^3;
Vl,j,i,sp	Merchantable volume for tree *l* of species *j* in stratum *i* in sample plot *sp*; m^3[6]
l	1,2,3…*l* sequence of individual trees in sample plot;
i	1,2,3 …*M* strata;
sp	1,2,3 …*SP* sample plots; and
j	1,2,3 …*J* tree species.

Therefore, the merchantable volume per unit area of species *j* in stratum *i* will be calculated as the mean merchantable volume in all sample plots in stratum *i*:

$$V_{j,i|BSL} = \frac{1}{SP} * \sum_{sp=1}^{SP} \frac{V_{j,i,sp}}{A_{sp}} \qquad \textbf{(2)}$$

Where:

$V_{j,i\|BSL}$	Mean merchantable volume per unit area of species *j* in stratum *i* in the baseline scenario, $m^3 \cdot ha^{-1}$;
$V_{j,i,sp}$	Merchantable volume for species *j* in stratum *i* in sample plot *sp*; m^3;
Asp	Area of sample plot *sp*, ha; [7]

[6] See Data and parameters not monitored (default or possibly measured one time) list for information on data selection (p51).
[7] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

i	1, 2, 3 …*M* strata;
sp	1, 2, 3 …*SP* sample plots; and
j	1, 2, 3 …*J* tree species.

$V_{j,i|BSL}$ will be used to develop the timber harvest plan (Box 1 above). The timber harvest plan sets the allowable mean extracted volume ($V_{EX,j,i|BSL}$) from this merchantable volume based on legal limits.

Further, based on $Vj_{,i|BSL}$, the timber harvest plan will specify the mean extracted volume that is harvested for the purpose of building forestry infrastructure ($V_{EX,INF,j,i|BSL}$).

Once the timber harvest plan is complete and $V_{EX,j,i|BSL}$ *as well as (*$_{VEX,INF,j,i|BSL}$*)* is calculated, the Biomass Conversion and Expansion Factors (BCEF) method[8,9] must be used to determine the carbon stock in harvested biomass.

This method is appropriate as forest inventory data and allowable harvest must be based on volume estimates to which expansion factors can be readily applied. The selected *BCEF* must have a minimum DBH compatible with the minimum DBH defined in the timber harvest plan (Box 1 above).

Therefore, the carbon stock of timber harvested per unit area for species *j* in stratum *i* will be calculated from this mean volume of extracted timber:

$$C_{HB,j,i|BSL} = (V_{EX,j,i|BSL} + V_{EX,INF,j,i|BSL}) * BCEF_R * CF_j \quad \textbf{(3)}$$

Where:

$C_{HB,j,i\|BSL}$	Mean carbon stock of harvested biomass per unit area for species *j* in stratum *i*, $tC \cdot ha^{-1}$;
$V_{EX,j,i\|BSL}$	Mean volume of extracted timber per unit area for species *j* in stratum *i*, $m^3 \cdot ha^{-1}$;
$V_{EX,INF,j,i\|BSL}$	Mean volume of extracted timber for forestry infrastructure per unit area for species j in stratum i, $m^3 \cdot ha^{-1}$;
$BCEF_R$	Biomass conversion and expansion factor applicable to wood removals in

[8] Somogyi, Z., E. Cienciala, R. Mäkipää, P. Muukkonen, A. Lehtonen and P.Weiss. (2006) Indirect methods of large-scale forest biomass estimation, Eur.J.ForestRes. 126 (2) pp.197–207. http://dx.doi.org/10.1007/s10342-006-0125-7.
[9] IPCC. (2006) IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. In: Eggleston, H. S., Buendia, L. ,Miwa, K., Ngara, T., Tanabe, K. (Eds.). IGES, Japan. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html.

	the project area, t.d.m m^{-3};[10]
CF_j	Carbon fraction of biomass for species *j*, tCt $d.m.^{-1}$;[11]
i	1,2,3 …*M* strata; and
j	1,2,3 …*J* tree species.

Not all of the harvested biomass leaves the forest because the timber harvested has two components: 1) wood removed to market (extracted timber) and 2) wood remaining in the forest as a result of harvest (see Section 8.1.2).

Therefore, the mean carbon stock of extracted timber per unit area for species *j* in stratum *i* will be calculated from the mean volume of extracted timber multiplied by density and carbon fractions:

$$C_{EX,j,i|BSL} = (V_{EX,j,i|BSL} + V_{EX,INF,j,i|BSL}) * D_j * CF_j \quad \textbf{(4)}$$

Where:

$C_{EX,j,i\|BSL}$	Mean carbon stock of extracted timber per unit area for species *j* in stratum *i*; $tC \cdot ha^{-1}$;
$V_{EX,j,i\|BSL}$	Mean volume of extracted timber per unit area for species *j* in stratum *i*; in $m^3 \cdot ha^{-1}$;
$V_{EX,INF,j,i\|BSL}$	Mean volume of extracted timber for forestry infrastructure per unit area for species j in stratum i, $m^3 \cdot ha^{-1}$;
D_j	Basic wood density of species *j*; t d.m. m^{-3}; [12]
CF_j	Carbon fraction of biomass for species *j*, tC t $d.m.^{-1}$;
i	1,2,3 …*M* strata; and
j	1,2,3 …*J* tree species.

[10] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p47).

[11] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p47).

[12] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p51).

8.1.2 Calculation of dead wood (logging slash) generated in the process of timber harvest

This section calculates $\Delta C_{DWSLASH,i,p|BSL}$. $\Delta C_{DWSLASH,i,p|BSL}$ includes the following:

a) The change in carbon stock in dead wood (ie, logging slash) left on the forest floor following timber harvest in stratum *i* in land parcel *p*, using $C_{EX,j,i|BSL}$ and $C_{HB,j,i|BSL}$ as calculated in Section 8.1.1.

b) The change in carbon stock in dead wood (ie, logging slash) that results from residual stand damage ($C_{RSD,\ j,i|BSL}$). Residual stand damage is the breaking or uprooting of other neighboring trees during the process of tree felling. Residual stand damage is calculated using the residual stand damage factor $F_{RSD|BSL}$.

c) The change in carbon stock in dead wood (ie, logging slash) left on the forest floor following the establishment of forestry infrastructure in stratum i in land parcel *p*. This is calculated using $C_{notHB,INF,j,i|BSL}$ based on $V_{notEX,INF,j,i|BSL}$ as defined in the timber harvest plan. This does only include the emissions from entire trees left to decay as a result of forestry infrastructure construction. Emissions from logging slash of trees harvested for consequent processing during the establishment of forestry infrastructure are included under point A above.

The simplifying assumption is made that dead wood left on the forest floor following timber harvest follows a ten year linear decay function, as permitted by the *VCS AFOLU Requirements*. This decay function is applied when the net greenhouse gas emissions/removals are calculated on an annual basis in Equations 11 and 12 below.

Therefore, the change in carbon stock in the dead wood pool in stratum *i* in land parcel *p* is calculated as the difference between the total carbon stock of the harvested biomass and the carbon stock of the extracted timber, plus the residual stand damage and biomass of trees left to decay as a result forestry infrastructure establishment:

$$\Delta C_{DWSLASH,i,p|BSL} = \left[\sum_{j=1}^{J} [(C_{HB,j,i|BSL} - C_{EX,j,i|BSL}) + C_{RSD,j,i|BSL} + C_{notHB,inf,j,i|BSL}] \right] \quad \textbf{(5)}$$

Where:

$\Delta C_{DWSLASH,i,p|BSL}$	Change in carbon stock of dead wood as logging slash resulting from timber harvest per unit area in stratum *i* in land parcel *p*, in tC ha-1;
$C_{HB,j,i|BSL}$	Mean carbon stock of harvested biomass per unit area for species *j* in stratum *i*, tC·ha^{-1};
$C_{EX,j,i|BSL}$	Mean carbon stock of extracted timber per unit area for species *j* in stratum *i*, tC·ha^{-1};

$C_{RSD,j,i\|\mathrm{BSL}}$	Mean carbon stock in timber from residual stand damage per unit area for species j in stratum i, tC·ha^{-1}
$C_{notHB,inf,j,i\|\mathrm{BSL}}$	Mean carbon stock of biomass that is not harvested during the establishment of forestry infrastructure per unit area for species j in stratum i, tC·ha^{-1}
i	1, 2, 3 …*M* strata; and
j	1, 2, 3 …*J* tree species.
P	*1, 2, 3 ...P* land parcels.

The mean carbon stock in timber from residual stand damage ($C_{RSD,j,i|BSL}$) is calculated as follows:

$$C_{RSD,j,i|\mathrm{BSL}} = C_{EX,j,i|BSL} * F_{RSD|\mathrm{BSL}} \quad \textbf{(6)}$$

Where:

$C_{RSD,j,i\|\mathrm{BSL}}$	Mean carbon stock in timber from residual stand damage per unit area for species j in stratum i, tC·ha^{-1};
$C_{EX,j,i\|BSL}$	Mean carbon stock of xtracted timber per unit area for species j in stratum i, tC·ha^{-1};
$F_{RSD\|\mathrm{BSL}}$	Factor for residual stand damage, dimensionless;
i	1, 2, 3 …M strata; and
j	1, 2, 3 …J tree species;

The mean carbon stock of biomass that is not harvested during the establishment of forestry infrastructure ($C_{notHB,INF,j,i|BSL}$) is calculated as follows:

$$C_{notHB,inf,j,i|\mathrm{BSL}} = V_{notEX,inf,j,i|BSL} * BCEF_R * CF_j \quad \textbf{(7)}$$

Where

$C_{notHB,inf,j,i\|\mathrm{BSL}}$	Mean carbon stock of biomass that is not harvested during the establishment of forestry infrastructure per unit area for species j in stratum i, tC·ha^{-1}
$V_{notEX,inf,j,i\|BSL}$	Mean volume of timber that is not extracted for wood processing during the establishment of forestry infrastructure per unit area for species j in stratum i, m^3·ha^{-1};
$BCEF_R$	Biomass conversion and expansion factor applicable to wood removals in the project area, t.d.m m^{-3};
CF_j	Carbon fraction of biomass for species j, tC t d.m.$^{-1}$
i	1, 2, 3 …M strata; and
j	1, 2, 3 …J tree species

8.1.3 Calculation of baseline carbon sequestered in wood products

This section calculates the net carbon stock change resulting from wood product conversion and retirement.

In all cases where wood is harvested for conversion to wood products, carbon stock in the wood products pool must be included in the baseline case.

Carbon stocks treated here are those stocks entering the wood products pool at the time of harvest.

All factors are derived from Winjum *et al* (1998).

The carbon stock of extracted timber across species is calculated as:

$$C_{EX,i|BSL} = \sum_{j=1}^{J} C_{EX,j,i|BSL} \quad \textbf{(8)}$$

Where:

$C_{EX,i\|BSL}$	Change in carbon stock of extracted wood products resulting from timber harvest per unit area in stratum *i* in land parcel *p*, in tC ha-1;
$C_{EX,j,i\|BSL}$	Mean carbon stock of extracted wood per hectare, tC/ha;
i	1, 2, 3 …*M* strata; and
j	1, 2, 3 …*J* tree species.

The wood product class(es), *k*, (sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other) that are the anticipated end use of the extracted timber must now be selected. It is acceptable practice to assign gross percentages of volume extracted to wood product classes on the basis of local expert knowledge of harvest activities and markets.

In accordance with the *VCS AFOLU Requirements*, the amount of carbon stored in wood products that would decay within 3 years after harvest (ie, the Wood Waste (WW) and the Short Lived Fraction (SLF)), are assumed to be emitted at the time of harvest.

Wood products that are retired between 3 and 100 years after harvest (ie, the Additional Oxidized Fraction, *OF*), must be accounted according to a 20 year linear decay function. This decay function is applied when the net greenhouse gas emissions/removals are calculated on an annual basis in Equations 11 and 12 below.

All other wood product pools are considered to permanently store carbon.

Therefore, the carbon stock of extracted timber that is immediately emitted to the atmosphere at the time of harvest is calculated as:

$$C_{WP0,i|BSL} = \sum_{k} C_{EX,i,k|BSL} * (WW_k + SLF_k) \quad \textbf{(9)}$$

Where:

$C_{WP0,i\|BSL}$	Carbon stock of extracted timber from stratum *i* that is assumed to be emitted immediately at the time of harvest, in tC·ha^{-1};
$C_{EX,i\|BSL}$	Mean carbon stock of extracted timber per unit area in stratum *i*, for wood product type *k*, tC·ha^{-1};
WW_k	Fraction of biomass carbon from wood waste that is assumed to be emitted to the atmosphere immediately at the time of harvest for wood product *k*, dimensionless; [13]
SLF_k	Fraction of biomass carbon from the shortlived wood product pool that is assumed to be emitted to the atmosphere immediately at the time of harvest for wood product *k*, dimensionless
i	1,2,3 …*M* strata; and
k	Wood products (sawnwood, wood base products, etc)

The amount of extracted carbon stock that is assumed to enter the wood products pool that is not immediately emitted at harvest is calculated as per Equation 8 below:

$$C_{WPi|BSL} = \sum_{k} C_{EX,i,k|BSL} - C_{WP0,i|BSL} \quad \textbf{(10)}$$

Where:

$C_{WP,i\|BSL}$	Carbon stock of extracted timber from stratum *i* that is assumed to enter the wood products pool that is not immediately emitted at the time of harvest, in tC·ha^{-1};
$C_{EX,i\|BSL}$	Mean carbon stock of extracted timber per unit area in stratum *i*, for wood product type *k*, tC·ha^{-1};
$C_{WP0,i\|BSL}$	Carbon stock of extracted timber from stratum *i* that is assumed to be emitted immediately at the time of harvest, in tC·ha^{-1};

[13] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p51).

i	1,2,3 …*M* strata; and
k	Wood products (sawnwood, wood base products, etc)

Therefore, the carbon stock of wood products assumed to be retired between 3-100 years following harvest is calculated as:

$$C_{WP100,i|BSL} = C_{WP,i|BSL} * OF_k \quad \textbf{(11)}$$

Where:

$C_{WP100,i,p|BSL}$	Cabron stored in wood products that are assumed to be retired between 3 - 100 years after harvest from stratum i in land parcel p, tC ha-1;
$C_{WP,i|BSL}$	Carbon stock of extracted timber from stratum *i* that is assumed to enter the wood products pool that is not immediately emitted at the time of harvest, in tC·ha^{-1};
OF_k	Fraction of biomass carbon for wood product type *k* that is assumed to be emitted to the atmosphere between 3 and 100 years of timber harvest, dimensionless;[14] and
i	1,2,3 …*M* strata.

8.1.4 Change in carbon stocks due to forest regrowth after harvest

This section calculates $\Delta C_{RG,i,p|BSL}$, the carbon sequestration resulting from forest regrowth after timber harvest and establishment of forestry infrastructure in stratum *i* in land parcel *p*; tC.

The carbon sequestration in the baseline scenario resulting from forest regrowth after timber harvest up to year *t* is equal to the forest regrowth rate of each stratum.

Therefore, carbon sequestration resulting from forest regrowth after timber harvest is calculated as:

$$C_{RG,i,p|BSL} = \sum_i RGRi \quad \textbf{(12)}$$

Where:

$C_{RG,i,p|BSL}$	Carbon sequestration resulting from forest regrowth after timber harvest and establishment of forestry infrastructure in stratum *i* in land parcel *p*, tC ha^{-1}yr^{-1};

[14] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

RGR_i	Regrowth rate of forest post timber harvest post forestry infrastructure establishment for stratum i, tC $ha^{-1}yr^{-1}$; [15]
i	1,2,3 …M strata

8.1.5 Calculation of baseline emissions from the combustion of fossil fuels in forestry and wood processing machinery

The implementation of the baseline activity (selective logging and/or clearcutting) entails the use of forestry and wood processing machinery, which leads to GHG emissions from fossil fuel combustion. Omission of any or all of the associated GHG emission sources is conservative.

The total GHG emissions from fossil fuel combustion in the baseline scenario (C_{FUEL}) is determined from the summation of all the emission sources presented in Table 2 using the following equation:

$$C_{FUEL} = \frac{E_{HARVEST} + E_{HAULING} + E_{TRANSPORT} + E_{PROCESSING}}{44/12} \quad \textbf{(13)}$$

Where:

C_{FUEL}	Total carbon emissions associated with the combustion of fossil fuel in forestry and wood processing machinery, in tC
$E_{HARVEST}$	Fossil fuel emissions due to harvesting operations such as felling and snigging, in tCO_2e;
$E_{HAULING}$	Fossil fuel emissions due to log hauling, in tCO_2e;
$E_{TRANSPORT}$	Fossil fuel emissions due to log transport from collection depot to processing plant, in tCO_2e;
$E_{PROCESSING}$	Fossil fuel emissions due to electricity consumption in sawmill, in tCO_2e;

8.1.5.1 Emissions Due to Harvesting Operations

Mechanical harvesting operations of merchantable logs contributes to GHG emissions. This operation in countries containing tropical forests commonly employs chainsaws, while in other regions harvesters are employed. Fossil fuel emissions from log harvesting are determined using the following procedure:

- Step 1: For the common practice in the host country, select the typical equipment type, amount and type of fuel consumed that is employed for harvesting. Information on

[15] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

harvesting practices can be found from reports on previous and existing harvesting practices in the host country. Potential sources should be a combination of direct measurements, manufacturer specifications, historical records of the project proponent (or other forest companies) and/or peer reviewed literature values.

- Step 2: Find the fuel consumption (kL m-3) of the selected equipment from the following data sources:
  - Reports on common practice for harvesting in the host country and/or manufacturers specifications
  - Published peer reviewed studies on harvesting operations (eg, Klvac and Skoupy (2009) in Appendix 4)
  - If a range for fuel consumption is provided, the project proponent is required to provide justification for their choice of fuel consumption in the project documents. If no justification can be derived, it is conservative to select the lower end of the range.
- Step 3: Select the emission factor associated with the fuel employed for harvesting from IPCC default emission factors for CO_2, CH_4 and N_2O emissions for Off-Road Mobile Sources and Machinery for the Forestry Sector (IPCC, 2006, Volume 2, Chapter 3, Section 3.3.1, Table 3.3.1, p. 3.36).
  - Guidance for converting the emission factors to a CO_2 equivalent (CO_2-e) emission factor is provided in Appendix 1.
  - Guidance for unit conversions of fuel emission factors is provided in Appendix 2.
- Step 4: Harvesting emissions are calculated following the equation below:

$$E_{HARVEST} = FC_{HARVEST} x EF_{FUEL} x\ V_{EX,j,i|BSL}\ x\ A \qquad \textbf{(14)}$$

Where:

$E_{HARVEST}$	Fossil fuel emissions due to harvesting operations such as felling and snigging, in tCO_2e;
$FC_{HARVEST}$	Fuel consumption of equipment employed for felling and snigging per m3 of merchantable log harvested, in kL/m3;
EF_{FUEL}	Fuel emission factor, in tCO2e/kL;
$V_{EX,j,i\|BSL}$	Mean volume of extracted timber per unit area for species j in stratum i, $m^3 \cdot ha^{-1}$;
A	Logging area, in ha;
i	1, 2, 3 … M strata; and

j 1, 2, 3 … J tree species.

8.1.5.2 Emissions Due to Log Hauling

Emissions associated with log hauling to the collection depot are calculated using the following procedure:

- Step 1: Select the typical equipment type, amount and type of fuel consumed that is employed for hauling based on common practice for harvesting in the host country. Information on harvesting practices can be found from reports on previous and existing harvesting practices in the host country.
- Step 2: Find the fuel consumption (kL m^{-3}) of the selected equipment from reports on common practice for harvesting in the host country and/or manufacturers specifications.

  If a range for fuel consumption is provided, the Project Proponent is required to provide justification for the choice of fuel consumption factor in the project documents. If no justification can be derived, it is conservative to select the lower end of the range.
- Step 3: Select the emission factor associated with CO_2, CH_4 and N_2O emissions for the fuel employed from IPCC default emission factors for Off-Road Mobile Sources and Machinery for the Forestry Sector (IPCC, 2006, Volume 2, Chapter 3, Section 3.3.1, Table 3.3.1, p. 3.36).
  - Guidance for converting the emission factors to a CO_2 equivalent (CO_2e) emission factor is provided in Appendix 1.
  - Guidance for unit conversions of fuel emission factors is provided in Appendix 2.
- Step 4: Emissions from log hauling are then determined by applying the following equation:

$$E_{HAULING} = FC_{HAULING} x EF_{FUEL} x\, V_{EX,j,i|BSL}\, x\, A \tag{15}$$

Where:

$E_{HAULING}$	Fossil fuel emissions due to log hauling, in tCO_2e;
$FC_{HAULING}$	Fuel consumption of equipment for hauling one m3 of merchantable log, in kL/m3;
EF_{FUEL}	Emissions due to log hauling, in tCO_2e/kL;
$V_{EX,j,i\|BSL}$	Mean volume of extracted timber per unit area for species j in stratum i, $m^3 \cdot ha^{-1}$;
A	Logging area, in ha;
i	1, 2, 3 …M strata; and
j	1, 2, 3 … J tree species.

8.1.5.3 Emissions Due to Log Transport

Emissions associated with log transport from the collection depot to the processing plant are calculated using the following procedure:

- Step 1: Select the vehicle: type, load capacity (m3 truck^{-1}) and type of fuel consumed for log transport based on common practice for transport in the host country. Information on harvesting practices can be found from reports on previous and existing harvesting practices in the host country.
- Step 2: Determine the number of trucks required using the following equation:

$$N_{TRUCKS-TRANSPORT} = \frac{V_{EX,j,i|BSL}\ x\ A}{CAP_{TRUCK}} \quad \textbf{(16)}$$

Where:

$N_{TUCKS-TRANSPORT}$	Number of truck trips required for log transport from collection depot to processing plant;
A	Logging area, in ha;
$V_{EX,j,i\|BSL}$	Mean volume of extracted timber per unit area for species j in stratum i, $m^3 \cdot ha^{-1}$;
CAP_{TRUCK}	Truck load capacity, in m3/truck;
i	1, 2, 3 … M strata; and
j	1, 2, 3 … J tree species.

- Step 3: Find the fuel efficiency (km kL^{-1}) of the selected vehicle from the following data sources:
  - Manufacturers specifications
  - Published peer reviewed studies on harvesting operations (eg, Kinjo et al., 2005).
  - If a range for fuel efficiency is provided, the Project Proponent is required to provide justification for the choice of fuel efficiency factor in the project documents. If no justification can be derived, it is conservative to select the upper end of the range.
- Step 4: Select the emission factor associated with CO_2, CH_4 and N_2O emissions for the fuel employed from IPCC default emission factors for Road Transport (IPCC, 2006, Volume 2, Chapter 3, Section 3.2.1.2, Table 3.2.1-2, p. 3.16-3.21).
  - Guidance for converting the emission factors to CO2-e emission factor is provided in Appendix 1.
  - Guidance for unit conversions of fuel emission factors is provided in Appendix 2.

- Step 5: Estimate the transport distance from the collection depot to the processing plant using the digital maps of the Project Area. If transport route(s) for the baseline scenario must be hypothesized, the Project Proponent is required to provide justification for their derivation of the transport route in the project documents. In addition, to be conservative, the transport route proposed must be the minimum possible route. The total log transport distance can be determined by the following:

$$KM_{TRANSPORT-TOTAL} = KM_{TRANSPORT} x N_{TUCKS-TRANSPORT} x\ 2 \quad \textbf{(17)}$$

Where:

$KM_{TRANSPORT-TOTAL}$	Total log transport distance in km;
$KM_{TRANSPORT}$	Log transport distance from collection depot to processing plant in km;
$N_{TRUCKS-TRANSPORT}$	Number of truck trips required for log transport from collection depot to processing plant;
2	Constant, indicating return trip;

- Step 6: Emissions due to log transport are then determined by applying the following equation:

$$E_{TRANSPORT} = \frac{KM_{TRANSPORT-TOTAL}}{EFF_{VEHICLE}} x EF_{FUEL} \quad \textbf{(18)}$$

Where:

$E_{TRANSPORT}$	Emissions due to log transport haulage from felling location to the collection depot/ sawmill, intCO2-e;
$KM_{TRANSPORT-TOTAL}$	Total log transport distance in km;
$EFF_{VEHICLE}$	Fuel efficiency for vehicle type, in km/kL;
EF_{FUEL}	Fuel emission factor, in tCO_{2}-e/kL.

8.1.5.4 Emissions Due to Timber Processing

Emissions as a result of processing, where the processing plant is situated in the project area, depend on the electricity source available at the processing site. Electricity can be supplied via the national grid, or where this is not available, supplied via on-site generators. In addition, mill residue/waste may also be used as an energy source during timber processing.

To avoid double accounting, if a processing plant utilizes mill residue/waste as an electricity source, then the emissions from electricity generated by mill residue/waste must not be considered here, as these emissions are accounted for under the dead wood pool.

If grid electricity is available, then emissions due to processing will be calculated using the following procedure:

- Step 1: Select an electricity demand factor for the timber processing facility from the following data sources:
  - National electricity demand factors in relevant literature for timber processing. Various country specific electricity demand factors have been compiled in Appendix 5.
  - If a national electricity demand factor is not available, select an electricity demand factor from a country that uses similar timber processing technology to that of the project's host country
  - If a range for the electricity demand factor is provided, the project proponent is required to provide justification for the choice of electricity demand factor in the projects documents. If no justification can be derived, it is conservative to select the lower end of the range.
- Step 2: Using the volume of merchantable logs, determine the electricity consumption required for the processing mill:

$$Q_{PROCESSING} = V_{EX,j,i|BSL} \ x \ A \ x E_{DEMAND} \quad \textbf{(19)}$$

Where:

$Q_{PROCESSING}$	Quantity of electricity consumption for processing in kWh;
$V_{EX,j,i\|BSL}$	Mean volume of extracted timber per unit area for species j in stratum i, $m^3 \cdot ha^{-1}$;
A	Logging area, in ha;
E_{DEMAND}	Electricity demand for processing per volume processed, in kWh/m^3;
i	1, 2, 3 … M strata; and
j	1, 2, 3 … J tree species.

- Step 3: Select an emission factor for electricity for the host country from IEA (2009), CO_2 emissions per kWh from electricity and heat generation, pp. 101-103.
- Step 4: Apply the following equation to determine the emissions due to processing:

$$E_{PROCESSING} = Q_{PROCESSING} \ x \ EF_{ELECTRICITY} \quad \textbf{(20)}$$

Where:

$E_{PROCESSING}$	Emissions due to electricity consumption in sawmill, in tCO_2e;

$Q_{PROCESSING}$	Quantity of electricity consumption for processing in kWh;
$EF_{ELECTRICITY}$	Electricity emission factor for the host country, in tCO_2e/kWh;

If grid electricity is not available, and an on-site generator is required to power the processing facility, then calculation of processing emissions is determined from the emissions associated with fuel consumption of the generator. Apply Steps 1 and 2 of Section above to determine the electricity consumption involved for processing. Then use the following procedure:

- Step 1: Select the typical load capacity (1/4, 1/2, full load), type of fuel consumed and operating time of the generator employed to power the processing facility. Such data can be obtained from the following data sources:
    - National reports from the relevant national forestry authority
    - Published peer reviewed literature on timber processing for cases of equivalent volumes and processing modes and of a country that uses similar timber processing technology to that of the project's host country.
- Step 2: Determine the power rating of the generator from the electricity required for processing and the operating hours required:

$$PR_{GENERATOR} = \frac{Q_{PROCESSING}}{T_{GENERATOR}} \qquad \textbf{(21)}$$

Where:

$PR_{GENERATOR}$	Power rating of generator or generator size in kW;
$Q_{PROCESSING}$	Annual quantity of electricity consumption for processing in kWh;
$T_{GENERATOR}$	Operating time of generator in h;

- Step 3: Using a fuel consumption chart for the generator selected for the baseline case, apply the power rating (kW) and an appropriate load capacity (1/4, 1/2, full) to determine the fuel consumption (kL h-1) of the generator. Fuel consumption charts can be found from manufacturers of generators (see Appendix 3).
- Step 4: Select an emissions factor for the fuel employed in the generator from IPCC (2006), Volume 2, Chapter 2 Stationary Combustion, Table 2.5, p. 2.22.
- Step 5: Apply the following equation to determine emissions due to processing:

$$E_{PROCESSING} = FC_{GENERATOR} \; x \; T_{GENERATOR} \; x \; EF_{FUEL} \qquad \textbf{(22)}$$

Where:

$E_{PROCESSING}$	Emissions due to electricity consumption in sawmill in tCO_2e;

$FC_{GENERATOR}$	Fuel consumption per hour of operation of generator, in kL/h;
$T_{GENERATOR}$	Operating time of generator in h;
EF_{FUEL}	Fuel emission factor, in tCO_2e/kL;

8.1.6 Calculation of baseline scenario greenhouse gas emissions from change in carbon stocks

This section calculates $GHG_{NET|BSL}$, the net greenhouse gas emissions in the baseline scenario, in tCO_2e.

The net carbon stock change to be converted to emissions is equal to the carbon stock change as a result of timber harvest plus the carbon stock change resulting from conversion and retirement of wood products minus carbon sequestration from forest regrowth after harvest.

In order to generate the annual carbon stock change in the baseline scenario, the total net change in carbon stocks for parcels within is multiplied by the area of forest in the particular age class (ie, years since harvest in the baseline).

The annualized calculations vary between years 1, 2-10; 11-20; and all years since the start of the project activity, depending on which decay functions apply.

Therefore, the net change in carbon stock from wood products and logging slash across all parcels within the first year of harvest in the baseline is calculated as:

$$\Delta C_{NET|BSL(1)} = \sum_{i,p} A_{1,i,p} * \sum_{i=1}^{M} \left(C_{DWSLASH,i,p\backslash BSL}/10 \right) + C_{WP0,i,p\backslash BSL} + \left(C_{WP100,i,p\backslash BSL}/20 \right) \qquad \textbf{(23)}$$

Where:

$\Delta C_{NET\|BSL(1)}$	Net change in carbon stock across all parcels in the baseline scenario in the first year since harvest in the baseline scenario, in tC;
$\Delta C_{DWSLASH,i,p\backslash BSL}$	Change in carbon stock of dead wood as logging slash resulting from timber harvest per unit area in stratum *i* in land parcel *p*, in tC ha-1;
$\Delta C_{WP0,i,p\backslash BSL}$	Change in carbon stock resulting from wood product conversion and retirement from stratum *i* in land parcel *p*, that is assumed to be emitted in the first year of harvest in the baseline tC ha-1;
$\Delta C_{WP100,i,p\backslash BSL}$	Carbon stored in wood products that is assumed to be retired between 3 - 100 years after harvest from stratum i in land parcel p, tC ha-1;

$A_{1,i,p}$	Area of stratum *i* in land parcel *p* that was harvested 1 year ago, ha; [16]
i	1, 2, 3 …*M* strata; and
p	*1, 2, 3 ...P* land parcels harvested within the project crediting period.

The net change in carbon stock from wood products and logging slash across all parcels the years 2 – 10 since harvest in the baseline are calculated as:

$$\Delta C_{NET|BSL(2-10)} = \sum_{i,p} A_{2-10,i,p} * \sum_{i=1}^{M} \left((\Delta C_{DWSLASH,i,p\backslash BSL}/10) + (\Delta C_{WP100,i,p\backslash BSL}/20) \right) \quad \textbf{(24)}$$

Where:

$\Delta C_{NET\|BSL(2\text{-}10)}$	Net change in carbon stock across all parcels in the baseline scenario in years 2 - 10 since harvest in the baseline scenario, in tC;
$\Delta C_{DWSLASH,i,p\backslash BSL}$	Change in carbon stock of dead wood as logging slash resulting from timber harvest per unit area in stratum *i* in land parcel *p*, in tC ha-1;
$\Delta C_{WP100,i,p\backslash BSL}$	Carbon stored in wood products that is assumed to be retired between 3 - 100 years after harvest from stratum i in land parcel p, tC ha-1;
$A_{2-10,i,p}$	Area of stratum *i* in land parcel *p* that was harvested between 2 and 10 year ago, ha; [17]
i	1, 2, 3 …*M* strata; and
p	*1, 2, 3 ...P* land parcels harvested within the project crediting period.

The net change in carbon stock from wood products across all parcels the years 11 – 20 since harvest in the baseline are calculated as per equation 13 below. Note that, from this point, there will be no more emissions quantified from decay of logging slash in these parcels.

$$\Delta C_{NET|BSL(11-20)} = \sum_{i,p} A_{11-20,i,p} * \sum_{i=1}^{M} \left(\Delta C_{WP100,i,p\backslash BSL}/20 \right) \quad \textbf{(25)}$$

Where:

$\Delta C_{NET\|BSL(11\text{-}20)}$	Net change in carbon stock across all parcels in the baseline scenario in years 11 - 20 since the start of the project activity, in tC;

[16] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).
[17] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

$\Delta C_{WP100,i,p\backslash BSL}$	Carbon stored in wood products that is assumed to be retired between 3 - 100 years after harvest from stratum i in land parcel p, tC ha-1;
$A_{11-20,i,p}$	Area of stratum *i* in land parcel *p* that was harvested between 11 and 20 years ago, ha; [18]
i	1, 2, 3 …*M* strata; and
p	*1, 2, 3 ...P* land parcels harvested within the project crediting period.

The net change (sequestration) in carbon stock due to forest regrowth across all parcels in all years since harvest in the baseline scenario are calculated according to Equation 14 below. Note that there will be no more emissions quantified from decay of logging slash or wood products.

$$\Delta C_{NET|BSL(1+)} = \sum_{i,p} A_{t*} * \sum_{i=1}^{M} \left(-\Delta C_{RG,i,p\backslash BSL}\right) \quad \textbf{(26)}$$

Where:

$\Delta C_{NET|BSL(1+)}$	Net change in carbon stock due to forest regrowth in all parcels that have been harvested in the baseline scenario, in tC;
$\Delta C_{RG,i,p\backslash BSL}$	Carbon sequestration resulting from forest regrowth after timber harvest in stratum *i* in land parcel *p*, tC ha-1;
A_{t*}	Cumulative area harvested until time t*, ha; [19]
*t**	1, 2,….10, time elapsed since the start of the project, in years;
i	1, 2, 3 …*M* strata; and
p	1, 2, 3 *...P* land parcels harvested within the project crediting period.

Therefore, net change in carbon stock across all parcels harvested over each year of the project crediting period in the baseline scenario since the start of the project activity is calculated as:

$$\Delta C_{NET|BSL,t*} = \sum_{p=1}^{P} \left[\Delta C_{NET,p|BSL(1)} + \Delta C_{NET,p|BSL(2-10)} + \Delta C_{NET,p|BSL(11-20)} + \Delta C_{NET,p|BSL(+1)} + C_{FUEL}\right] \quad \textbf{(27)}$$

Where:

$\Delta C_{NET|BSL,t}$	Net change in carbon stock across all parcels in the baseline scenario in the year t*

[18] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

[19] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection.

	since the start of the project activity, in tC;
$\Delta C_{NET,p\|BSL(1)}$	Net change in carbon stock in the baseline scenario for all parcels *p* that are within 1 year of harvest in the baseline scenario, in tC;
$\Delta C_{NET,p\|BSL(2-10)}$	Net change in carbon stock in the baseline scenario for all parcels *p*, that were harvested between 2 – 10 years ago in the baseline scenario, in tC;
$\Delta C_{NET,p\|BSL(11-20)}$	Net change in carbon stock in the baseline scenario in parcel *p*, that were harvested between 11 – 20 years ago in the baseline scenario, in tC;
$\Delta C_{NET,p\|BSL(+1)}$	Net change in carbon stock due to forest growth in the baseline scenario for all parcels *p* that have been harvested in the baseline scenario, in tC;
C_{FUEL}	Total carbon emissions associated with the combustion of fossil fuel in forestry and wood processing machinery, in tC
*t**	Time elapsed since the start of the project, in years
p	1, 2, 3 ...*P* land parcels harvested within the project crediting period

The net carbon stock change in the baseline scenario must be converted to net greenhouse gas emissions and is calculated as:

$$GHG_{NET|BSL,t*} = \Delta C_{NET|BSL,t*} * \frac{44}{12} \tag{28}$$

Where:

$GHG_{NET\|BS,t*L}$	Net greenhouse gas emissions in the baseline scenario in the year t* since the start of the project activity, tCO_2e;
$\Delta C_{NET\|BSL}$	Net change in carbon stock across all parcels in the baseline scenario in the year t* since the start of the project activity, tC; and
44/12	Ratio of molecular weights of carbon dioxide and carbon, $tCO_2\text{-e}\ tC^{-1}$.

8.2 Project Emissions

This section calculates $GHG_{NET|PRJ}$, the net greenhouse gas emissions in the project scenario, in tCO2e.

Greenhouse gas emissions from Improved Forest Management (IFM) activities implemented in the project scenario must be accounted subject to application of the *de minimis* rule, as prescribed by the *VCS AFOLU Requirements*. Project emissions include the change in carbon stocks of ongoing forest growth, forest disturbances, and illegal logging. As commercial timber harvest and activities that result in forest degradation are not eligible under the methodology in the project scenario, emissions sources from combustion of fossil fuels from vehicles, machinery and equipment are *de minimis* and not accounted by the methodology in the project scenario.

The type and extent of the activities implemented in the project scenario will be described by the project proponent as part of the documentation submitted with the project documents.

In accordance with the applicability conditions, the project scenario does not allow commercial timber harvest. As a result, carbon stock changes due to vegetation management and fuel removal will be negligible.

Thus, net greenhouse gas emissions in the project scenario will be equal to carbon sequestration through ongoing forest growth minus any emissions resulting from forest disturbance (both illegal logging and natural disturbances).

Ex-ante and ex-post estimations of natural disturbance for the project scenario must be estimated following Section 8.2.2.1.[20]

The potential for illegal extraction of trees from the project area must be assessed ex-ante and ex-post through a participatory rural appraisal (PRA) of the communities in and surrounding the project area following Section 8.2.2.2a.[21]

At all subsequent verifications, data collected for monitored parameters for natural disturbance and illegal logging must be included using the equations given under Sections 8.2.2 and 8.2.3 below.

It is not a requirement of this methodology for the project proponent to estimate carbon stock change from forest growth in the project scenario of undisturbed forest. However, where the project proponent chooses to determine stock change from forest growth in the project scenario, a detailed sampling plan must be provided in the project documents and follow the equations in Section 8.2.1 below.

8.2.1 Ongoing forest growth in the project scenario

This section calculates $\Delta C_{AB,t|PRJ}$ annual carbon stock change in aboveground biomass of trees in the project scenario, in tCO_2e.

8.2.1.1 Allometry

The project proponent must select or develop an appropriate allometric equation for forest type/group of species j (eg, tropical humid forest or tropical dry forest) or for each species or family j (group of species) found in the inventory (hereafter referred to as species group) that

[20] *Ex ante* estimations of areas burned and naturally disturbed shall be based on historic incidence of fire and natural disturbance in the Project region.

[21] If the belief is that zero illegal logging will occur within the project boundaries then ex-ante this parameter may be set to zero if clear infrastructure, hiring and policies are in place to prevent illegal logging.

converts tree dimensions from field timber inventories on sample plots to aboveground biomass of trees.

Equation selection or development must follow the criteria described for *fj(X,Y...)*, the aboveground biomass of trees based on allometric equation for species group *j* based on measured tree variable(s), in the parameters section below.

8.2.1.2 Measurements

Only the individual trees, species and strata which were to be harvested in the baseline scenario are to be measured. The tree dimensions and minimum diameter at breast height (DBH) specified by the selected allometric equation in Section 8.2.1.1 must apply to these trees.

Any minimum values employed in inventories are held constant for the duration of the project.

8.2.1.3 Determining Sample Plot Carbon Stocks

The carbon stock in aboveground biomass for each individual tree of species group *j* in the sample plot located in stratum *i* will be estimated using the selected or developed allometric equation applied to the tree dimensions resulting from Section 8.2.1.2.

Therefore, the sum of the carbon stock in each sample plot will be calculated as:

$$C_{AB,j,i,t,sp|PRJ} = \sum_{l=1}^{L_{j,i,sp,t}} f_j(X,Y\ldots) * CF \quad \textbf{(29)}$$

Where:

$C_{AB,j,i,t,sp\|PRJ}$	Carbon stock in aboveground biomass of trees of species *j* in plot *sp* in stratum *i* at time *t* in the project scenario, tC
CF_j	Carbon fraction of biomass for tree group *j*, tC t d.m.$^{-1}$; [22]
$f_j(X,Y\ldots)$	Aboveground biomass of trees based on allometric equation for species group *j* based on measured tree variable(s), t. d.m. tree^{-1}; [23]
i	1, 2, 3, …M strata;
j	*1, 2, 3 … J* tree species;
l	*1, 2, 3, …* $L_{j,i,t,sp}$ sequence number of individual trees of species group *j* in

[22] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).
[23] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

	stratum *i* at time *t* in sample plot *sp;*
t	*0, 1, 2, 3, …*t^* years elapsed since start of the project activity; and
sp	1, 2, 3 …*SP* sample plots.

8.2.1.4 Determining Stratum Carbon Stocks

The total carbon stock in the aboveground biomass of all trees present in sample plot *sp* in stratum *i* at time *t*, must be calculated as:

$$C_{AB,i,t,sp|PRJ} = \sum_{j=1}^{J} C_{AB,j,i,sp|PRJ} \quad \textbf{(30)}$$

Where:

$C_{AB,i,t,sp\|PRJ}$	Aboveground biomass carbon stock of all trees of stratum *i* at time *t* in sample plot *sp* in the project scenario, tC;
$C_{AB,j,i,t,sp\|PRJ}$	Carbon stock in aboveground biomass of trees of species *j* in stratum *i* at time *t* in plot *sp* in the project scenario, tC;
i	1, 2, 3, …M strata;
j	*1, 2, 3 … J* tree species; and
t	*0, 1, 2, 3, …*t^* years elapsed since start of the project activity.

8.2.1.5 Determining Mean Carbon Stocks

Therefore, the mean carbon stock in aboveground biomass for each stratum per unit area is calculated as:

$$C_{AB,i,t|PRJ} = \frac{1}{SP} * \sum_{sp=1}^{SP} \left(\frac{C_{AB,i,t,sp|PRJ}}{A_{sp}} \right) \quad \textbf{(31)}$$

Where:

$C_{AB,i,t\|PRJ}$	Mean aboveground biomass carbon stock of trees in stratum *i* at time *t*, $tC \cdot ha^{-1}$;
$C_{AB,i,t,sp\|PRJ}$	Aboveground biomass carbon stock of trees in stratum *i* at time *t* in sample plot *sp*, tC;

Asp	Area of sample plot *sp*, ha; [24]
sp	*1, 2, 3 … SP* sample plots;
i	*1, 2, 3* … *M* strata; and
t	*0, 1, 2, 3* … *t** years elapsed since the start of the project activity.

8.2.1.6 Determining Carbon Stock Changes

The annual carbon stock change in aboveground biomass of trees in year *t* is the difference in mean carbon stock in aboveground biomass between sampling events and, when expressed in tCO_2e, is calculated as:

$$\Delta C_{AB,t|PRJ} = \left(\sum_{i=1}^{M}\left(A_i * \frac{C_{AB,i,t2|PRJ} - C_{AB,i,t1|PRJ}}{T}\right)\right) * \frac{44}{12} \qquad \textbf{(32)}$$

Where:

$\Delta C_{AB,t\|PRJ}$	Annual carbon stock change in aboveground biomass of trees in year *t*,tCO_2eyr^{1};
$C_{AB,i,t\|PRJ}$	Mean aboveground biomass carbon stock of trees in stratum *i* at time *t*, $tCha^{-1}$;
A_i	Area covered by stratum *i*, ha;
sp	*1, 2, 3 … SP* sample plots;
T	Number of years between monitoring time *t*1 and *t*2 (*T* = *t*2 – *t*1); years;
i	1, 2, 3 … M strata;
t	*1, 2, 3* … *t** years elapsed since the start of the project activity; and
44/12	Ratio of molecular weights of carbon dioxide and carbon, $tCO_2e\ tC^{-1}$.

The carbon stock change in aboveground biomass of trees ($\Delta C_{AB,t|PRJ}$) is the output of this section and is necessary to calculate net greenhouse gas emissions in the project scenario.

8.2.2 Forest disturbance in the project scenario

This section calculates $\Delta C_{DIST\_FR,t|PRJ}$, carbon stock change due to fire disturbance in the project scenario; tCO_2e, $\Delta C_{DIST,t|PRJ}$, carbon stock change due to non-fire natural disturbance in the project scenario; tCO_2e.

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[24] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

8.2.2.1 Natural disturbance

It is a requirement that any greenhouse gas emissions from natural disturbance above *de minimis* that may occur in the project area are monitored.

Estimation of emissions from natural disturbance must be calculated depending on the type of disturbance event. Disturbance due to fire is calculated following Option A, and all non-fire natural disturbance (eg, wind, disease, pest events) is calculated following Option B.

Option A: Natural Disturbance - Fire

For fire damage it is assumed that a fire burning in the project scenario would also have burned in the baseline scenario. Project emissions are therefore equal to the fire damage to biomass absent in the baseline scenario (harvested and removed) but present in the project scenario.

Where fires occur *ex post* in the project area, the area burned must be delineated.

Therefore, based on the *IPCC 2006 Inventory Guidelines*, estimation of greenhouse gas emissions from biomass burning must be calculated as:

$$\Delta C_{DIST-FR,t|PRJ} = \sum_{i=1}^{M} A_{burn,i,t} * B_{i,t|PRJ} * COMF_i * G_{g,i} * 10^{-3}.GWP_{CH4} \quad \textbf{(33)}$$

Where:

$\Delta C_{DIST\_FR,t\|PRJ}$	Net greenhouse gas emissions resulting from fire disturbance in year *t*, tCO_2e
Aburn,i,t	Area burnt for stratum *i* at time *t*, ha; [25]
$B_{i,t\|PRJ}$	Average aboveground biomass stock present in the project scenario but absent in the baseline scenario before burning stratum *i*, time *t*; t d. m. ha^{-1};
$COMF_i$	Combustion factor for stratum *i*, dimensionless; [26]
Gg,i	Emission factor for stratum *i* for methane, g kg^{-1} dry matter burnt; [27]
GWP_{CH4}	Global warming potential for CH_4 (IPCC default: 21), $tCO_2e\ tCH_4^{-1}$;
i	1, 2, 3 …*M* strata; and
t	1, 2, 3, … *t** years elapsed since the start of the IFM project activity.

[25] See *Data and parameters used in monitoring* parameter list for information on data selection (p59).
[26] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).
[27] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p 51).

The average aboveground biomass stock present in the project scenario but absent in the baseline scenario before burning for a particular stratum must be calculated as:

$$B_{i,t|PRJ} = \sum_{j=1}^{J} \{V_{EX,i,j|BSL} * BCEF_R\} \quad \textbf{(34)}$$

Where:

$B_{i,t\|PRJ}$	Average aboveground biomass stock present in the project scenario but absent in the baseline before burning for stratum *i*, time *t*, t d. m. ha^{-1};
$V_{EX,j,i\|BSL}$	Mean volume of extracted timber per unit area for species *j* in stratum *i*, m^3·ha^{-1};
$BCEF_R$	Biomass conversion and expansion factor applicable to wood removals in the project area, t.d.m m^{-3}; [28]
i	1, 2, 3 …*M* strata;
j	1, 2, 3 …*J* tree species; and
t	1, 2, 3, … *t** years elapsed since the start of the IFM project activity.

Option B: Natural Disturbance - Non-Fire

For non-fire natural disturbance, it is assumed that a disturbance event in the project scenario would also have occurred in the baseline scenario. Project emissions are therefore equal to the non-fire natural disturbance to biomass absent in the baseline scenario (harvested and removed) but present in the project scenario.

It is conservatively assumed that the natural disturbance is a stand-replacing disturbance, and that the biomass change as a result of the natural disturbance ($\Delta C_{DIST,t|PRJ}$) is emitted in the year of disturbance.

Where non-fire natural disturbances occur ex post in the project area, the area disturbed must be delineated.

$$\Delta C_{DIST,t|PRJ} = \sum_{i=1}^{M} \left(A_{dist,i,t} * \sum_{j=1}^{J} \{C_{AB,j,i|BSL}\} \right) * \frac{44}{12} \quad \textbf{(35)}$$

Where:

$\Delta C_{DIST,t|PRJ}$ Net greenhouse gas emissions resulting from non-fire natural disturbance in

[28] See Data and parameters not monitored (default or possibly measured one time) parameter list for information on data selection (p51).

	year t, tCO_2e ;
$A_{dist,i,t}$	Area disturbed for stratum i at time t, ha; [29]
$C_{AB,i\|BSL}$	Carbon stock in aboveground biomass per unit area in stratum i, $tC \cdot ha^{-1}$;
44/12	Ratio of molecular weights of carbon dioxide and carbon, $tCO_2e\ tC^{-1}$;
i	1, 2, 3 …M strata;
j	1, 2, 3 …J tree species; and
t	1, 2, 3, … t^* years elapsed since the start of the IFM project activity.

8.2.2.2 Illegal logging

It is a requirement that any greenhouse gas emissions from illegal logging above *de minimis* that may occur in the project area ($\Delta C_{DIST\_IL,i,t|PRJ}$) are monitored.

At the time of methodology approval, remote sensing technology using optical sensors is not capable of direct measurements of biomass and changes thereof[30] but has some capability to identify forest strata that have undergone a change in biomass[31].

As remote methods for monitoring illegal logging are not available at the time of methodology approval, the following ground-based methods must be used.

Option A: PRA

A participatory rural appraisal (PRA) of the communities surrounding the project area must be completed to determine if there is the potential for illegal extraction of trees from the project area. If this assessment finds no potential pressure for these activities then illegal logging ($\Delta C_{DIST\_IL,i,t|PRJ}$) can be assumed to be zero and no monitoring is needed.

The PRA must be repeated every 2 years.

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[29] See data and parameters used in monitoring parameter list for information on data selection (p62).
[30] However, technology is developing rapidly, including techniques such as RADAR, SAR, or LiDAR.
[31] For example, a multi-temporal set of remotely sensed data can be used to detect changes in the structure of the forest canopy. A variety of techniques, such as Spectral Mixture Analysis (Souza et al. 2005), SAR or LiDAR, can be used under this approach but no specific technology is prescribed here. Some of the newer technologies can estimate carbon contents of forest types, if supported by field information such as sample plots to calibrate the technology and fieldwork leading to allometric equations of key species. The project proponent should use techniques that are suitable to their specific situation and that have been published in peer-reviewed papers.

Option B: Sampling

If the results of the PRA suggest that there is a potential for illegal logging activities, then limited field sampling must be undertaken.

The area that is potentially subject to degradation ($A_{DIST\_IL,i}$) uses the distance of illegal logging penetration from all access points (access buffer), such as roads and rivers or previously cleared areas, to the project area determined from the PRA.

The area subject to illegal logging must be delineated ($A_{DIST\_IL,i}$) based on an access buffer from all access points, such as roads and rivers or previously cleared areas, to the project area, with a width equal to the distance of degradation penetration.

$A_{DIST\_IL,I}$ must be sampled by surveying several transects of known length and width across the access-buffer area (equal in area to at least 1% of $A_{DIST\_IL,i}$) to determine the presence or absence of new tree stumps. The CDM tool for significance[32] must be applied to determine significance where there is evidence that trees are being harvested.

Where application of the CDM tool demonstrates that illegal logging is insignificant then illegal logging can be assumed to be zero and no monitoring is needed.

This limited sampling must to be repeated each time the PRA indicates a potential for illegal logging.

Where limited sampling provides evidence that trees are being removed in the buffer area, then systematic sampling must be implemented based on a detailed sampling plan. The sampling plan must be designed using plots systematically placed over the buffer zone so that they sample at least 3% of the area of the buffer zone ($A_{DIST\_IL,i}$). The diameter of all tree stumps will be measured and conservatively assumed to be the same as the DBH. Where the stump is a large buttress, several individuals of the same species nearby must be located and a ratio of the diameter at DBH to the diameter of buttress at the same height above ground as the measured stumps must be determined. This ratio will be applied to the measured stumps to estimate the likely DBH of the cut tree.

The aboveground carbon stock of each harvested tree will be estimated using the allometric regression equations chosen for forest growth in the project scenario[33]. The mean aboveground carbon stock of the harvested trees ($C_{DIST\_IL,i,t|PRJ}$) is conservatively estimated to be, the total emissions and, consequently all emissions enter the atmosphere.

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[32]http://cdm.unfccc.int/EB/031/eb31_repan16.pdf

[33] If species-specific equations are used and species cannot be identified from stumps then it shall be assumed that the harvested species is the species most commonly harvested. A PRA shall be used to determine the most commonly harvested species.

This sampling procedure must be repeated every 5 years and the results annualised by dividing the total emissions by five.

Therefore, where the PRA or the limited sampling indicate no illegal logging occurring:

$$\Delta \boldsymbol{C}_{\boldsymbol{DIST-IL,t|PRJ}} = \mathbf{0} \qquad \textbf{(36)}$$

Where the PRA and the limited sampling indicate degradation is occurring, net carbon stock changes as a result of illegal logging must be calculated as:

$$\Delta C_{DIST-IL,t|PRJ} = \sum_{i=1}^{M}\left(A_{DIST-IL,j} * \frac{C_{DIST-IL,i,t|PRJ}}{AP_i}\right) x \left(1 + \frac{V_{EX,INF,j,i|BSL}}{V_{EX,j,i|BSL}}\right) + {C_{FUEL}}\Big/{\sum_{i=1}^{I} \mathrm{C}_{\mathrm{EX,i|BSL}}}\ x \frac{44}{12}\ x\ C_{DIST-IL,t|PRJ} \qquad \textbf{(37)}$$

Where:

$\Delta C_{DIST\_IL,t\|PRJ}$	Net carbon stock changes as a result of illegal logging at time *t*, tCO_2e;
$A_{DIST\_IL,i}$	Area potentially impacted by illegal logging in stratum *I*, ha; [34]
$C_{DIST\_IL,i,t\|PRJ}$	Biomass carbon of trees cut and removed through illegal logging in stratum *i* at time *t*, tCO_2e;
$V_{EX,j,i\|BSL}$	Mean volume of extracted timber per unit area for species *j* in stratum *i*, $m^3 \cdot ha^{-1}$;
$V_{EX,INF,j,i\|BSL}$	Mean volume of extracted timber for forestry infrastructure per unit area for species j in stratum i, $m^3 \cdot ha^{-1}$;
C_{FUEL}	Total carbon emissions associated with the combustion of fossil fuel in forestry and wood processing machinery, in tC;
$C_{EX,i\|BSL}$	Change in carbon stock of extracted wood products resulting from timber harvest per unit area in stratum *i* in land parcel *p*, in tC ha-1;
AP_i	Total area of illegal logging sample plots in stratum *i*, ha;[35]
i	1, 2, 3 …*M* strata in the in the project case; and
t	1, 2, 3, … *t* years elapsed since the projected start of the project activity.

This approach not only considers the carbon stock reductions due to illegal logging, but also considers fuel emissions of illegal logging operations and potential emissions from infrastructure development for conducting illegal logging.

The emissions of infrastructure development due to illegal logging are estimated by determining an expansion factor based on regular baseline harvesting practices (ie, the relation of volume extracted due to infrastructure development compared to the merchantable volume extracted). As

[34] See *Data and parameters used in monitoring* parameter list for information on data selection (p62).
[35] See *Data and parameters used in monitoring* parameter list for information on data selection (p62).

it is unlikely that illegal logging will result in large scale infrastructure development (ie, equaling the baseline scenario), this approach is considered conservative.

Fuel emissions from illegal logging operations are determined by using the specific fuel emissions of the baseline scenario (ie, total fuel emissions are divided by the total carbon stock changes due to baseline logging operations) which are then multiplied by the illegal logging volume. As it is unlikely that illegal logging would involve the deployment of large, fuel intensive machinery (ie, equaling the baseline scenario), this is considered conservative.

The calculation of emissions from illegal logging therefore requires use of both parameters available at validation (Section 9.1) and parameters monitored (section 9.2).

8.2.3 Net greenhouse gas emissions in the project scenario

This section calculates $\Delta C_{NET,t|PRJ}$, the net greenhouse gas emissions in the project scenario in year *t*, in tCO_2e.

The net greenhouse gas emissions in the project scenario are the sum of net greenhouse gas emissions resulting from fire and non-fire forest disturbance, plus any carbon stock changes that occur as a result of illegal logging, minus the annual carbon stock change in the aboveground biomass of trees due to forest growth.

Therefore, net greenhouse gas emissions in the project scenario in year *t*, is calculated as:

$$\Delta C_{NET,t|PRJ} = \left(\Delta C_{DIST-FR,t|PRJ} + \Delta C_{DIST,t,PRJ} + \Delta C_{DIST-IL,t|PRJ}\right) - \Delta C_{AB,t|PRJ} \quad \textbf{(38)}$$

Where:

$\Delta C_{NET,t\|PRJ}$	Net greenhouse gas emissions in the project scenario in year *t*, tCO_2-e;
$\Delta C_{DIST\_FR,t\|PRJ}$	Net greenhouse gas emissions resulting from fire disturbance in year *t*, tCO_2e
$\Delta C_{DIST,t\|PRJ}$	Net greenhouse gas emissions resulting from non-fire natural disturbance in year *t*, tCO_2e ;
$\Delta C_{DIST\_IL,t\|PRJ}$	Net carbon stock changes as a result of illegal logging at time *t*, tCO_2e;
$\Delta C_{AB,t\|PRJ}$	Annual carbon stock change in aboveground biomass of trees in year *t*, tCO_2e□yr^{-1}; and
t	*1, 2, 3, … t** years elapsed since start of the project activity.

The net greenhouse gas emissions across in the project scenario since the start of the project is calculated as:

$$GHG_{NET|PRJ} = \sum_{t=1}^{t^*} \Delta C_{NET,t|PRJ} \quad \textbf{(39)}$$

Where:

$GHG_{NET\|PRJ}$	Net greenhouse gas emissions in the project scenario since the start of the project activity, tCO_2e;
$\Delta C_{NET,t\|PRJ}$	Net greenhouse gas emissions in the project scenario in year *t*, tCO_2e; and
t	*1, 2, 3, … t** years elapsed since start of the project activity.

8.3 Leakage

8.3.1 Activity shifting leakage

There may be no leakage due to activity shifting.

Where the project proponent controls multiple parcels of land within the country the project proponent must demonstrate that the management plans and/or land-use designations of other lands they control have not materially changed as a result of the planned project (designating new lands as timber concessions or increasing harvest rates in lands already managed for timber) because such changes could lead to reductions in carbon stocks or increases in GHG emissions.

This must be demonstrated through:

- Historical records showing trends in harvest volumes paired with records from the with-project time period showing no deviation from historical trends;

- Forest management plans prepared ≥24 months prior to the start of the project showing harvest plans on all owned/managed lands paired with records from the with-project time period showing no deviation from management plans.

At each verification, documentation must be provided covering the other lands controlled by the project proponent where leakage could occur, including, at a minimum, their location(s), area and type of existing land use(s), and management plans.

Where activity shifting occurs or a project proponent is unable to provide the necessary documentation at first and subsequent verification, the project must not meet the requirements for verification. Therefore, the project must be subject to the conditions described in the *VCS AFOLU Guidance Document* on projects which fail to submit periodic verification after the commencement of the project. The project proponent may optionally choose to submit a methodology deviation with their future verifications to address activity shifting leakage.

Where the project proponent has control only over resource use in the project area and has no access to other forest resource, then the only type of leakage emissions calculated is GHG emissions due to market effects that result from project activity.

8.3.2 Market leakage

Leakage due to market effects is equal to the net emissions from planned timber harvest activities in the baseline scenario multiplied by an appropriate leakage factor:

$$GHG_{LK|LtPF.t*} = LF_{ME} * GHG_{NET|BSL,t*} \quad \textbf{(40)}$$

Where:

$GHG_{LK\|LtPF,t*}$	Total market leakage as a result of IFM LtPF activities, in the year t* since the start of the project activity, tCO2e;
LF_{ME}	Leakage factor for market-effects calculations, dimentionless;
$GHG_{NET\|BS,t*L}$	Net greenhouse gas emissions in the baseline scenario in the year t* since the start of the project activity, tCO_2e.

The leakage factor (see Box 2 below) is determined by considering where in the country logging will be increased as a result of the decreased timber supply caused by the project.

If the ratio of merchantable biomass to total biomass is higher in the project area, it is likely that additional logging will be performed in these areas as a result of reduced logging in the project area in the project scenario.

The leakage factor is thus defined as a dimensionless number with values between 0 and 1 assigned *ex ante* on the basis of a comparison between the ratio of merchantable biomass to total biomass across all strata in the base year, and the ratio of merchantable biomass to total biomass of the country's forest estate where harvesting would likely be displaced to.

Box 2: Leakage Factor Calculation

The leakage factor is determined by considering where in the country logging will be increased as a result of the decreased supply of the timber caused by the project. If the areas liable to be logged have a higher ratio of merchantable biomass to total biomass higher than the project area it is likely that the proportional leakage is higher and vice versa:

Therefore,

$LF_{ME} = 0$

if it can be demonstrated that no market-effects leakage will occur within national boundaries, that is if no new concessions are being assigned AND annual extracted volumes cannot be increased within existing national concessions AND illegal logging is absent (or *de minimis*) in the host country.

The amount of leakage is determined by where in the country's forest estate harvesting would likely be displaced. If harvesting is displaced to forests where a lower proportion of forest biomass is merchantable material from harvestable species than in the project area, then in order to extract a given volume higher emissions should be expected as more trees will need to be cut to supply the same volume.

In contrast if a higher proportion of the total biomass of commercial species is merchantable in the displacement forest than in the project forests, then a smaller area would have to be harvested and lower emissions would result.

Therefore, each project must calculate within each stratum the ratio of merchantable biomass to total biomass (PMP_i). This shall then be compared to the ratio of merchantable biomass to total biomass for each forest type (PML_{FT}).

The following deduction factors (LF_{ME}) shall be used:

PML_{FT} is equal (± 15%) to PMP_i $LF_{ME} = 0.4$

PML_{FT} is > 15% less than PMP_i $LF_{ME} = 0.7$

PML_{FT} is > 15% greater than PMP_i $LF_{ME} = 0.2$

Where:

PML_{FT} mean merchantable biomass as a proportion of total aboveground tree biomass for each forest type, %;

PMP_i merchantable biomass as a proportion of total aboveground tree biomass for stratum i within the project boundaries, %; and

LF_{ME} Leakage factor for market-effects calculations; dimensionless.

Where sufficient variation exists in PMP_i relative to PML_{FT} that multiple values of LF_{ME} result, then an area weighted final value for LF_{ME} shall be calculated. The area of stratum i as a proportion of the total project area shall be multiplied by LF_{ME}. All values are then summed to arrive at the area weighted final value of LF_{ME}.

8.4 Summary of GHG Emission Reduction and/or Removals

Net GHG emission reductions are calculated as:

$$GHG_{CREDITS|LtPF,t*} = GHG_{NET|BSL,t*} - GHG_{NET\backslash PRJ,t*} - GHG_{LK|LtPF,t*} \quad \textbf{(41)}$$

Where:

$GHG_{CREDITS|LtPF,t*}$	project greenhouse gas credits associated with the implementation of improved forest management (IFM) activities in the year t* since the start of the project activity, in the project scenario, tCO_2e;
$GHG_{NET|BS,t*L}$	net greenhouse gas emissions in the baseline scenario in the year t* since the start of the project activity, tCO_2e;
$GHG_{NET|PRJ,t*}$	net greenhouse gas emissions in the project scenario in the year t* since the start of the project activity, tCO_2e; and
$GHG_{LK|LtPF,t*}$	total greenhouse gas emissions due to leakage arising outside the project boundary as a result of the implementation of improved forest management (IFM) activities in the year t* since the start of the project activity, in the project scenario, tCO_2e.

8.4.1 Project Verified Carbon Units

The number of Verified Carbon Units (VCUs) for each year t in the project crediting period is the greenhouse gas emission reductions and removals adjusted for uncertainty and risk.

8.4.1.1 Adjustment for uncertainty

Estimated greenhouse gas emissions and emission reductions from IFM activities have uncertainties associated with parameters and coefficients including estimates of area, carbon stocks, regrowth and expansion factors. It is assumed that the uncertainties associated with input data are available, either as default uncertainty values given in most recent IPCC guidelines, or as statistical estimates based on sampling.

Uncertainty at all times is defined at the 95% confidence interval where the estimated variance exceeds +/- 15 percent from the mean. Procedures including stratification and the allocation of sufficient measurement plots will help ensure that low uncertainty results and ultimately full crediting can result.

It is good practice to consider uncertainty at an early stage to identify the data sources with the highest uncertainty to allow the opportunity to conduct further work to diminish uncertainty.

Uncertainties arising from the measurement and monitoring of carbon pools and greenhouse gases must always be quantified. Errors in each pool must be weighted by the size of the pool so that projects may reasonably target a lower precision level in pools that only form a small proportion of the total stock.

For both the baseline and the with-project case the total uncertainty is equal to the square root of the sum of the squares of each component uncertainty and is calculated at the time of reporting through propagating the error in the baseline stocks and the error in the project stocks.

Therefore, total uncertainty for LtPF project is calculated as:

$$U_{TOTAL|LtPF} = \sqrt{U^2{}_{|PRJ} + U^2{}_{|BSL}} \quad \textbf{(42)}$$

Where:

$U_{total|LtPF}$	Total uncertainty for LtPF Project, dimensionless;
$U_{|PRJ}$	Total uncertainty for the improved forest management activities in the project scenario, dimensionless; and
$U_{|BSL}$	Total uncertainty for the baseline scenario, dimensionless.

The project proponent must justify the selection of uncertainty propagation in the project documents. If $U_{total|LtPF} \leq 0.15$ then no deduction will result for uncertainty.

If $U_{total|LtPF}>0.15$ then the amount of greenhouse gas emission credits associated with IFM activities will be deducted as follows:

$$Credits_{total|LtPF} = GHG_{credits|LtPF} * \left(1 - U_{total|LtPF}\right) \quad \textbf{(43)}$$

Where:

$Credits_{total|LtPF}$	Total greenhouse gas credits adjusted for uncertainty for each year *t* in the project crediting period;
$GHG_{credits|LtPF}$	Project greenhouse gas credits associated with the implementation of improved forest management (IFM) activities in the project scenario, $tCO_2e \cdot year^{-1}$; and
$U_{total|LtPF}$	Total uncertainty for LtPF Project, dimensionless.

8.4.1.2 Calculation of verified carbon units

The amount of greenhouse gas emission reductions estimated under Section 8.4.1.1 above must be adjusted to account for risk, following application of the most recent version of the VCS *AFOLU Non-Permanence Risk Tool*.

Therefore, the amount of VCU's that can be issued at time t=t2 (the date of verification) for monitoring period T=t2-t1, is calculated as:

$$VCU_{net|LtPF} = \left(Credits_{total,t2|LtPF} - Credits_{total,t1|LtPF}\right) - Bu_{|IFM-VCS} \quad \textbf{(44)}$$

Where:

$VCU_{net\,|\,LtPF}$	Number of verified carbon units; dimensionless;
$Credits_{total.t1\,|\,LtPF}$	Net anthropogenic greenhouse gas removals by sinks, as estimated for t*=t1 in tCO_2e;
$Credits_{total.t2\,|\,LtPF}$	Net anthropogenic greenhouse gas removals by sinks, as estimated for t*=t2 in tCO_2e; and
$Bu_{|IFM\text{-}VCS}$	Total number of credits withheld in VCS AFOLU pooled buffer account

9 MONITORING

9.1 Data and Parameters Available at Validation

In addition to the parameters listed in the tables presented in the following sections, the provisions on data and parameters not monitored in the tools referred to in this methodology apply. In choosing key parameters or making important assumptions based on information that is not specific to project circumstances, such as in use of existing published data, the project proponent must follow a conservative approach. That is, if different values for a parameter are equally plausible, a value that does not lead to over-estimation of net anthropogenic GHG removals by sinks must be selected.

Note that the calculation of baseline emissions from fossil fuel combustion requires the determination of a set of parameters (eg, specific fuel consumption of a harvester, in kL/m3). As a general procedure, the determination of all parameters must follow one of the subsequent pathways:

1. Historic Data Pathway: Where the project proponent has a history of logging operations, the equipment type and fuel consumption data from the project proponent's operation must be considered.

2. Common Practice Pathway: Where the project proponent has no history of logging operations, regional or national standards and typical machinery (ie, default values) must be considered. This includes:

   - Identification of equipment type (eg, harvester or chain saw);

   - Identification of the specific fuel consumption (ie, in kL/m3) of equipment type.

   The following sources of information are permitted for the common practice pathway:

   - Data from other forest management companies in the region; or

- Data from peer reviewed literature (ie, available from a recognized, credible source and must be reviewed for publication by an appropriately qualified, independent organization or an appropriate peer review group, or published by a government agency).

Further, the source of all data must be appropriate to the methodology's geographic scope and eligible project activities.

Data / Parameter	$F_{V,INF,HWP}$
Data unit	%
Description	The fraction of merchantable timber volume from clearing of forest roads, skidtrails and log landings that is to be processed into wood products .Based on this fraction as well as forest inventory or sample plot data and forestry infrastructure data, $V_{EX,INF,j,i\|BSL}$ and $V_{notEX,INF,j,i\|BSL}$ will be calculated.
Equations	To be applied in the timber harvest plan
Source of data	A credible and conservative value for $F_{V,INF,HWP}$ must be set based on one of the following sources in order of their appearance: Forest management records of the baseline agent or other similar forestry companies Peer-reviewed literature Government statistics from the region If the project proponent cannot provide such a credible estimate, then it is conservatively assumed that all timber cleared for the purpose of forestry infrastructure is processed into sawnwood and hence must be accounted for under the harvested wood products section.
Value applied	n.a.
Justification of choice of data or description of measurement methods and procedures applied	n.a.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$V_{EX,INF,j,i\|BSL}$
Data unit	m^3 ha-1

Description	Mean volume of timber extracted for wood processing during the process of forestry infrastructure establishment per unit area for species j in stratum i
Equations	(3), (4), (37)
Source of data	$V_{EX,INF,j,i\|BSL}$ is provided in the timber harvest plan. It is calculated by multiplying $F_{V,INF,HWP}$ with the merchantable volume (from sample plots or existing forest inventory data) to be harvested/cleared for the purpose of forestry infrastructure development.
Value applied	n.a.
Justification of choice of data or description of measurement methods and procedures applied	n.a.
Purpose of Data	Determination of baseline scenario
Comments	n.a.

Data / Parameter	$V_{notEX,INF,j,i\|BSL}$
Data unit	m^3 ha-1
Description	Mean volume of timber that is not extracted for wood processing during the establishment of forestry infrastructure per unit area for species j in stratum i
Equations	(7)
Source of data	$V_{notEX,INF,j,i\|BSL}$ is provided in the timber harvest plan. It is calculated by multiplying $1-F_{V,INF,HWP}$ with the merchantable volume (from sample plots or existing forest inventory data) to be harvested/cleared for the purpose of forestry infrastructure development.
Value applied	n.a.
Justification of choice of data or description of measurement methods and procedures applied	n.a.
Purpose of Data	Determination of baseline scenario
Comments	n.a.

Data / Parameter	$F_{RSD\|BSL}$

<table>
<tr><td>Data unit</td><td>Dimensionless</td></tr>
<tr><td>Description</td><td>Residual Stand Damage Factor</td></tr>
<tr><td>Equations</td><td>(6)</td></tr>
<tr><td>Source of data</td><td>Choose data from peer reviewed literature (ie, available from a recognized, credible source and must be reviewed for publication by an appropriately qualified, independent organization or an appropriate peer review group, or published by a government agency), eg, Brown, S. Pearson T., Moore, N., Parveen A., Ambagis, S., Shoch, D. (2005). Impact of selective logging on the carbon stocks of tropical forests: Republic of Congo as a case study. Deliverable 6: Logging Impact on carbon stocks, Report submitted to United States Agency for International Development, Cooperative Agreement No. EEM-A-00-03-00006-00.</td></tr>
<tr><td>Value applied</td><td>
<table>
<tr><th>f_{RSD} (tCdamaged tCextracted^{-1})</th><th>Commerical Log Length (m)</th><th>Country</th><th>Reference</th></tr>
<tr><td>1.74</td><td>22</td><td>Congo</td><td>Brown et al. (2005)</td></tr>
<tr><td>2.30</td><td>17</td><td>Malaysia</td><td>Pinard and Putz (1996)</td></tr>
<tr><td>2.78</td><td>10.8</td><td>Belize</td><td>Brown et al. (2005)</td></tr>
</table>
<table>
<tr><th>f_{RSD} (tCdamaged tCextracted^{-1})</th><th>Commerical Log Length (m)</th><th>Country</th><th>Reference</th></tr>
<tr><td>3.10</td><td>9.8</td><td>Bolivia</td><td>Pearson et al. (2005)</td></tr>
</table>
</td></tr>
<tr><td>Justification of choice of data or description of measurement methods and procedures applied</td><td>n.a.</td></tr>
<tr><td>Purpose of Data</td><td>Determination of baseline scenario</td></tr>
<tr><td>Comments</td><td>Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.</td></tr>
</table>

Data / Parameter	EF_{FUEL}
Data unit	tCO_2e/kL
Description	Fuel emission factor
Equations	14
Source of data	Data must be determined following either the historic data pathway, (if the PP has a history of logging operations) or the

	common practice pathway as stipulated at the beginning of this section.
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation..

Data / Parameter	$FC_{HARVEST}$
Data unit	kL/m^3
Description	Fuel consumption of equipment employed for felling and snigging per m3 of merchantable log harvested;
Equations	14
Source of data	Data must be determined following either the historic data pathway, (if the project proponent has a history of logging operations) or the common practice pathway as stipulated at the beginning of this section.
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$FC_{HAULING}$
Data unit	kL/m^3
Description	Fuel consumption of equipment for hauling one m3 of merchantable log.
Equations	15
Source of data	Data must be determined following either the historic data pathway, (if the project proponent has a history of logging

	operations) or the common practice pathway as stipulated at the beginning of this section.
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$KM_{TRANSPORT}$
Data unit	km truck-1
Description	Log transport distance from collection depot to processing plant;
Equations	17
Source of data	Digital maps specifying harvesting areas and logging and transport roads to processing facility
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline activity emissions
Comments	N.A.

Data / Parameter	CAP_{TRUCK}
Data unit	m^3 truck-1
Description	Truck load capacity
Equations	16
Source of data	Data must be determined following either the historic data pathway, (if the project proponent has a history of logging operations) or the common practice pathway as stipulated at the beginning of this section.
Value applied	Various
Justification of choice of data or description of	N.A.

measurement methods and procedures applied	
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$EFF_{VEHICLE}$
Data unit	km kL-1
Description	Fuel efficiency for vehicle type
Equations	18
Source of data	Data must be determined following either the historic data pathway, (if the project proponent has a history of logging operations) or the common practice pathway as stipulated at the beginning of this section..
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	E_{DEMAND}
Data unit	kWh m^{-3}
Description	Electricity demand for processing per volume processed
Equations	19
Source of data	Data must be determined following either the historic data pathway, (if the project proponent has a history of logging operations) or the common practice pathway as stipulated at the beginning of this section.
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.

Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$EF_{ELECTRICITY}$
Data unit	tCO_2e kWh-1
Description	Emission factor for electricity in the host country
Equations	20
Source of data	Country-specific data from International Energy Agency
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$T_{GENERATOR}$
Data unit	h
Description	Total operating time of generator
Equations	21
Source of data	Data must be determined following either the historic data pathway, (if the project proponent has a history of logging operations) or the common practice pathway as stipulated at the beginning of this section.
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$FC_{GENERATOR}$
Data unit	kL h-1
Description	Fuel consumption per hour of operation of generator
Equations	22
Source of data	Data must be determined following either the historic data pathway, (if the project proponent has a history of logging operations) or the common practice pathway as stipulated at the beginning of this section.
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data / Parameter	$PR_{GENERATOR}$
Data unit	kW
Description	Power rating of generator or generator size;
Equations	21
Source of data	Data must be determined following either the historic data pathway, (if the project proponent has a history of logging operations) or the common practice pathway as stipulated at the beginning of this section.
Value applied	Various
Justification of choice of data or description of measurement methods and procedures applied	N.A.
Purpose of Data	Determination of baseline scenario
Comments	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data/ Parameter:	$V_{l,j,i,sp}$

Data unit:	m^3
Used in equations:	(1)
Description:	Merchantable volume for tree *l* of species *j* in sample plots *p* in stratum *i*
Source of data:	Calculated from volume tables or equations linking diameter at breast height (DBH, at typically 1.3 m aboveground level), and/or merchantable height (MH), to commercial (merchantable) volume of trees in the sample plots above the minimum DBH set in the timber harvest plan. If locally derived equations or yield tables are not available use relevant regional, national or default equations from IPCC literature, national inventory reports or published peer-reviewed studies– such as those provided in Tables 4.A.1 to 4.A.3 of the GPG-LULUCF (IPCC 2003).
Measurement procedures (if any):	N/A
Any comment:	It is necessary to verify the applicability of equations used. Allometric equations can be verified by both: 1. Verification of equation conditions Justification should be provided for the applicability of the equation to the project locations. Such justification should include identification of climatic, edaphic, geographical and taxonomic similarities between the project location and the location in which the equation was derived. Any equation used should have an r2 value of greater than 0.5 (50%) and a p value that is significant (<0.05 at the 95% confidence level). 2. Additional field verification The following limited measures method must be used for field verification: select at least 10 trees per species distributed across the age range (but excluding trees less than 15 years old for which there is rarely a great relative inaccuracy in equations) ; measure DBH, and height to a 10 cm diameter top or to the first branch; calculate stem volume from measurements; and plot the estimated volume of all the measured trees along with the curve of volume against diameter as predicted by the allometric equation. If the estimated volume of the measured trees are distributed both

	above and below the curve (as predicted by the allometric equation) the equation may be used. The equation may also be used if the measured individuals have a volume consistently higher than predicted by the equation. The equation may not be used if >75% of the measured trees have a volume lower than the predicted curve. In this instance another equation must be selected.

Data/ parameter:	CF_j
Data unit:	$tC·td.m.^{-1}$
Used in equations:	(3),(4),(17)
Description:	Carbon fraction of dry matter for species j
Source of data:	Either the default value $0.5tC·td.m.^{-1}$ or species specific values from the literature must be used. The same value, however, must be used in all instances where this parameter is used.
Measurement procedures (if any):	N/A
Any comment:	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data/ parameter:	D_j
Data unit:	$t.d.m.\ m^{-3}$
Used in equations:	(4)
Description:	Basic wood density of species *j* in $t\ d.m.\ m^{-3}$
Source of data:	Must be chosen with priority from higher to lower preference as follows: National species-specific or group of species-specific values (eg, from National GHG inventory); Species-specific or group of species-specific values from neighboring countries with similar conditions. When species-specific data from neighboring countries is of higher quality, being more representative of the species in the project scenario, it may be preferable to use these values than lower quality national data; Global species-specific or group of species-specific (eg, IPCC 2006 AFOLU Chapter 4 Tables 4.13 and 4.14). Species-specific wood densities may not always be available, and

	may be difficult to apply with certainty in the typically species rich forests of the humid tropics, hence it is acceptable practice to use wood densities developed for forest types or plant families or species groups.
Measurement procedures (if any):	N/A
Any comment:	Default values must be updated whenever new guidelines are produced by the IPCC

Data/ parameter:	$f_j(X,Y...)$
Data unit:	t d.m. tree^{-1}
Used in equations:	17
Description:	Allometric equation(s) for species *j* linking measured tree variable(s) to aboveground biomass of living trees
Source of data:	Equations must have been derived using a wide range of measured variables (eg, DBH, Height, etc.) based on datasets that comprise at least 30 trees. Equations must be based on statistically significant regressions and must have an r2 that is ≥ 0.8. The source of equation(s) must be chosen with priority from higher to lower preference, as available, as follows: National species-, genus-, family-specific; Species-, genus-, family-specific from neighboring countries with similar conditions (ie, broad continental regions); National forest-type specific; Forest-type specific from neighboring countries with similar conditions (ie, broad continental regions); Forest type-specific such as those provided Tables 4.A.1 to 4.A.3 of the GPG-LULUCF (IPCC 2003); or in Pearson, T., Walker, S. and Brown, S. 2005. Sourcebook for Land Use, Land-Use Change and Forestry Projects. Winrock International and the World Bank Biocarbon Fund. 57pp.; or in Chave, J., C. Andalo, S. Brown, M. A. Cairns, J. Q. Chambers, D. Eamus, H. Folster, F. Fromard, N. Higuchi, T. Kira, J.-P. Lescure, B. W. Nelson, H. Ogawa, H. Puig, B. Riera, T. Yamakura. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145: 87-99. Species-, genus- and family-specific allometric equations may not always be available, and may be difficult to apply with certainty in the typically species rich forests of the humid tropics. Hence it is

	acceptable practice to use equations developed for regional forest types, provided that their accuracy has been validated with direct site-specific data following guidance given below. If a forest-type specific equation is used, it should not be used in combination with species-specific equation(s) (ie, it must be used for all tree species[36]).
Measurement procedures (if any):	N/A
Any comment:	It is necessary to validate the applicability of equations used. Source data from which equation(s) was derived should be reviewed and confirmed to be representative of the forest type/species and conditions in the project and covering the range of potential independent variable values. Allometric equations can be validated either by: 1. Limited Measurements select at least 30 trees (if validating forest type-specific equation, selection should be representative of the species composition in the project area, ie, species representation in roughly in proportion to relative basal area). Minimum diameter of measured trees must be 20cm and maximum diameter must reflect the largest trees present or potentially present in the future in the project area (and/or leakage belt); measure DBH, and height to a 10 cm diameter top or to the first branch; calculate stem volume from measurements and multiplying by species-specific density to gain biomass of bole; apply a biomass expansion factor to estimate total aboveground biomass from stem biomass[37]; and plot the estimated biomass of all the measured trees along with the curve of biomass against diameter as predicted by the allometric equation. If the estimated volume of the measured trees are distributed both above and below the curve (as predicted by the allometric equation)

[36]Note that forest type specific and pantropical equations will typically not include palm species or hollow-stem species (e.g. Cecropia) and so specific equations for these growth forms will be needed

[37] See IPCC 2006 INVGLs AFOLU Chapter4 Table 4.5

	the equation may be used. The equation may also be used if the measured individuals have a biomass consistently higher than predicted by the equation. If >75% of the measured trees have a biomass lower than the predicted curve, destructive sampling must be undertaken or another equation must be selected. 2. Destructive Sampling select at least 5 trees (if validating forest type-specific equation, selection should be representative of the species composition in the project area, ie, species representation in roughly in proportion to relative basal area) at the upper end of the range of independent variable values existing in the project area; measure DBH and commercial height and calculate volume using the same procedures/equations used to generate commercial volumes to which BCEFs will be applied; fell and weigh the aboveground biomass to determine the total (wet) mass of the stem, branch, twig, leaves, etc. Extract and immediately weigh subsamples from each of the wet stem and branch components, followed by oven drying at 70 degrees C to determine dry biomass; determine the total dry weight of each tree from the wet weights and the averaged ratios of wet and dry weights of the stem and branch components; and plot the estimated biomass of all the measured trees along with the curve of biomass against diameter as predicted by the allometric equation. If the estimated volume of the measured trees are distributed both above and below the curve (as predicted by the allometric equation) the equation may be used. The equation may also be used if the measured individuals have a biomass consistently higher than predicted by the equation. If >75% of the measured trees have a biomass lower than the predicted curve another equation must be selected. Details of destructive sampling measurements are given in: Brown, S. 1997. Estimating biomass and biomass change of tropical forests: a primer. FAO Forestry Paper 134, Rome, Italy. Available at http://www.fao.org/docrep/W4095E/W4095E00.htm If using species-specific equations, and new species are encountered in the course of monitoring, new allometric equations must be sourced from the literature and validated, if necessary, as per requirements and procedures above.

	Default values must be updated whenever new guidelines are produced by the IPCC

Data/ parameter:	$BCEF_R$
Data unit:	$t.d.mm^{-3}$
Used in equations:	3, 22
Description:	Biomass conversion and expansion factor applicable to wood removals in the project area
Source of data:	The source of data must be chosen with priority from higher to lower preference as follows: Existing local forest type-specific; National forest type-specific or eco-region-specific (eg, from national GHG inventory); Forest type-specific or eco-region-specific from neighboring countries with similar conditions. Sometimes (c) might be preferable to (b); Global forest type or eco-region-specific (eg, IPCC 2006 INV GLs AFOLU Chapter 4 Table 4.5). Alternatively: BCEFR = BEFR * D Where BCEF values are not directly available, they can be calculated as Biomass Expansion Factor (BEF)* basic wood density (D). Application of this equation requires caution because basic wood density and biomass expansion factors tend to be correlated. If the same sample of trees was used to determine D, BEF or BCEF, conversion will not introduce error, therefore, it is acceptable to use this equation. If, however, basic wood density is not known with certainty, transforming one into the other might introduce error, as BCEF implies a specific but unknown basic wood density, therefore, all conversion and expansion factors must be derived or their applicability checked locally.
Measurement procedures (if any):	N/A
Any comment:	The combustion factor is a measure of the proportion of the fuel that is actually combusted, which varies as a function of the size and architecture of the fuel load (ie, a smaller proportion of large, coarse fuel such as tree stems will be burnt compared to fine fuels, such as

	grass leaves), the moisture content of the fuel and the type of fire (ie, intensity and rate of spread). Default values must be updated whenever new guidelines are produced by the IPCC

Data/ parameter:	G_{gi}
Data unit:	g kg^{-1}dry matter burnt
Used in equations:	(21)
Description:	Emission factor for stratum *i* for gas *g*
Source of data:	Defaults can be found in Volume 4, Chapter 2, of the IPCC 2006 Inventory Guidelines in table 2.5
Measurement procedures (if any):	N/A
Any comment:	Default values must be updated whenever new guidelines are produced by the IPCC

Data/ parameter:	*OF, SLF, WW*
Data unit:	Kg kg^{-1}
Used in equations:	7, 9
Description:	*OF* = Fraction of wood products that will be emitted to the atmosphere between3and100yearsafterproduction; *SLF* = Fraction of wood products that will be emitted to the atmosphere within 3 years of production; and *WW* = Fraction of extracted biomass effectively emitted to the atmosphere during production Wood waste fraction(WW): Winjum et al. 1998indicatethattheproportionofextracted biomass that is oxidized (burning or decaying) from the production of commodities to be equal to19%fordevelopedcountries, 24% for developing countries. Short-lived fraction (SLF) Winjumetal1998 give decay rates for proportions of wood products, which were converted to with short-term (<3yr) uses (applicable internationally) as below: Sawnwood 0.12 Woodbase panels 0.06

	Other industrial roundwood 0.18 Paper and Paperboard 0.24 Additional oxidized fraction (OF) Winjum et al 1998 gives annual oxidation fractions for each class of wood products split by forest region (boreal, temperate and tropical). This methodology projects these fractions over 95 years to give the additional proportion that is oxidized between the 3rd and the 100th year after initial harvest:
Source of data:	The source of data is the published paper of Winjum et al.1998[38]
Measurement procedures (if any):	N/A
Any comment:	Parameter needs to be reviewed as part of the baseline re-evaluation.

Wood Product Class	OF		
	Boreal	Temperate	Tropical
Sawnwood	0.39	0.62	0.86
Woodbase panels	0.62	0.86	0.98
Other industrial roundwood	0.86	0.98	0.99
Paper and paperboard	0.39	0.62	0.99

Data/ parameter:	PML_{FT}
Data unit:	%
Used in equations:	Section 8.3.2, Leakage, Box 2.
Description:	Mean merchantable biomass as a proportion of total aboveground tree biomass for each forest type.
Source of data:	The source of data must be chosen with priority from higher to lower preference as follows: peer-reviewed published sources (including carbon/biomass maps or growing stock volume[39] maps with a scale of at least 1km);

[38] Winjum ,J.K., Brown,S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. ForestScience44:272-28431

[39] Volumes shall be converted to merchantable biomass using wood densities / specific gravities. A weighted

Wood density shall be used to convert multi-species data on growing stock volume to merchantable biomass

	official Government data and statistics ;or original field measurements. The forest types considered must be only those relevant for the specific market effects leakage, that is, only forest types with active timber production. An appropriate source of data will be Government records on annual allowable cuts for the areas of commercial forests. Where volumes are used the source of data wood density is required to convert to merchantable biomass. The source of data on wood densities must be chosen as per the species specific density parameter, D_j.
Measurement procedures (if any):	
Any comment:	Parameter needs to be re-assessed and updated (if appropriate) as part of the baseline re-evaluation.

Data/ parameter:	RGR_i
Data unit:	$tC.ha^{-1}.yr^{-1}$
Used in equations:	10
Description:	Forest regrowth rate post timber harvest for stratum *i*
Source of data:	Regrowth rate must be calculated from either data generated in a reference area using measurements of timber volume in a chronosequence of replicated sample plots; or published data on forest growth after timber harvest of the same forest type within the same region as the project; or the IPCC default values for aboveground net biomass growth in natural forests[40].
Measurement procedures (if any):	
Any comment:	Default values must be updated whenever new guidelines are produced by the IPCC

Data/ parameter:	$V_{EX,j,i\|BSL}$

[40] IPCC Guidelines for National Greenhouse Gas Inventories(2006),Table4.9

Data unit:	$m^3 \cdot ha^{-1}$
Used in equations:	3, 4, 22, 27
Description:	Mean volume of extracted timber per unit area for species *j* in stratum *i*
Source of data:	The timber harvest plan sets the allowable mean extracted volume from the merchantable volume of timber in the forest inventory ($V_{j,i\|BSL}$),based on legal limits.
Measurement procedures (if any):	N/A
Any comment:	

Data/ parameter:	$TH_{i,p}$
Data unit:	Years
Used in equations:	
Description:	Number of years since timber harvest in stratum *i* in land parcel *p*
Source of data:	The timber harvest schedule specifies the year (*1,2,3...*) timber harvest in each land parcel is scheduled to occur and the number of years each land parcel is in a post harvest state during the project crediting period.
Measurement procedures (if any):	
Any comment:	

Data/ parameter:	$A_{i,p}$
Data unit:	Ha
Used in equations:	20
Description:	Area covered by stratum *i* over land parcel *p*
Source of data:	Geodetic coordinates and/or Remote Sensing data and/or legal parcel records
Measurement procedures (if any):	
Any comment:	It must be assumed ex-ante that land parcel boundaries and strata areas must not change through time

Data/ parameter:	$A_{1,i,p}$

Data unit:	Ha
Used in equations:	(11)
Description:	The area of stratum *i* in land parcel *p* that was harvested 1 year ago
Source of data:	Geodetic coordinates, GIS Files or legal parcel records
Measurement procedures (if any):	
Any comment:	

Data/ parameter:	$A_{2-10,i,p}$
Dataunit:	Ha
Usedin equations:	(12)
Description:	The area of stratum *i* in land parcel *p* that was harvested between 2 and 10 year ago
Sourceof data:	Geodetic coordinates, GIS Files or legal parcel records
Measurement procedures (if any):	
Any comment:	

Data/ parameter:	$A_{11-20,i,p}$
Data unit:	Ha
Used in equations:	13
Description:	The area of stratum *i* in land parcel *p* that was harvested between 11 and 20 years ago
Source of data:	Geodetic coordinates, GIS Files or legal parcel records
Measurement procedures (if any):	
Any comment:	

Data/ parameter:	A_{t+}
Data unit:	Ha
Used in equations:	14
Description:	Cumulative area harvested until time t*
Source of data:	Geodetic coordinates, GIS Files or legal parcel records

Measurement procedures (if any):	
Any comment:	

Data/ parameter:	A_{sp}
Data unit:	Ha
Used in equations:	2, 19
Description:	Area of sample plots *p*
Source of data:	Recording and archiving of size of sample plots
Measurement procedures (if any):	Standard procedures for plot delineation in forest timber inventory surveys must be used (see references in Box 3 for example procedures)
Any comment:	*Ex-ante* the size of the plots must be defined and recorded in the monitoring plan.

9.2 Data and Parameters Monitored

In addition to the parameters listed in the tables below, the provisions on data and parameters not monitored in the tools referred to in this methodology apply. In choosing key parameters or making important assumptions based on information that is not specific to the project circumstances, such as in use of existing published data, the project proponent must retain a conservative approach. That is, if different values for a parameter are equally plausible, a value that does not lead to over-estimation of net anthropogenic GHG removals by sinks must be selected.

Data/ parameter:	Illegal Logging PRA Results
Data unit:	Dimensionless
Used in equations:	Used in Section 8.2.2.2a
Description:	
Source of data:	PRA
Measurement procedures (if any):	The PRA must evaluate whether timber harvest may be occurring in the project area and must consist of semi-structured interviews / questionnaires. If ≥10% of those interviewed / surveyed believe that illegal logging may be occurring within the project boundary then the limited on-the-ground illegal logging survey must be triggered. An additional output of the PRA must be a depth of penetration of illegal logging pressure. A maximum distance must be recorded for

	penetration into the forest from access points (such as roads, rivers, already cleared areas) for the purpose of harvesting timber.
Measurement Frequency	Every two years
QA/QC Procedures	
Any comment:	Ex ante estimation must be made of illegal logging in the with-project case. If the belief is that zero illegal logging will occur within the project boundaries then this parameter may be set to zero if clear infrastructure, hiring and policies are in place to prevent illegal logging.

Data/ parameter:	Result of Limited Illegal Logging Survey
Data unit:	Dimensionless
Used in equations:	Section 8.2.2.2b
Description:	
Source of data:	Limited on-the-ground illegal logging survey
Measurement procedures (if any):	Sampled by surveying multiple transects of known length and width across the access-buffer area to check whether new tree stumps are evident or not. The access-buffer area must be equal in area to at least 1% of ADIST_IL,i
Measurement Frequency	Must to be repeated each time the PRA indicates a potential for illegal logging.
QA/QC Procedures	
Any comment:	Ex ante an estimation must be made of illegal logging in the with-project case. If the belief is that zero illegal logging will occur within the project boundaries then this parameter may be set to zero if clear infrastructure, hiring and policies are in place to prevent illegal logging.

Data/ parameter:	$A_{burn,i,t}$
Data unit:	Ha
Used in equations:	21
Description:	Area burnt in stratum *i* at time *t*
Source of data:	Geodetic coordinates and / or Remote Sensing data
Measurement procedures (if any):	N/A
Measurement Frequency	Areas burnt must be monitored at least every five years
QA/QC Procedures	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management

	must be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or form the IPCC GPG LULUCF 2003, is recommended.
Any comment:	Ex ante estimations of areas burned must be based on historic incidence of fire in the Project region

Data/ parameter:	*Adist,i,t*
Data unit:	Ha
Used in equations:	23
Description:	Area disturbed in stratum *i* at time *t*
Source of data:	Geodetic coordinates and / or Remote Sensing data
Measurement procedures (if any):	N/A
Measurement Frequency	Areas disturbed must be monitored at least every five years
QA/QC Procedures	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or form the IPCC GPG LULUCF 2003, is recommended.
Any comment:	Ex ante estimations of areas disturbed must be based on historic incidence of natural disturbance in the Project region

Data/ parameter:	$A_{DIST\_IL,i}$
Data unit:	Ha
Used in equations:	24
Description:	Area potentially impacted by illegal logging in stratum *i*
Source of data:	GIS delineation and ground-truthing
Measurement procedures (if any):	ADIST_IL,i must be composed of a buffer from all access points (access buffer), such as roads and rivers or previously cleared areas. The width of the buffer must be determined by the depth of degradation penetration as defined as a PRA output
Measurement Frequency	Repeated each time the PRA indicates a potential for degradation
QA/QC Procedures	
Any comment:	Ex ante a limited survey can be used to determine a likely depth of degradation penetration

Data/ parameter:	$C_{DIST\_IL,i,t\|PRJ}$
Data unit:	tCO_2e
Used in equations:	24, 25
Description:	biomass carbon of trees cut and removed through illegal logging in stratum i at time t
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	The sampling plan must be designed using plots systematically placed over the buffer zone so that they sample at least 3% of the area of the buffer zone (ADIST_IL,i). The diameter of all tree stumps will be measured and conservatively assumed to be the same as the DBH. Where the stump is a large buttress, several individuals of the same species nearby must be located and a ratio of the diameter at DBH to the diameter of buttress at the same height above ground as the measured stumps must be determined. This ratio will be applied to the measured stumps to estimate the likely DBH of the cut tree. The aboveground carbon stock of each harvested tree will be estimated using the allometric regression equations chosen for forest growth in the project scenario. The mean aboveground carbon stock of the harvested trees is conservatively estimated to be the total emissions and to all enter the atmosphere
Measurement Frequency	Repeated each time limited sampling of ADIST_IL, indicates illegal logging
QA/QC Procedures	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or form the IPCC GPG LULUCF 2003, is recommended.
Any comment:	If species-specific equations are used and species cannot be identified from stumps then it must be assumed that the harvested species is the species most commonly harvested. A PRA must be used to determine the most commonly harvested species.

Data/ parameter:	AP_i
Data unit:	Ha
Used in equations:	24

Description:	Total area of illegal logging sample plots in stratum *i*
Source of data:	Ground measurement
Measurement procedures (if any):	A sampling plan must be designed using multiple sample plots systematically placed across the buffer zone so that they sample at least 3% of the area of the buffer zone.
Measurement Frequency	Not more than five years
QA/QC Procedures	Standard quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or form the IPCC GPG LULUCF 2003, is recommended.
Any comment:	Ex ante estimation should be made of area of plots. This should be set to exactly 3% of the buffer zone ADIST_IL,i

Data/ parameter:	PMP_i
Data unit:	%
Used in equations:	Section 8.3.2, Box 2: 'Leakage Factor Calculation'
Description:	Merchantable biomass as a proportion of total aboveground tree biomass for stratum *i* within the project boundaries
Source of data:	Within each stratum divide the summed merchantable biomass (defined as total gross biomass of a tree15cm DBH or larger) by the summed total of aboveground tree biomass.
Measurement procedures (if any):	
Measurement Frequency	Not more than five years
QA/QC Procedures	Standard quality control /quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs already applied in national forest monitoring, or available from published handbooks, or form the *IPCC GPGLULUCF 2003*, is recommended.
Any comment:	Ex-ante a time zero measurement must be made of this factor. The timber harvest plan sets the allowable mean extracted volume from the merchantable volume of timber in the forest inventory (Vj,i|BSL), based on legal limits.

Data/ parameter:	$A_{i,}$
Data unit:	Ha
Used in equations:	20
Description:	Area covered by stratum *i*
Source of data:	Geodetic coordinates and/or Remote Sensing data and/or legal parcel records
Measurement procedures (if any):	
Measurement Frequency	
QA/QC Procedures	
Any comment:	In the baseline scenario strata areas must not change through time. In the project scenario it must be assumed *ex-ante* that stand boundaries and strata areas must not change through time. *Ex post* adjustments of the project scenario strata may be needed if unexpected disturbances occur during the project crediting period, severely affecting different parts of an originally homogenous stratum. This disturbance will be delineated as a separate stratum for the purpose of monitoring the carbon stock changes.

9.3 Description of the Monitoring Plan

The following parameters must be monitored in this methodology:

- Illegal logging PRA
- Result of limited illegal logging survey
- Area burnt in stratum *i* at time *t* ($A_{burn,i,t}$)
- Area potentially impacted by illegal logging in stratum *i* ($A_{DIST\_IL,\ i}$)
- Total area of illegal logging sample plots in stratum *i* (AP_i)
- Merchantable biomass as a proportion of total aboveground tree biomass for stratum *i* (PMP_i)
- Area covered by stratum *i* (A_i)
- Diameter at breast height of tree (*DBH*)

These parameters will be required at each verification and are used in equations 20, 21 and 23.

9.3.1 Scope of monitoring and the monitoring plan

Monitoring is required to:

a) Determine changes in forest carbon stocks and greenhouse gas emissions from project activity;

b) Confirm project activity; and

c) Determine changes in forest carbon stocks and greenhouse gas emissions from disturbance and illegal logging.

In some project cases monitoring may also be implemented to update stratification.

It is a requirement that the monitoring plan presented in the project documents must address the monitoring of project implementation, the monitoring of actual carbon stock changes from project activity, and estimation of ex-post net carbon stock changes from disturbance and illegal logging.

The description of the monitoring plan in the project documents will include the following for each of these monitoring tasks:

a) Technical description of the monitoring task;

b) A list of data and parameters to be collected;

c) Overview of data collection procedures;

d) Quality control and quality assurance procedure;

e) Data archiving; and

f) Organization and responsibilities of the parties involved in all the above.

9.3.2 General requirements for monitoring

All data collected as part of monitoring will be archived electronically and be kept at least for 2 years after the end of the project crediting period. All measurements will be conducted according to relevant standards.

Data archiving must take both electronic and paper forms, and copies of all data must be provided to each project proponent.

All electronic data and reports must also be copied on durable media such as CDs and copies of the CDs are to be stored in multiple locations.

The archives must include:

- Copies of all original field measurement data, laboratory data, data analysis spreadsheets;
- Estimates of the carbon stock changes in all pools and non-CO2 GHG and corresponding calculation spreadsheets;
- GIS products; and
- Copies of the measuring and monitoring reports.

9.3.3 Monitoring of project implementation

Information must be provided, and recorded in the project documents, to establish that:

- Geographic position of the project boundary is recorded for all areas of land;
- Geographic coordinates of the project boundary (and any stratification inside the boundary) are established, recorded and archived. This will be achieved by field survey (eg, using Geodetic coordinates) or by using georeferenced spatial data (eg, maps, GIS datasets, aerial photography, or georeferenced remote sensing images);
- Commonly accepted principles of forest inventory and management are implemented;
- Standard operating procedures (SOPs) and quality control/quality assurance (QA/QC) procedures for forest inventory including field data collection and data management must be applied. Use or adaptation of SOPs already applied in national forest monitoring or available from published handbooks or from the IPCC GPG LULUCF 2003 is recommended; and
- Project plan, together with a record of the plan as actually implemented during the project, must be available for validation or verification as appropriate.

9.3.4 Stratification

This methodology requires that an ex ante stratification of the project area in the project scenario is described in the project documents as documented in the timber harvest plan, or developed by the project proponent through sampling in the project area.

The monitoring plan may include sampling to adjust the number and boundaries of the strata defined ex ante where an update is required because of:

a) Unexpected disturbances occurring during the project crediting period affecting differently various parts of an originally homogeneous stratum and/or

b) Forest management activities that are implemented in a way that affects the existing stratification in the project scenario.

Established strata may also be merged if the reasons for their establishment have disappeared.

9.3.5 Monitoring of actual carbon stock changes

Carbon stocks will be measured according to the stock assessment equations in this methodology with field sampling based on forest inventory methods. Various sources exist to assist with the design of a verifiable forest field inventory based on best practice for sampling, data management and analysis (Box 3).

In the project area (or areas) the inventory plan must be specified in the project documents and include:

a) Adequate forest stratification, sample size estimation methods and consider uncertainty; and

b) Sampling framework including sample size, plot size, plot shape and information to determine plot location.

To determine the sample size and allocation among strata, this methodology uses the most recent version of the tool for the “Calculation of the number of sample plots for measurements within A/R CDM project activities”[41] approved by the CDM Executive Board.

Carbon stock changes over time must be estimated by taking measurements in plots at each monitoring event. Monitoring events must take place at intervals of 5, or preferably 3 years. For intermittent years it is good practice to use extrapolations of trends as they have occurred up till that moment. Monitoring reports can use such extrapolated parameter values for the determination of net emissions by sources and removals resulting from the project.

The design of the sampling regime will be determined by the number of strata and timber harvest the baseline case.

9.3.6 Conservative approach and uncertainty

The project proponent must also apply all relevant equations for the ex-ante calculation of net anthropogenic GHG removals by sinks with care and provide transparent estimations for the parameters that are monitored during the project crediting period. These estimates must be based on measured or existing published data where possible and the project proponent should retain a conservative approach. That is, if different values for a parameter are equally plausible, a

[41] http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html

value that does not lead to over-estimation of net anthropogenic GHG removals by sinks must be selected.

An uncertainty analysis is required for all estimates from monitoring related to change in area, change in carbon stocks and emissions for both the baseline and project case.

Box 3: Resource Material for the Design of Forest Field Inventories

IPCC Good Practice Guidance on Land Use. Land Use Change and Forestry (IPCC 2003)

http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html

The Sourcebook for Land Use Change and Forestry Projects (Pearson et al. 2005)

http://www.winrock.org/feature_ecosystem_200802.asp

Measurement guidelines for the sequestration of forest carbon (Pearson et al. 2007)

http://www.nrs.fs.fed.us/pubs/3292

Field Measurements for Forest Carbon Monitoring A Landscape-Scale Approach (Hoover.

2008)

The Winrock sampling calculator http://www.winrock.org/Ecosystems/tools.asp?BU=9086

The CDM A/R Methodological Tool "Calculation of the number of sample plots for measurements within A/R CDM project activities" (Version 02) http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html

The California Climate Action Reserve Registry Forest Project Protocol (Version 2) 2009 http://www.climateactionreserve.org/how-it-works/protocols/adopted- protocols/forest/forest-project-protocol-update/

Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States (Smith et al. 2006)http://nrs.fs.fed.us/pubs/8192

A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects (MacDicken. 1997) http://www.winrock.org/fnrm/publications.asp?BU=9058

10 REFERENCES AND OTHER INFORMATION

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Klvac, R., Skoupy, A. (2009). Characteristic fuel consumption and exhaust emissions in fully mechanized logging operations. Journal of Forest Research, 14 (6), 328-334

Poole, A. and Pinheiro, P. (2003).Developing energy profiles for sawmills in the Amazon region - First field visit to Rondolandia and Ji-Parana, accessed 25 July 2009;

APPENDIX 1: CONVERTING OTHER GHGS TO CO_2E

Other GHGs considered in this methodology (subject to significance as determined in Section 1.2.3) are methane (CH_4) and nitrous oxide (N_2O).

Non-CO_2 gas emission factors must be expressed in carbon dioxide equivalents by multiplying their emission factors by their corresponding global warming potentials (GWPs) and summating the results together to obtain an overall emission factor in terms of carbon dioxide equivalents:

$$EF = EF_{CH4} \, x \, GWP_{CH4} + EF_{N2O} \, x \, GWP_{N2O} \qquad \textbf{(45)}$$

Where:

EF_{CH4}	Emission factor for methane gas, activity data-specic, tCH_4/activity data unit;
GWP_{CH4}	Global warming potential of methane, tCO_2e/tCH_4;
EF_{N2O}	Emission factor for nitrous oxide gas, activity data-specific, tN_2O//activity data unit;
GWP_{N2O}	Global warming potential of nitrous oxide, in tCO_2e/tN_2O;

Where CH_4 and N_2O are determined to be insignificant to the overall calculations, and HFCs, PFCs and SF_6 are not included, then CO_2 becomes the sole greenhouse gas quantified. Throughout this methodology, even where CO_2 becomes the sole GHG emission quantified, it is expressed as CO_2-e.

APPENDIX 2: CONVERTING UNITS FOR FUEL EMISSION FACTOR

IPCC (2006) emission factors for GHGs (CO_2, CH_4 and N_2O) are recorded in units of kg of GHG (TJ of fuel)$^{-1}$. As such, for each GHG, the emission factor must be multiplied by the fuel heating value (in TJ kg^{-1}) and density (kg kL^{-1}) to obtain an emission factor in tGHG kL^{-1}. (eg, tCO_2-e kL^{-1}, tCH_4 kL^{-1} and tN_2O kL^{-1}).

$$EF_{FUEL-GHG} = \frac{EF_{IPCC-FUEL}\ x\ HV_{FUEL}\ x\ \rho_{FUEL}}{1000} \quad \textbf{(46)}$$

Where:

$EF_{FUEL-GHG}$	Fuel emission factor for the greenhouse gas (CO_2, CH_4 or N_2O), in tGHG/kL;
$EF_{IPCC-FUEL}$	IPCC fuel emission factor for greenhouse gas (CO_2, CH_4 or N_2O), in kgGHG/TJ;
HV_{FUEL}	Heating value of fuel, in TJ/kg;
ρ_{FUEL}	Density of fuel, in kg/kL;

APPENDIX 3: FUEL CONSUMPTION CHARTS

As referenced in Section 8.1.5.4, the fuel consumption rate of a generator can be derived from fuel consumption charts for generators. Table A3 offers default factors depending on the generator size (kW) and on the anticipated load (Diesel Service and Supply, 2009).

Table A3: Fuel Consumption Chart for a Diesel Generator

Generator Size (kW)	1/4 Load (kL h^{-1})	Full Load (kL h^{-1})	Generator Size (kW)	1/4 Load (kL h^{-1})	Full Load (kL h^{-1})
20	0.002	0.006	500	0.042	0.135
40	0.006	0.015	750	0.062	0.202
60	0.007	0.018	1000	0.082	0.269
100	0.01	0.028	1250	0.102	0.336
125	0.012	0.034	1500	0.122	0.403
150	0.014	0.041	1750	0.142	0.47
200	0.018	0.055	2000	0.162	0.537
300	0.026	0.081	2250	0.182	0.604

APPENDIX 4: HARVESTER FUEL CONSUMPTION FACTOR

As referenced in Section 8.1.5.1, the emission factors for equipment required for harvesting operations derived from from Klvac and Skoupy (2009) are listed in Table A4.

Table A4: Equipment Types and Fuel Consumption for Harvesting Operations

Operation	Equipment	Factor	Data	Unit
Felling	harvester	Fuel consumption, $FC_{harvest}$	1.28 - 1.73	L m^{-3}

APPENDIX 5: ELECTRICITY DEMAND OF SAWMILL PROCESSES

An electricity demand factor may be used to determine the electricity consumption (kWh) required for a particular volume of merchantable logs. As referenced in Section 8.1.5.4, the table below presents data from three international sawmill processes and shows that an approximate range for the electricity demand is 20-40 kWh/m^3.

Where a country specific-value for the electricity demand is available, it must be used. Where a country-specific value is not available, a factor from a country that uses similar timber processing technology to that of the project's host country must be used.

Table A5: Electricity Demand For Sawmill Processing In Various Countries

Country	Electricity (kWh day^{-1})	Harvest Volume (m^3 day^{-1})	e_{demand} (kWh m^{-3})	Data Source
Indonesia	600	20	30	Budiono (unknown)
Brazil	2756	136	20	Poole and Pinheiro (2003)
New Zealand	-	-	26-41	Li et al. (2006)

DOCUMENT HISTORY

Version	Date	Comment
v1.0	11 Feb 2011	Initial version released.
v1.1	10 Nov 2011	Updates: 1) In Equation 7 parameter CEX,i,k|BSL was clarified to be the mean carbon stock of extracted timber per unit area in stratum *I*, for wood product type *k*. 2) Section 4.1.2, was clarified that only individual trees, species and strata which were to be harvested in the baseline scenario may be modeled for on-going forest growth in the project scenario. 3) Equation 21 was modified to clarify that net greenhouse gas emissions in the project scenario are a result of the sum of emission from disturbance minus the annual carbon stock change in the aboveground biomass of trees due to forest growth. 4) Parameter BECFR was clarified to have the unit t.d.m m^{-3}.
v1.2	27 Mar 2013	Updates: The methodology was updated in order to comply with Section 4.5.3 of the VCS *AFOLU Requirements*, v3.2, which requires methodologies to set out criteria and procedures to reliably establish the pattern of carbon loss in the baseline scenario. Specifically, the methodology has been updated to account for a 10-year linear decay of the dead wood pool, an immediate release of the wood waste and short-term wood product pools and a 20-year linear decay of the medium-term wood product pool.
v1.3	28 Apr 2016	The methodology was revised to include emissions from: • Cleared biomass as a result of forestry infrastructure such as forestry roads, skidtrails and log landings • Residual stand damage • Fossil fuel combustion in forestry and wood processing machinery

VERIFIED CARBON STANDARD
A Global Benchmark for Carbon

Approved VCS Methodology
VM0011

Version 1.0
Sectoral Scope 14

Methodology for Improved Forest Management – Logged to Protected Forest:

Calculating GHG Benefits from Preventing Planned Degradation

Scope

This Methodology provides a procedure to determine the net greenhouse gas (GHG) emission reductions associated with an Improved Forest Management - Logged to Protected Forest (IFM-LtPF) activity where the baseline activity is selective logging.

Authors

Samuel Phua, Sunil Sharma, Marnie Telfer, Helen Chandler

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Executive Summary

The Methodology provides a procedure to determine the net anthropogenic greenhouse gas (GHG) emission reductions associated with an Improved Forest Management - Logged to Protected Forest (IFM-LtPF) activity which prevents the degradation of a forest through the cessation of a baseline activity of selective logging.

The Methodology is written to be compliant with VCS 2007.1. The Methodology specifically applies to previously logged or intact tropical forests, where the baseline activity can be clearly demonstrated and substantiated to be selective logging.

The key components of the Methodology are:

(1) Applicability criteria and decision pathway for applying this Methodology based on the availability of data sources
(2) Justification for a baseline activity of selective logging, additionality and definition of project boundary
(3) Accounting for carbon changes of the baseline activity of selective logging
(4) Accounting for emissions due to implementation of the baseline and IFM-LtPF project activity
(5) Leakage assessment and management
(6) Uncertainty analysis
(7) Monitoring methodology

The application of this Methodology is based on the justification that selective logging is the most likely baseline activity above all other possible land use alternatives.

The Methodology calculates the net anthropogenic emission reductions by firstly estimating emissions due to forest degradation and the implementation of the baseline activity, selective logging. From this, GHG emissions associated with the implementation of the IFM-LtPF project activity, plus any emissions due to leakage of the baseline activity occurring outside the Project Area (as a result of the IFM-LtPF project activity), are subtracted from the baseline emissions to provide the net anthropogenic emission reductions of the IFM-LtPF project.

The baseline scenario, selective logging, as defined in the Methodology, involves the annual removal of merchantable trees with a minimum diameter at breast height as defined by the relevant authority in the host country. According to the data available, the Methodology provides guidance on determining the quantity and type of wood product that would be removed, as well as the nature of its fate as a result of the baseline scenario. In summary, emissions due to carbon lost from forest degradation from selective logging are attributable to (i) emissions from the oxidation of both short-term and long-term harvested wood products that are removed from the Project Area, (ii) emissions from the decay of the trimmings and branches, as well as any residual stand damage accumulating in the dead wood pool, and (iii) emissions from carbon that is forfeited due to forest growth that did not occur (foregone) as a result of the selective logging. These emissions are offset by (iv) regrowth in already harvested areas following logging.

The monitoring methodology provides guidance for the monitoring of the parameters employed to calculate carbon changes due to forest degradation, as well as emissions due to implementation of project and baseline activities. Following the implementation of the monitoring methodology, the results are applied to the above-mentioned accounting components (3) to (6) to revise the net anthropogenic GHG emission reductions for the subsequent reporting period.

The application of the Methodology is intended to not only mitigate GHGs, but to trigger a long term sustainable shift in the status of the forest in the covered region, hence aiding in the conservation of biodiversity. In addition, local communities will have new avenues for revenues that replace and exceed revenues to be derived from the removal of their forest.

Table of Contents

1 Introduction

The Methodology herein is applicable to a project activity that reduces greenhouse gas (GHG) emissions by preventing the degradation of a forest, either intact[1] or previously logged, that has been legally authorised by local, national or sub-national regulatory bodies to be harvested.

A common practice of IFM in tropical forests is selective logging. In selective logging operations (which is the baseline scenario of the Methodology), trees that meet the requirements as specified by the relevant authority in the host country of (i) minimum diameter at breast height, (ii) species, (iii) accessibility, and (iv) tree quality, are considered merchantable.

1.1 Methodology Applicability Criteria

The Methodology is applicable under the criteria and conditions presented in Table 1-1:

Table 1-1. Methodology applicability criteria

Criteria	Description
Project Type	Improved Forest Management - Logged to Protected Forest; with no removals (e.g. harvesting, planned biomass burning) occurring in the Project Area upon implementation of the actual project (with the exception of felling sample trees for validating or deriving project-specific parameters presented in Section 7.2.4).
Condition of the Forest	Intact forest or previously logged forest (also known as forest degraded due to logging) Land within the Project Area must have qualified as forest at least 10 years before the project start date.
Type of Forest	Tropical forests including evergreen tropical rainforests, moist deciduous forests, tropical dry forests and tropical upland forests (see Appendix A for definition), except peat swamp forests.
Forest Product Type	Harvested wood products i.e., sawlog, pulplog and commercially harvested fuelwood (See Appendices A and B.9).
Driver of Degradation	Legally sanctioned logging (timber and commercially harvested fuelwood) undertaken in accordance with the relevant laws, regulations and codes of practice of the country in which the Methodology is being applied.
Baseline Activities to be Displaced	Legally sanctioned selective logging for specific forest product types presented above.
Project Area	Must be designated, sanctioned or approved by the relevant authority in the host country for the selective logging

[1] Defined herein as forests that have not yet been logged.

Criteria	Description
Carbon Pools	Carbon Pools considered: • Aboveground biomass (AGB) of all trees as defined by the relevant authority in the host country • Harvested wood products (HWPs) based on domestic production not domestic consumption • Deadwood (DW). Carbon Pools not considered: • Aboveground biomass (non-trees) • Belowground biomass • Soil • Litter.

1.2 Methodology Overview

1.2.1 Net Anthropogenic GHG Emission Reductions

The Methodology estimates the net anthropogenic GHG emission reductions associated with an IFM-LtPF project ($C'_{IFM-LtPF,t}$) that replaces a baseline of selective logging in a tropical forest. It does this by estimating the annual total carbon emissions associated with the baseline scenario ($C'_{baseline,t}$) and by subtracting the emissions associated with project activity ($C'_{actual,t}$) and leakage ($C'_{leakage,t}$), in year, *t*, years elapsed since the start of the IFM-LtPF project activity. The parameters $C'_{baseline,t}$, $C'_{actual,t}$ and $C'_{leakage,t}$ are determined in Sections 3, 4 and 5, respectively.

The net anthropogenic GHG emission reductions in tonnes of carbon dioxide equivalents (tCO_2-e) of the IFM-LtPF project activity will be[2] calculated as follows:

Equation 1-1

$$C'_{IFM-LtPF,t} = C'_{baseline,t} - C'_{actual,t} - C'_{leakage,t}$$

Parameter	Description	Unit
$C'_{IFM-LtPF,t}$	Annual net anthropogenic GHG emission reductions in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$C'_{baseline,t}$	Annual total carbon emissions associated with the baseline scenario in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

[2] Throughout, four main terms are used: "must be", "should be", "will be" and "can be". The term "must be" represents an action to be taken, according to a mandatory condition specified in the Standards or Guidelines; the term "should be" represents an action to be taken, according to a best practice condition; the term "will be" represents an action to be taken, as developed specifically in this Methodology; whilst the term "can be" is used to indicate possibility.

Parameter	Description	Unit
$C'_{actual,t}$	Annual total carbon emissions associated with the project activity in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$C'_{leakage,t}$	Annual total carbon emissions associated with leakage in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

The term "ex ante" is defined as the estimation of the net GHG emission reductions, before the start of the IFM-LtPF project activity, for the project crediting period. The term "ex post" is defined as the calculation of the actual net GHG emission reductions for the years elapsed since the start of the IFM-LtPF project activity. See Appendix A of the Methodology for a list of definitions of other terms.

For an ex ante estimation of annual net anthropogenic GHG emission reductions, $C'_{IFM-LtPF,t}$, equations in Sections 3 and 4 for baseline accounting and actual project activity emissions, respectively, must be applied. The ex ante estimation for leakage assessment will be zero. The Project Proponent must provide estimates of the values of those parameters that are not available before the start of the monitoring activities and must retain a conservative approach in making these estimates.

1.2.2 Data Sources Required

Due to the nature of IFM-LtPF projects, the emission reductions will be largely dependent on emissions arising from the baseline scenario ($C'_{baseline,t}$), which, in turn, is a function of emissions from the implementation of the baseline activity (i.e. selective logging) ($C'_{emissions,t}$) and primarily, the emissions arising from forest degradation due to the baseline activity ($C'_{degradation,t}$). The method to calculate $C'_{degradation,t}$ depends on the available data for the Project Area.

This IFM-LtPF Methodology includes: (1) protecting currently logged or degraded forests from further logging and degradation; and (2) protecting unlogged forests that would be logged in the absence of carbon finance. For both, the Project Proponent must provide documentary evidence to prove that the Project Area will be legally harvested if the IFM-LtPF project is not implemented in the area and must include these documents Project Description (PD). The following documentary evidences are relevant, but not limited to:

(i) A legally authorised letter or a document that clearly demonstrates the area will be selectively logged in the absence of the IFM-LtPF project; and

(ii) An approved Forest Inventory Report (FIR) or an equivalent document including a forest management plan or a timber harvesting plan. This document must also include map(s) of the geographical extent of the Project Area where selective logging has occurred or would occur; or

(iii) Preparation of the FIR or an equivalent document (by the relevant authority in the host country) which specifies the geographical extent of the Project Area where selective logging would occur.

Figure 1-1 presents a schematic of the dual-pathway for data availability in determining a suitable method. The Existing Inventory Data pathway represents the case where a Forest Inventory Report (FIR) or an equivalent document, is available. Within this pathway, two methods exist for determining emissions due to degradation of the Project Area. These are: (i) combined methods of wood density and biomass conversion and expansion factor (BCEF) or (ii) allometric equations. The choice of method is based on the level of detail in the existing inventory data.

The Measured Data pathway must be applied for the following cases:

(i) where there is no Forest Inventory Report (FIR) or equivalent document available

(ii) where the FIR is still in preparation by the relevant authority in the host country

(iii) where the validation of existing data is not accepted (see Section 3.2.1.1).

In order to apply this pathway, upfront monitoring is required, and carbon emissions will be based on the data obtained from the measurements taken in the Permanent Sample Plots (PSPs) in the forest using allometric equations (see Section 7.1.2).

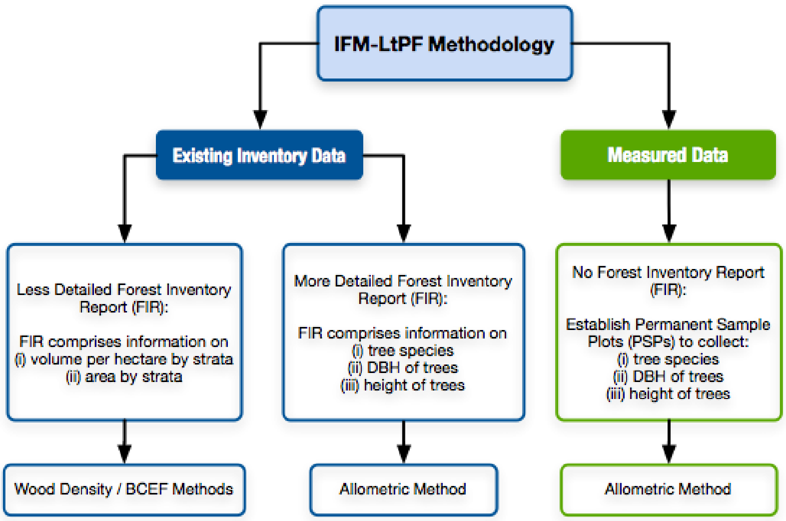

Figure 1-1. Schematic of data sources required for IFM-LtPF Methodology

1.2.3 Significance

To test for the significance of emission sources, the Project Proponent must use the most recent CDM Tool - "Tool for testing significance of GHG emissions in A/R CDM project activities" (see CDM-EB, 2007a).

1.2.4 VCUs and the Non-Permanence Risk Withholding Buffer Percentage

A procedure for determining the non-permanence risk rating (i.e., the potential reversibility of sequestered/protected carbon) is described in Section 7.2.5. The outcome of the risk rating is the determination of the non-permanence buffer withholding percentage ($NP_{buffer}\%$) required to calculate the number of carbon credits to be deposited in the VCS buffer withholding pool. The latter is calculated as follows:

Equation 1-2

$$CC_{NPbuffer,t} = NP_{buffer,t}\% \times C'_{degradation,t}$$

Parameter	Description	Unit
$CC_{NPbuffer,t}$	Annual carbon credits deposited in the VCS non-permanence buffer withholding account in year t, (where t=1,2,3 ... t* years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$NP_{buffer,t}\%$	Annual buffer withholding percentage required for the VCS buffer withholding pool in year *t,* (where *t*=1,2,3 ... *t** years elapsed since the start of the IFM-LtPF project activity)	%
$C'_{degradation,t}$	Annual total carbon emissions associated with degradation as a result of the baseline activity in year *t,* (where *t*=1,2,3 ... *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

The number of VCUs that can be traded annually from the IFM-LtPF project activity is determined by subtracting the carbon credits deposited in the buffer account from the carbon credits determined post uncertainty deduction issued in year *t*:

Equation 1-3

$$VCU_t = CC_{IFM-LtPF,t} - CC_{NPbuffer,t}$$

Parameter	Description	Unit
VCU_t	Annual total tradeable Verified Carbon Units in year *t,* (where *t*=1,2,3 ... *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$CC_{IFM-LtPF,t}$	Annual carbon credits post uncertainty deduction in year *t*, (where *t*=1,2,3 ... *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$CC_{NPbuffer,t}$	Annual carbon credits deposited in the VCS non-permanence buffer withholding account in year *t*, (where *t*=1,2,3 ... *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

2 Project Baseline, Additionality and Boundary

2.1 Project Baseline Justification and Additionality

Since the Methodology is limited to a baseline scenario of selective logging, it must therefore be demonstrated that selective logging is the most likely baseline scenario above all other possible scenarios.

2.1.1 Selection of Baseline Amongst Alternative Scenarios

The procedure to identify the baseline scenario as selective logging for a VCS IFM-LtPF project activity, has been adapted from Steps 1 and 2 of the "Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities" (CDM-EB, 2007b, pp. 2-7).

Step 1: Identify credible alternative baseline scenarios to the proposed VCS IFM-LtPF project activity.

Sub-step 1a: Identify all realistic and credible alternative baseline scenarios to the proposed VCS IFM-LtPF project activity.

Realistic and credible baseline scenarios would be those that may have occurred in the Project Area in the absence of the VCS IFM-LtPF project activity. The scenarios must take into account relevant national and or sectoral policies and circumstances such as historical land use and practices, and economic trends and must at least include (CDM-EB, 2007b, p. 2):

- continuation of pre-project land use
- the protection of the land within the Project Area without being registered under the VCS as an IFM-LtPF project activity.

To identify realistic and credible baseline scenarios, data from the following sources must be applied:

(i) land use records

(ii) field surveys

(iii) data and feedback from stakeholders.

To establish that all identified baseline scenarios are credible, the Project Proponent must ascertain the following:

- all land uses within the Project Area of the proposed IFM-LtPF project activity that are currently existing, or have existed but no longer exist, are deemed credible
- for all other baseline scenarios, credibility must be justified and justification must include elements of spatial planning information, if applicable, or legal requirements. In the absence of adequate justification, an assessment of economic feasibility of the proposed alternative baseline scenario must be provided.

Sub-step 1b: Identify realistic and credible alternative baseline scenarios with enforced mandatory legislation and regulations.

For the alternative baseline scenarios identified in Sub-step 1a, the Project Proponent must demonstrate that these alternatives comply with mandatory applicable legislation and regulations in the host country.

In the case where an identified alternative does not comply with mandatory applicable legislation and regulations, the Project Proponent must demonstrate that non-compliance of such legislation and regulations are the current practices in the host country, to the extent that the legislation and regulations are systematically not enforced and that non-compliance of such legislation and regulations is widespread.

Alternative baseline scenarios that do not comply with mandatory applicable legislation and regulations in the host country, and where widespread non-compliance cannot be demonstrated, must be removed from the list of realistic and credible baseline scenarios.

Selective logging must be present in the list from Sub-steps 1a and 1b for the Methodology to be applicable.

Step 2: Determine alternative baseline scenarios.

Sub-step 2a: Identify barriers that would prevent the implementation of at least one alternative baseline scenario.

For the alternative baseline scenarios identified in Sub-step 1b, the Project Proponent must identify any barriers that prevent the implementation of at least one of the alternatives. The barriers must not be specific to the Project Proponent but must apply to the activity itself, regardless of the entity that is developing the project.

A list of potential barriers can be found in CDM-EB (2007b), pp. 4-5.

Sub-step 2b: Eliminate baseline scenarios that are prevented by the identified barriers.

Determine which baseline scenarios identified in the Sub-step 1b are prevented by at least one of the barriers listed in Sub-step 2a. Eliminate these scenarios from the list (of alternative baseline scenarios) produced in Sub-step 1b.

Selective logging must be present in the resultant list for the Methodology to be applicable.

In applying Sub-steps 2a and 2b, the Project Proponent must provide transparent and documented evidence, and offer conservative interpretations of this documented evidence, as to how it demonstrates the existence and significance of the identified barriers. Anecdotal evidence can be included, but this alone is not sufficient proof of barriers (CDM-EB, 2007b, point 17, p. 6).

A list of the types of evidence acceptable can be found in CDM-EB (2007b), pp. 6-7.

Sub-step 2c: Determine the baseline scenario.

From Sub-step 2b, the refined list of alternative baseline scenarios that are in compliance with mandatory applicable legislation and regulations (or for which widespread non-compliance can be demonstrated), and are not prevented by barriers, must contain selective logging as an alternative baseline for the current Methodology to be applied.

If selective logging is the only alternative scenario that is not prevented by any barrier, then this scenario is identified as the baseline activity.

If there are several alternative baseline scenarios in the list produced from Sub-step 2b (and this may include the proposed IFM-LtPF project activity undertaken without being registered as a VCS activity), then apply the Investment Analysis procedure (CDM-EB, 2007b, Step 3, pp. 7-11) to demonstrate that selective logging is the most economically and/or financially attractive baseline scenario amongst all the alternative baseline scenarios.

Selective logging must be demonstrated to be the most economically and/or financially attractive baseline scenario for the Methodology to be applicable.

2.1.2 Establishment of the Baseline Scenario: Selective Logging

Upon demonstrating that the most conservative baseline scenario is selective logging, and in order to establish this baseline, the Project Proponent must provide the following information:

(i) documented history of the operator (e.g., operator shall have five to 10 years of management records to show normal historical practices)

(ii) legal requirements for forest management and land use in the area; and

(iii) proof that operator’s environmental practices equal or exceed those commonly considered a minimum standard among similar landowners in the area.

If the Project Proponent is not a logging operator, but instead a new management entity with no history of logging practices in the project region and who takes over ownership of a property specifically to reduce forest emissions, then the baseline of selective logging is to be based on the projected management plans of the previous property owners. The established baseline must represent what would have most likely occurred in the absence of the IFM-LtPF project.

2.1.3 Additionality

For the specific case of demonstration and assessing additionality, the Project Proponent must use the latest version of the VCS tool for the Demonstration and Assessment of Additionality in VCS Agriculture Forestry and Other Land Use Project.

2.2 Project Boundaries

Project boundaries must be defined in terms of the following categories:

- Geographic boundary
- Temporal boundaries
- Carbon pools
- GHG sinks and sources.

2.2.1 Geographic Boundary

The Geographic Boundary includes the Project Area and the leakage area(s) and is described in the sections below. The land eligibility for the Project Area is discussed in Section 2.2.1.1.

2.2.1.1 Project Area and Land Eligibility

The Project Area is the forest area within the defined Geographic Boundary which would be degraded through selective logging under the baseline scenario. The term "forest area" must be appropriately defined in a way that is consistent with the thresholds used to define the term "forest" in the host country where the project activity will be implemented. Where the country has adopted a forest definition for the Kyoto Protocol, the minimum thresholds of the vegetation indicators used for defining "forest" will be used (see Appendix A). Otherwise, the definition used to define "forest" in the national GHG inventory will be used.

The Project Area must be designated, sanctioned or approved by the relevant authority in the host country.

The Project Proponent must provide sanctioned or approved document(s) which designates or specifies the geographical boundary of the Project Area. The Project Proponent must also provide the following information about the Project Area: name, local name, compartment number, harvesting blocks, identification number and area for each forest compartment in the Project Area, the geographic co-ordinates obtained from the Global Positioning System (GPS) or from the geo-referenced digital maps and, digital or GIS maps. In addition, the Project Proponent requires to provide digital map of the geographic boundary distinguishing the Project Area and the Leakage Area. In the case this Methodology is used for multiple discrete land parcels, each land parcel is treated as a separate Project Area and requires all the detail information/documentation as well as the digital maps as stated above.

If the Project Area has already been stratified, similar information must be provided for each stratum including stratified maps for the Project Area.

After the project has commenced, the Project Area will remain fixed throughout the crediting period.

2.2.1.1.1 Stratification of the Project Area

Stratification of the Project Area is required to divide the forest area into relatively homogeneous units or 'strata' in order to minimise variation among the strata. The stratification enhances the measuring precision and also minimises the cost of measurement. Where stratification of the Project Area has not been done, stratification is required before establishing PSPs for monitoring. Various criteria including forest parameters such as species, canopy density, tree height, age, etc., as well as physical parameters such as slope and drainage condition, are to be used to define the stratification. The most appropriate criteria for stratification are to be those which are directly related to the variables to be measured and monitored.

The forest stratification can be performed using forest type maps, topographic maps, interpretation of aerial photographs and satellite data with subsequent field verification. Remote sensing and GIS software is useful for spatial analysis and mapping for stratification.

The Project Area is a summation of the areas defining each stratum, j:

Equation 2-1

$$A_{project,t=0} = \sum_{j=1}^{J} A_{project,j,t=0}$$

Parameter	Description	Unit
$A_{project,t=0}$	Project Area where the IFM-LtPF project activity will be implemented; determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	ha
$A_{project,j,t=0}$	Project Area within each stratum *j*, (where *j*=1,2,3 … *J* strata) where the IFM-LtPF project activity will be implemented; determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	ha

Both $A_{project,t=0}$ and $A_{project,j,t=0}$ are employed in both Sections 3.2 and 3.3 to calculate emissions from degradation due to selective logging.

In the case of existing stratification in the Project Area, the Project Proponent must review the strata using the latest available maps and data sources. If the existing stratification is not relevant for implementing the GHG project, the Project Proponent must update the strata, following the approach discussed above, and derive a Project Area map based on the revised stratification.

The Project Proponent must describe the approach used for stratifying the Project Area and also include GIS map(s) illustrating each stratum with specific detail. These maps must be revised if there is any update in the stratification in the event that there is a change in the carbon in the existing stratum.

2.2.1.2 Leakage area(s)

The leakage area(s) is defined as the area(s) to which the activity (i.e. selective logging) has shifted. This applies to lands owned and/or operated by the Project Proponent outside the Project Boundary, as well as to other areas within the host country (caused by market leakage effects), since both activity shifting and market leakage are considered in the IFM-LtPF Methodology. Section 5 addresses leakage accounting in more detail.

The Project Proponent must identify the strata in the leakage area similar to the Project Area through analysing the forest and topographical characteristics as described in Section 2.2.1.1.1. These areas must also be illustrated in the maps of the project.

2.2.2 Temporal Boundaries

2.2.2.1 Project crediting period

The project crediting period shall be determined in accordance with applicable VCS rules.

2.2.2.2 Monitoring and reporting periods

The monitoring period corresponds to the time taken between one monitoring event and the immediate next monitoring event for collecting measurements in the PSPs in the Project Area, and for reviewing non-monitored parameters. According to international industry practices for forest carbon assessment, the maximum interval between one monitoring event and the immediate next, should not exceed five years (Pearson et al., 2005).

The results of project monitoring must be used to re-calculate the emissions associated with the project and this must be included in a report submitted for independent verification by an accredited third party.

2.2.2.3 Historical reference period

The historical reference period is a predetermined amount of time before the project start date, from which data can be taken in order to make ex ante estimation of natural disturbances and illegal harvesting and also to analyse leakage due to implementation of the project. A five-year timeframe for a historical reference period as close as possible to the project start date shall be used so as to limit uncertainty of the data collected.

2.2.3 Carbon Pools

Table 2-3 presents the justification, for inclusion or exclusion of carbon pools in the present IFM-LtPF Methodology in accordance with applicable VCS rules.

Table 2-3. Summary of carbon pools eligible under the Methodology

Carbon Pool	Status for IFM-LtPF Methodology	Justification
Aboveground Biomass (tree[#])	Included	Anticipated to significantly increase under IFM-LtPF
Aboveground Biomass (non-tree)	Not included	Unlikely to decrease as a result of the project activities, or increase due to the baseline
Belowground Biomass	Not included	Unlikely to decrease as a result of the project activities, or increase due to the baseline
Deadwood	Included	Anticipated to significantly decrease under IFM-LtPF
Litter	Not included	Unlikely to decrease as a result of the project activities, or increase due to the baseline
Soil	Not included	Unlikely to decrease as a result of the project activities, or increase due to the baseline

Carbon Pool	Status for IFM-LtPF Methodology	Justification
Harvested Wood Products	Included	Anticipated to significantly decrease under IFM-LtPF

Trees are perennial plants and primarily constitute forest biomass. The FAO considers all living trees with a minimum diameter of 10 cm (over bark) when estimating the biomass in a tropical forest (Brown, 1997). This Methodology applies to all trees with a minimum diameter at breast height as specified by the relevant authority in the host country.

2.2.4 GHG Sources and Sinks

2.2.4.1 Consideration of GHGs

The six primary GHGs that contribute to climate change (WBCSD and WRI, 2004) and their global warming potentials (Forster et al., 2007) are listed in Table 2-4. Forster et al. (2007) present global warming potentials (GWPs) for three given time horizons: 20-year, 100-year and 500-year in the IPCC's Fourth Assessment Report (AR4) (IPCC, 2007).

The Project Developer shall use GWP of the 100-year time horizon as specified in the VCS rules. Table 2-4 presents the GWPs for the six primary GHGs for 100-year time horizon in accordance to the IPCC's Second Assessment Report. However, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride are synthetic industrial gases and therefore not included under Agriculture, Forestry and Other Land Use (AFOLU) methodologies.

Methane and nitrous oxide gases are not included for soil fluxes since soil is not included as a carbon pool in this Methodology. However, methane and nitrous oxide gases are included for calculating emissions from fossil fuel use in machinery, subject to significance (see Section 1.2.3). This significance accounting approach is in line with IPCC's definition of good practice (Penman et al., 2003) and the CDM "Tool for testing significance of GHG emissions in A/R CDM project activities" (CDM-EB, 2007a).

Carbon dioxide is included since it is intuitively present in both sources and sinks. Tables 2-5 and 2-6 present potential sources and sinks for CO_2, CH_4 and N_2O and whether or not a source/sink is included in the baseline and actual project implementation, respectively.

Table 2-4. The six primary greenhouse gases that contribute to climate change (WBCSD and WRI, 2004) and their associated global warming potentials for a 100-year time horizon

Greenhouse Gas	Chemical Formula	Global Warming Potential (100-year horizon)	Consideration
carbon dioxide*	CO_2	1	included

Greenhouse Gas	Chemical Formula	Global Warming Potential (100-year horizon)	Consideration
methane	CH_4	21	not included for soil fluxes; included for fossil fuel use in machinery but subject to significance. It is also included to calculate emissions from natural disturbances such as forest fires, subject to significance (see Section 1.2.3).
nitrous oxide	N_2O	310	not included for soil fluxes; included for fossil fuel use in machinery but subject to significance. It is also included to calculate emissions from natural disturbances such as forest fires, subject to significance (see Section 1.2.3).
hydrofluorocarbons	HFCs	see Forster et al. (2007) for list of HFCs	not included
perfluorocarbons	PFCs	see Forster et al. (2007) for list of PFCs	not included
sulphur hexafluoride	SF_6	23,900	not included

* Where CH_4 and N_2O are determined to be insignificant (determined from Section 1.2.3) to the overall calculations, and HFCs, PFCs and SF_6 are not included, then CO_2 becomes the sole contributor. Throughout this Methodology, even if CO_2 becomes the sole contributor toward GHG emissions, it is expressed as CO_2-e.

Table 2-5. Sources and sinks for the three primary greenhouse gases (further to consideration stated in Table 2-3), carbon dioxide, methane and nitrous oxide for baseline consideration in the Project Area

Greenhouse Gas	Source (S) / Sink (CS)	Project Area Baseline Consideration and Justification
carbon dioxide	Forest degradation (S)	included; carbon stock determination
	Fossil fuel use in machinery (S)	included; since logging is the baseline activity
	Electricity consumption (S)	included
	Forest fires (S)	not included
	Commercially harvested fuelwood (S)	included
	Fuelwood gathered for domestic use (S)	not included
	Biomass burning in the course of land use conversion (S)	not included
	Embodied carbon in AGB (CS)	included, carbon stock determination
	Forest regrowth (CS)	included
	Harvested wood products (S and CS)	included
	Deadwood (S and CS)	included
methane	Pestilence (S)	not included; unlikely scenario
	Biomass burning in the course of land use conversion (S)	not included; unlikely scenario
	Fossil fuel use in machinery (S)	included but subject to significance; since logging is the most likely scenario
	Deadwood (S and CS)	not included
nitrous oxide	Biomass burning in the course of land use conversion (S)	not included; unlikely scenario
	Fossil fuel use in machinery (S)	included but subject to significance; since logging is the most likely scenario

Table 2-6. Sources for the three primary greenhouse gases (further to consideration stated in Table 2-3), carbon dioxide, methane and nitrous oxide for the actual project implementation

Greenhouse Gas	Source^	Actual Project Activity Consideration and Justification
carbon dioxide	Electricity consumption	included
	Flights	included
	Ground travel	included
	Aerial surveillance	included
	Natural disturbances such as forest fires	included
methane	Electricity consumption	included but subject to significance
	Flights	included but subject to significance
	Ground travel	included but subject to significance
	Aerial surveillance	included but subject to significance
	Natural disturbances such as forest fires	included but subject to significance
nitrous oxide	Electricity consumption	included but subject to significance
	Flights	included but subject to significance
	Ground travel	included but subject to significance
	Aerial surveillance	included but subject to significance
	Natural disturbances such as forest fires	included but subject to significance

^ Note that for the actual project implementation, there are no sinks for GHG emissions and as such, the term 'sink (CS)' is not stated.

3 Baseline Accounting

3.1 Estimation of Emissions from Degradation

Section 3 of the Methodology provides the method for calculating emissions for the baseline activity. As the Methodology is developed for a baseline activity of legally sanctioned selective logging, the annual GHG emissions resulting will be due to degradation of the Project Area ($C'_{degradation,t}$), as well as annual emissions due to the selective logging operations ($C'_{emissions,t}$):

Equation 3-1

$$C'_{baseline,t} = C'_{degradation,t} + C'_{emissions,t}$$

Parameter	Description	Unit
$C'_{baseline,t}$	Annual total carbon emissions associated with the baseline scenario in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$C'_{degradation,t}$	Annual total carbon emissions associated with degradation as a result of the baseline activity in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$C'_{emissions,t}$	Annual total carbon emissions associated with the baseline activity of selective logging operations in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

For an IFM-LtPF project, determination of GHG emission reductions relies on comparing a baseline scenario of selective logging to a “with GHG project” scenario that assumes all the selective logging will cease. Emissions from degradation due to the baseline selective logging operations are determined by conducting a carbon mass balance over the entire Project Area.

In the baseline scenario described by this Methodology, selective logging involves the harvesting of merchantable trees larger than the minimum diameter at breast height as specified by the relevant authority in the host country. The selective logging operations have been treated as an annual event resulting in the removal of a specified volume of merchantable logs from the harvested merchantable trees in the Project Area. The annual harvest volume, i.e. the merchantable logs’ volume, is obtained from the inventoried growing stock of the forest by employing a sustainable and commonly used method in the host country. Here the term “growing stock” implies the total volume (over bark) of all the living trees as defined by the relevant authority in the host country. The growing stock data for the Project Area is either available from the Existing Inventory Data pathway or Measured Data pathway before the start date of the IFM-LtPF project.

At the site of the logging operations, the felled trees are converted to merchantable logs. The branches, bark and foliage are trimmed off the felled trees and left on the forest floor, becoming part of the deadwood (DW) pool and decaying slowly over time. Trees that are damaged during the logging operations are considered as residual stand damage, and are also included as carbon input to the DW pool. Carbon emissions from the DW pool into the atmosphere are accounted for by considering the net accumulation per year into the pool, multiplied by the rate of decay of the dry matter.

The subsequent processing of merchantable logs is dependent upon their species type, diameter class and end-product use. Some merchantable logs are taken to an on-site processing plant (i.e. a sawmill) resulting in sawn timber. With further value-added processing, these sawn timbers are converted into long-term harvested wood products (ltHWPs). Other merchantable logs are removed directly from the Project Area, for example commercially harvested fuelwood, and are converted into short-term harvested wood products (stHWPs). Long-term HWPs are defined as those with a half-life of over 30 years, while short-term HWPs are those with a half-life of approximately 2 years (IPCC, 2006, Vol 4, Table 12-2). It is possible for a Project Area to have a combination of both ltHWPs and stHWPs.

In the case of merchantable logs intended to be used in the manufacture of ltHWPs, the proportion of log converted to sawn timber is known as the lumber recovery factor. The remaining proportion of the merchantable log (residues that include sawdust and wood chips) is set aside within the project boundary and can either decay in the stockpile or be utilised as an energy source for processing. The emissions from ltHWPs are then accounted for by applying a (delayed) rate of oxidation of the ltHWP pool.

In the case of merchantable logs intended to be used in the manufacture of stHWPs, the stHWPs are further classified into commercially harvested fuelwood and paper products. For commercially harvested fuelwood, immediate oxidation occurs when the fuelwood is consumed. For paper products, emissions due to paper products are accounted for by applying a (delayed) rate of oxidation of the stHWP (to be converted into paper products only) pool.

Over the lifetime of logging operations, the previously harvested areas will experience regrowth. The carbon increase in the forest due to regrowth must be subtracted from the carbon lost due to degradation. Conversely, the logging operations remove trees every year which would otherwise experience growth. This loss in growth, defined as the amount of growth foregone, must be determined and added to the overall carbon lost due to degradation. The total carbon emissions associated with degradation as a result of the baseline activity accounts for all of these processes and is calculated as follows:

Equation 3-2

$$C'_{degradation,t} = \left[\left(C_{DW_{decay},t} + C_{ltHWP_{oxidation},t} + C_{stHWP_{oxidation},t} + C_{growth\_foregone,t} - C_{regrowth,t} \right) \times \frac{44}{12} \right]$$

Parameter	Description	Unit
$C'_{degradation,t}$	Annual total carbon emissions associated with degradation as a result of the baseline activity in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$C_{DW_{decay},t}$	Annual carbon leaving the deadwood pool due to the decay of deadwood in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{ltHWP_{oxidation},t}$	Annual carbon due to the combined delayed oxidation of long-term harvested wood products and immediate oxidation of long-term harvested wood products residues in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{stHWP_{oxidation},t}$	Annual carbon due to immediate oxidation of short-term harvested wood products (commercially harvested fuelwood) and delayed oxidation of short-term harvested wood products (paper products) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{growth\_foregone,t}$	Annual carbon lost due to growth foregone in the aboveground biomass in the Project Area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{regrowth,t}$	Annual carbon increase in the biomass due to regrowth following logging in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
44/12	The ratio of molecular weight of carbon dioxide to carbon, *see* Appendix C	tCO_2-e tC^{-1}

Ex ante estimations of $C'_{degradation,t}$ will be made using data from Forest Inventory Report (FIR) or an equivalent document, or measured data using the sequence of equations in Section 3.2.

Figure 3-1 presents a schematic of the dual-pathway for data availability in determining a suitable method to apply. As the baseline refers to selective logging that has been sanctioned by the host country's authority, it is most likely that a Forest Inventory Report (FIR) or an equivalent document, is available: the Existing Inventory Data pathway.

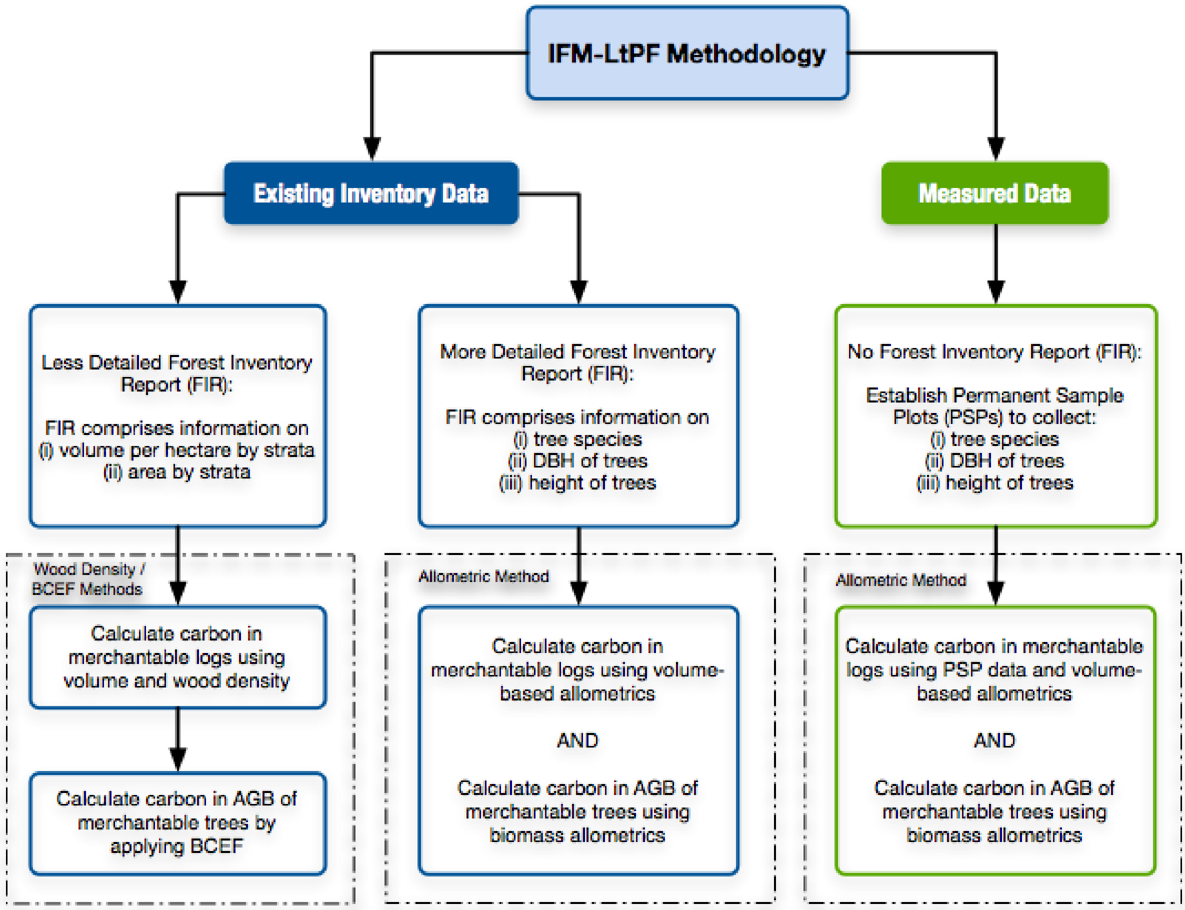

Figure 3-1. Schematic of accounting approach based on available data

There are two methods for determining the quantity of carbon in merchantable logs and the growing stock within the Existing Inventory Data pathway, depending on the detail of data in the FIR: Wood density plus the Biomass Conversion and Expansion Factor (BCEF) methods, or the use of the allometric method (see Section 3.2.1). The methods are selected based on the level of information provided in the FIR or equivalent document. For a less detailed FIR, where only stratified volume per hectare and area data is provided, the wood density plus BCEF methods must be applied. For a more detailed FIR, where information on tree species, diameter at breast height (DBH) and height of trees is provided, carbon is calculated using volume and biomass allometric equations. For the Existing Inventory Data pathway, prior to applying either the wood density and BCEF or allometric methods, the FIR must be validated conservatively according to Section 3.2.1.1.

In the case where there is legal approval for selective logging in the Project Area and the FIR or an equivalent document is under preparation by the relevant authority in the host country, there is only one pathway for determining the quantity of carbon in merchantable logs and the growing stock: the Measured Data pathway. This pathway is based on the data obtained from measurements in Permanent Sample Plots (PSPs) in the Project Area (see Section 7.1.2).

3.2 CALCULATION OF PRIMARY PARAMETERS IN THE PROJECT AREA

This section first presents the method to validate the existing inventory data. Then, the calculations to obtain the primary parameters: annual carbon in merchantable logs, $C_{merch,t}$, annual carbon in the AGB of the growing stock, $C_{AGB\_gstock,t}$ and annual net harvest area, $A_{NHA\_annual,t}$ are presented.

3.2.1 EXISTING INVENTORY DATA PATHWAY

3.2.1.1 Validation of existing forest inventory data

The Existing Inventory Data pathway applies where an existing legally approved FIR or an equivalent document, presents inventory data not more than five years old. According to Pearson et al. (2005), carbon in the aboveground biomass (AGB) is likely to change at a much faster rate than the carbon stock in the soil. It is thus appropriate that monitoring of the AGB in the forest be carried out at five-yearly intervals. This monitoring period also complies with the carbon verification and certification of the projects under the Clean Development Mechanism (CDM) policy (Pearson et al., 2005). Furthermore, the data in the FIR must have been obtained from an adequate number of representative sample plots in strata similar to the Project Area. The data in the FIR, or equivalent document, should only be employed after validation by the Project Proponent using the following procedure:

Step 1: Stratify the Project Area by following the procedure described in Section 2.2.1.1.1 and check with the existing stratification to verify whether it is similar to the Project Area stratification or not.

Step 2: If the existing stratification is not similar to the Project Area stratification, the existing inventory data must not be used. Apply the Measured Data pathway.

Step 3: If the existing stratification is similar to the Project Area stratification, randomly establish 6 to 10 preliminary sample plots in each stratum as suggested for measuring the variance (Pearson et al., 2005) and measure the trees in the sample plots for their diameter at breast height and tree height. Guidance on the size and shape of the sample plots to be established is described in Section 7.1.2.2.

Step 4: Estimate the carbon in the AGB for each forest product type (if specified) for each stratum using the biomass allometric method as presented in Section 3.2.1.2.

Step 5: Calculate the carbon in the AGB per hectare and the 95 percent confidence interval for each stratum from the measured data. A 95 percent confidence interval is considered an appropriate measure for carbon stock (Pearson et al., 2005; Brown, 2002).

Step 6: Estimate the carbon in the AGB per hectare for each forest product type (if specified) for each stratum from the existing data in the FIR or equivalent document, as stated in Section 3.2.1. The specific method chosen in Section 3.2.1 depends on the type of data presented in the FIR or equivalent document.

Step 7: Compare the mean values between the measured and existing data:

If the mean value for the existing data is within the 95 percent confidence interval of the measured data, use the lower bound of the 95 percent confidence interval. This is a conservative estimate of carbon stock for the baseline scenario.

If the mean value for the existing data is greater than the 95 percent confidence interval, use the mean value of the measured data as a conservative estimate of carbon stock for the baseline scenario.

If the mean value for the existing data is lower than the 95 percent confidence interval, use the existing data, which is a conservative estimate of carbon stock for the baseline scenario.

If the FIR or an equivalent document contains inventory data collected more than five years ago, or the inventory data has been obtained without proper stratification and sampling of the Project Area, then the Project Proponent must take the Measured Data pathway for calculating carbon emissions for the baseline scenario.

3.2.1.2 Where a less detailed FIR is available

For a less detailed FIR, only stratified volume per hectare and area data is provided. Thus, the wood density and BCEF methods must be applied to calculate carbon in merchantable logs and growing stock.

3.2.1.2.1 Carbon in the merchantable logs using wood density method

A. Where inventory data does not distinguish between different forest product types

Step 1: Select a sustainable and commonly employed method of the host country to convert growing stock data to merchantable logs' volume to be removed. The Project Proponent must justify in the PD that the chosen method is appropriate, and demonstrate that the method is commonly employed in the host country.

Step 2: Apply the method selected and justified in Step 1 to strata level growing stock data ($\bar{V}_{gstock,j,t=0}$), to obtain merchantable logs' volume per hectare in stratum, j ($\bar{V}_{merch,j,t=0}$).

Step 3: Choose the most applicable wood density for a forest with corresponding climate region and ecological zone[3] (see Appendix B, Section B.1, Table B-1).

Step 4: Choose the most applicable carbon fraction[4] of wood from the following data sources:

(i) National carbon fraction (e.g. from National GHG Inventory)

(ii) Default IPCC carbon fraction of wood for a forest with corresponding climate domain (see Appendix B, Section B.2, Table B-2).

[3] As defined in IPCC (2006) Table 4-1, p 4.46, for climate region and ecological zone of forests.

[4] Throughout the Methodology, when determining carbon fraction, where merchantable logs are referred to, the carbon fraction of wood applies. Where aboveground biomass is referred to, the carbon fraction of aboveground biomass applies.

Step 5: Apply the following equation to convert the merchantable logs' volume to carbon per hectare in the stratum, *j*, using the wood density and carbon fraction:

Equation 3-3

$$\overline{C}_{merch,j,t=0} = D \times CF_{wood} \times \overline{V}_{merch,j,t=0}$$

Parameter	Description	Unit
$\overline{C}_{merch,j,t=0}$	Average carbon per hectare in merchantable logs in stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	$tC\ ha^{-1}$
D	Wood density for the tropical forest with corresponding climate region and ecological zone (see Appendix B)	$(t\ d.m.)\ m^{-3}$
CF_{wood}	Carbon fraction of wood for the tropical forest (see Appendix B)	$tC\ (t\ d.m.)^{-1}$
$\overline{V}_{merch,j,t=0}$	Average merchantable logs' volume per hectare in stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	$m^3\ ha^{-1}$

Step 6: Convert the strata level average carbon per hectare to the average carbon per hectare in the merchantable logs for the entire Project Area:

Equation 3-4

$$\overline{C}_{merch,t=0} = \frac{\sum_{j=1}^{J}\left(\overline{C}_{merch,j,t=0} \times A_{project,j,t=0}\right)}{A_{project,t=0}}$$

Parameter	Description	Unit
$\overline{C}_{merch,t=0}$	Average carbon per hectare in merchantable logs in the Project Area determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	$tC\ ha^{-1}$
$\overline{C}_{merch,j,t=0}$	Average carbon per hectare in merchantable logs in stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	$tC\ ha^{-1}$
$A_{project,j,t=0}$	Project Area within each stratum *j*, (where *j*=1,2,3 … *J* strata) where the IFM-LtPF project activity will be implemented; determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	ha

Parameter	Description	Unit
$A_{project,t=0}$	Project Area where the IFM-LtPF project activity will be implemented; determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	ha

B. Where inventory data distinguish between different forest product types

This Methodology accounts for three forest product types: sawlog, pulplog and commercially harvested fuelwood. These can be categorised into long-term and short-term harvested wood products as presented in Appendix B, Section B.9, Figure B-1. If the growing stock of different forest product types *p*, per hectare at the strata level *j*, is available, calculate the average carbon in the merchantable logs per hectare for these forest product types using the following procedure:

Step 1: Select a sustainable and commonly employed method of the host country to convert growing stock data to the merchantable logs' volume to be removed, for the different forest product types. The Project Proponent must justify that the chosen method is appropriate and demonstrate that the method is commonly employed in the host country.

Step 2: Apply the method selected and justified in Step 1, to strata level growing stock data ($\bar{V}_{gstock,p,j,t=0}$) to obtain the merchantable logs' volume per hectare at the strata level *j* ($\bar{V}_{merch,p,j,t=0}$).

Step 3: Choose the most applicable wood density for a forest with corresponding climate region and ecological zone[4] (see Appendix B, section B.1, Table B-1).

Step 4: Choose the most applicable carbon fraction of wood from the data sources presented in Step 4 of Section 3.2.1.2.1,A.

Step 5: Apply the following equation to estimate average carbon per hectare of the forest product types at the strata level:

Equation 3-5

$$\bar{C}_{merch,p,j,t=0} = D \times CF_{wood} \times \bar{V}_{merch,p,j,t=0}$$

Parameter	Description	Unit
$\bar{C}_{merch,p,j,t=0}$	Average carbon per hectare in merchantable logs of forest product type *p*, in stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	tC ha^{-1}
D	Wood density for the tropical forest with corresponding climate region and ecological zone (see Appendix B)	(t d.m.) m^{-3}
CF_{wood}	Carbon fraction of wood for the tropical forest (see Appendix B)	tC (t d.m.)$^{-1}$

Parameter	Description	Unit
$\bar{V}_{merch,p,j,t=0}$	Average merchantable logs' volume per hectare of forest product type *p*, in stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	$m^3\ ha^{-1}$

Step 6: The average carbon per hectare in the merchantable logs for different forest product types in the Project Area is calculated as follows:

Equation 3-6

$$\overline{C}_{merch,p,t=0} = \frac{\sum_{j=1}^{J}\left(\overline{C}_{merch,p,j,t=0} \times A_{project,j,t=0}\right)}{A_{project,t=0}}$$

Parameter	Description	Unit
$\overline{C}_{merch,p,t=0}$	Average carbon per hectare in merchantable logs of forest product type *p*, in the Project Area determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	$tC\ ha^{-1}$
$\overline{C}_{merch,p,j,t=0}$	Average carbon per hectare in merchantable logs of forest product type *p*, in stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	$tC\ ha^{-1}$
$A_{project,j,t=0}$	Project Area within each stratum *j*, (where *j*=1,2,3 … *J* strata) where the IFM-LtPF project activity will be implemented; determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	ha
$A_{project,t=0}$	Project Area where the IFM-LtPF project activity will be implemented; determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	ha

Step 7: The average carbon per hectare in all the merchantable logs including the different forest product types in the Project Area, is calculated as follows:

Equation 3-7

$$\overline{C}_{merch,t=0} = \sum_{p=1}^{P}\overline{C}_{merch,p,t=0}$$

Parameter	Description	Unit
$\overline{C}_{merch,t=0}$	Average carbon per hectare in merchantable logs in the Project Area determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	tC ha^{-1}
$\overline{C}_{merch,p,t=0}$	Average carbon per hectare in merchantable logs of forest product type *p*, in the Project Area determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	tC ha^{-1}

3.2.1.2.2 Carbon in the AGB of the growing stock using BCEF method

The carbon in the AGB of the growing stock can be calculated by applying the stratum-level BCEF method as presented in Figure 3-1 using the following procedure:

Step 1: Choose the most applicable BCEF value for each stratum in the Project Area from the following data sources:

(i) National factor (e.g. from National GHG Inventory)

(ii) Default IPCC BCEF for the corresponding forest, climate and growing stock in the Project Area (see IPCC, 2006, Chapter 4, Table 4.5, pp. 4.51-4.52).

If a factor for the forest type and the climatic region of the Project Area is not found, select the factor with the closest corresponding information.

Step 2: Choose the most applicable carbon fraction in the AGB of trees from the data sources presented in Step 4 of Section 3.2.1.2.1,A.

Step 3: Apply the following equation to convert the average growing stock per hectare to average carbon per hectare in the AGB in the growing stock in stratum *j*, using the values for BCEF and carbon fraction:

Equation 3-8

$$\overline{C}_{AGB\_gstock,j,t=0} = BCEF_j \times CF_{AGB} \times \overline{V}_{gstock,j,t=0}$$

Parameter	Description	Unit
$\overline{C}_{AGB\_gstock,j,t=0}$	Average carbon per hectare in the aboveground biomass of the growing stock in stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	tC ha^{-1}
$BCEF_j$	Biomass conversion and expansion factor for converting average growing stock per hectare to carbon in the aboveground biomass for stratum *j*, (where *j*=1,2,3 … *J* strata)	(t d.m.) m^{-3}
CF_{AGB}	Carbon fraction in the aboveground biomass of trees for the tropical forest (see Appendix B)	tC (t d.m.)$^{-1}$

Parameter	Description	Unit
$\overline{V}_{gstock,j,t=0}$	Average growing stock per hectare for stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	m^3 ha^{-1}

Step 4: Convert the average carbon per hectare in the AGB of the strata level to the whole forest level:

Equation 3-9

$$\overline{C}_{AGB\_gstock,t=0} = \frac{\sum_{j=1}^{J}\left(\overline{C}_{AGB\_gstock,j,t=0} \times A_{project,j,t=0}\right)}{A_{project,t=0}}$$

Parameter	Description	Unit
$\overline{C}_{AGB\_gstock,t=0}$	Average carbon per hectare in the aboveground biomass of the growing stock in the Project Area determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	tC ha^{-1}
$\overline{C}_{AGB\_gstock,j,t=0}$	Average carbon per hectare in the aboveground biomass of the growing stock in stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	tC ha^{-1}
$A_{project,j,t=0}$	Project Area within each stratum *j*, (where *j*=1,2,3 … *J* strata) where the IFM-LtPF project activity will be implemented; determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	ha
$A_{project,t=0}$	Project Area where the IFM-LtPF project activity will be implemented; determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	ha

3.2.1.3 Where a detailed FIR is available

If the FIR or an equivalent document provides field inventory data on tree species, diameter at breast height (DBH) and tree height (H) of the growing stock at the sample plot level *s*, in each stratum *j*, the volume allometric method can be used for estimating the carbon in the merchantable logs and in the AGB of the growing stock.

3.2.1.3.1 Carbon in the merchantable logs using volume allometric method

Use the following steps to calculate the carbon in the merchantable logs applying the volume allometric method:

A. Where inventory data does not distinguish between different forest product types

Step 1: To estimate the growing stock per hectare using DBH and tree height for each tree, select species-specific or group of species-specific volume allometric equations from the following data sources:

(i) Published peer reviewed studies for equations from tropical forests with corresponding climate region and ecological zone (e.g. Akindele and Lemay, 2006; Segura and Kanninen, 2005)

(ii) Published documents from the relevant forestry authority of the host country, e.g. National Inventory Report.

If species-specific or group of species-specific volume allometric equations are not available, general volume equations can be obtained from the relevant forestry authority of the host country. For this case, the Project Proponent is required to verify the applicability of this equation in the first monitoring event (see Section 7.2.4.2). If the equation is not applicable, derive a Project Area-specific equation (see specifically Step 5 of Section 7.2.4.2 for guidelines).

Step 2: Apply the following equation to sum the volume of each tree *n*, of species *i*, in sample plot *s*, to obtain the average growing stock in all the sample plots within a stratum *j*:

Equation 3-10

$$\overline{V}_{gstock,j,t=0} = \frac{1}{A_{s,j,t=0}} \times \sum_{s=1}^{S} \left\{ \sum_{i=1}^{I} \left[\sum_{n=1}^{N_i} f_V(DBH_{n,i,s,j,t=0}, H_{n,i,s,j,t=0}) \right] \right\}$$

Parameter	Description	Unit
$\overline{V}_{gstock,j,t=0}$	Average growing stock per hectare for stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	$m^3\ ha^{-1}$
$f_V(DBH_{n,i,s,j,t=0}, H_{n,i,s,j,t=0})$	Volume allometric equation as a function of diameter at breast height and height; determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	dimensionless
$DBH_{n,i,s,j,t=0}$	Diameter at breast height for individual tree *n* (where *n*=1,2,3 … N_i for species, *i*), of species *i* (where *i*=1,2,3 … *I* species) in sample plot *s* (where *s*=1,2,3 … *S* sample plot), of stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	cm
$H_{n,i,s,j,t=0}$	Height for individual tree *n*, (where *n*=1,2,3 … N_i for species, *i*), of species *i*, (where *i*=1,2,3 … *I* species) in sample plot *s*, (where *s*=1,2,3 … *S* sample plot), of stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	m
$A_{s,j,t=0}$	Total area of sample plots *s*, (where *s*=1,2,3 … *S* sample plot), in stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	ha

Step 3: After estimating growing stock per hectare at the strata level, to calculate the carbon in the merchantable logs ($\overline{C}_{merch,t=0}$), apply Steps 2 to 6 as shown in the Section 3.2.1.2.1,A.

B. Where inventory data distinguish between different forest product types

If the different forest product types are distinguished based on the DBH of the tree, and are to be accounted for in GHG emissions calculations, apply the following steps:

Step 1: To estimate growing stock per hectare for each product type using DBH and tree height for each tree, select species-specific or group of species-specific volume allometric equations from the data sources presented in Step 1 of Section 3.2.1.3.1,A.

If species-specific or group of species-specific volume allometric equations are not available, general volume equations can be obtained from the relevant forestry authority of the host country. For this case, the Project Proponent is required to verify the applicability of this equation in the first monitoring event (see Section 7.2.4.2). If the equation is not applicable, derive a Project Area-specific equation (see specifically Step 5 of Section 7.2.4.2 for guidelines).

Step 2: Apply the allometric equations to individual tree *n*, of species *i*, to determine the average growing stock per hectare of the forest product type *p*, in a stratum *j*, as follows:

Equation 3-11

$$\overline{V}_{gstock,p,j,t=0} = \frac{1}{A_{s,j,t=0}} \times \sum_{s=1}^{S}\left\{\sum_{i=1}^{I}\left[\sum_{n=1}^{N_i} f_V(DBH_{n,i,s,j,t=0}, H_{n,i,s,j,t=0})_p\right]\right\}$$

Parameter	Description	Unit
$\overline{V}_{gstock,p,j,t=0}$	Average growing stock per hectare for product type *p,* in stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	m^3 ha^{-1}
$f_V(DBH_{n,i,s,j,t=0}, H_{n,i,s,j,t=0})_p$	Volume allometric equation as a function of diameter at breast height and height for the forest product type *p*; determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	dimensionless
$DBH_{n,i,s,j,t=0}$	Diameter at breast height for individual tree *n* (where *n*=1,2,3 … N_i for species, *i*), of species *i,* (where *i*=1,2,3 … *I* species) in sample plot *s* (where *s*=1,2,3 … *S* sample plot), of stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	cm
$H_{n,i,s,j,t=0}$	Height for individual tree *n,* (where *n*=1,2,3 … N_i for species, *i*), of species *i*, (where *i*=1,2,3 … *I* species) in sample plot *s*, (where *s*=1,2,3 … *S* sample plot), of stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	m

Parameter	Description	Unit
$A_{s,j,t=0}$	Total area of sample plots *s*, (where *s*=1,2,3 … *S* sample plot) in stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	ha

Step 3: After estimating growing stock per hectare for different forest product types *p*, at the strata level, to calculate the average carbon per hectare in the merchantable logs ($\overline{C}_{merch,t=0}$), apply Steps 1 to 7 as shown in the Section 3.2.1.2.1,B.

3.2.1.3.2 Carbon in the AGB of the growing stock using biomass allometric method

The carbon in the AGB of the growing stock per hectare can be calculated based on the carbon fraction and growing stock. The growing stock is calculated by applying biomass allometric equations as a function of DBH, tree height, and wood density. This method of carbon estimation in the AGB of the growing stock is also used for estimating the carbon in the growth foregone due to selective logging as described in Section 3.3.4. The data on DBH and tree height are obtained from measurement of trees in the PSPs using the method presented in Section 7.1.2.

Calculate the carbon in the AGB of the growing stock applying the biomass allometric method by using the following procedure:

Step 1: Select species-specific or group of species-specific biomass allometric equations for estimating the AGB using the tree measurements from the following data sources:

(i) Published peer reviewed studies for equations from tropical forests with corresponding climate region and ecological zone (e.g. Pearson et al., 2005)

(ii) Published documents from the relevant authority of the host country, e.g. National Inventory Report.

If species-specific or group of species-specific biomass allometric equations are not available, general biomass allometric equations can be obtained from literature such as the IPCC GPG LULUCF (2003), Chapter 4, Annex 4A.1, Table 4.A.1, p. 4.114, or Pearson et. al. (2005), Appendix C, p. 43. For this case, select the most applicable allometric equation for a tropical forest with corresponding climate region and ecological zone and verify the applicability of this equation in the first monitoring event (see Section 7.2.4.2). If the equation is not applicable, derive a Project Area-specific equation (see specifically Steps 1 and 5 in Section 7.2.4.2 for guidelines).

Step 2: Find species-specific or group of species-specific wood densities from the data sources presented in Appendix B, Section B.1.

Step 3: Apply the biomass allometric equation to convert the DBH, tree height and wood density to the AGB of all the individual trees *n*, of species *i*, in the sample plot *s*, of the stratum *j*:

Equation 3-12

$$\overline{B}_{AGB\_gstock,j,t=0} = \frac{1}{A_{s,j,t=0}} \times \sum_{s=1}^{S}\left\{\sum_{i=1}^{I}\left[\sum_{n=1}^{N_i} f_B(DBH_{n,i,s,j,t=0}, H_{n,s,i,j,t=0}, D_i)\right]\right\}$$

Parameter	Description	Unit
$\overline{B}_{AGB\_gstock,j,t=0}$	Average aboveground biomass of the growing stock in stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	(t d.m.) ha^{-1}
$f_B(DBH_{n,i,s,j,t=0}, H_{n,s,i,j,t=0}, D_i)$	Biomass allometric equation as a function of diameter at breast height, height determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year, and wood density	dimensionless
$DBH_{n,i,s,j,t=0}$	Diameter at breast height for individual tree *n*, (where *n*=1,2,3 … N_i for species, *i*), of species *i*, (where *i*=1,2,3 … *I* species) in sample plot *s*, (where *s*=1,2,3 … *S* sample plot), of stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	cm
$H_{n,i,s,j,t=0}$	Height for individual tree *n*, (where *n*=1,2,3 … N_i for species, *i*), of species *i* (where *i*=1,2,3 … *I* species) in sample plot *s*, (where *s*=1,2,3 … *S* sample plot), of stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	m
D_i	Wood density for species, *i*, if D_i is not available, the density (D) for the tropical forest with the corresponding climate region and ecological zone	(t d.m.) m^{-3}
$A_{s,j,t=0}$	Total area of sample plots *s*, (where *s*=1,2,3 … *S* sample plot), in stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	ha

Note that for estimating the annual average growth foregone in the Project Area due to selective logging, the AGB of the merchantable trees ($\overline{B}_{AGB\_merch,j.m_1}$ and $\overline{B}_{AGB\_merch,j.m_2}$, see Equation 3-36a) are obtained by applying the DBH and height of the merchantable trees at the stratum level, $DBH_{n,i,s,j,t}$ and $H_{n,i,s,j,t}$, respectively, to Equation 3-12 in monitoring events m_1 and m_2. Similarly, the annual average regrowth of the AGB in the naturally disturbed area ($\overline{B}_{AGB\_nd,j.m_1}$ and $\overline{B}_{AGB\_nd,j.m_2}$, see Equation 4-17b) is estimated by applying the DBH and height of all trees $DBH_{tree\_nd,n,i,s_{nd},j,t}$ and $H_{tree\_nd,n,i,s_{nd},j,t}$, respectively, in the sample plot established in the naturally disturbed areas, s_{nd}, to Equation 3-12 (see Step 5 of Section 4.4). Note that the subscript *s* in Equation 3-12 must consequently be replaced with the subscript s_{nd}.

Step 4: Convert the average AGB for the strata level to average AGB in the Project Area:

Equation 3-13
$$\overline{B}_{AGB\_gstock,t=0} = \frac{\sum_{j=1}^{J}\left(\overline{B}_{AGB\_gstock,j,t=0} \times A_{project,j,t=0}\right)}{A_{project,t=0}}$$

Parameter	Description	Unit
$\overline{B}_{AGB\_gstock,t=0}$	Average aboveground biomass per hectare of the growing stock in the Project Area determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	(t d.m.) ha^{-1}
$\overline{B}_{AGB\_gstock,j,t=0}$	Average aboveground biomass of the growing stock in stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	(t d.m.) ha^{-1}
$A_{project,j,t=0}$	Project Area within each stratum *j*, (where *j*=1,2,3 … *J* strata) where the IFM-LtPF project activity will be implemented; determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	ha
$A_{project,t=0}$	Project Area where the IFM-LtPF project activity will be implemented; determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	ha

Step 5: Choose the carbon fraction of the AGB from the data sources presented in Step 4 of Section 3.2.1.2.1,A.

Step 6: Convert the average AGB to average carbon per hectare in the AGB in the Project Area:

Equation 3-14
$$\overline{C}_{AGB\_gstock,t=0} = \overline{B}_{AGB\_gstock,t=0} \times CF_{AGB}$$

Parameter	Description	Unit
$\overline{C}_{AGB\_gstock,t=0}$	Average carbon per hectare in the aboveground biomass of the growing stock in the Project Area determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	tC ha^{-1}
$\overline{B}_{AGB\_gstock,t=0}$	Average aboveground biomass per hectare of the growing stock in the Project Area determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	(t d.m.) ha^{-1}
CF_{AGB}	Carbon fraction in the aboveground biomass of trees for the tropical forest (see Appendix B)	tC (t d.m.)$^{-1}$

3.2.2 MEASURED DATA PATHWAY

If the Project Proponent has obtained approval for selective logging from the relevant authority of the host country and also provides evidence of preparation of the FIR or an equivalent document, then data collection through field measurements in PSPs (see Section 7.1.2) after proper stratification (see Section 2.2.1.1.1) is required. This approach has been termed as Measured Data pathway in this Methodology.

The data collected through the measurement in the PSPs provides the diameter at breast height (DBH) and tree height (H) of the growing stock at the sample plot level *s*, in each stratum *j*. The volume and biomass allometric methods described for the Existing Inventory Data pathway where the detailed FIR is available, Sections 3.2.1.3.1 and 3.2.1.3.2, respectively, will be used for calculating the carbon in the merchantable logs and the AGB in the growing stock.

3.2.3 DETERMINATION OF ANNUAL HARVEST VOLUME AND NET HARVEST AREA

3.2.3.1 Where the FIR or equivalent document contains a detailed harvesting plan

In the case where the FIR or equivalent document, contains a detailed harvesting plan, the plan must provide a detailed prescription for selective logging, clearly stating the total volume of wood to be harvested, the annual net harvest area, as well as a specification of the period when selective logging operations are to be carried out in the Project Area. Since the document is legally approved by the relevant authority in the host country, the total volume of wood to be harvested must be converted to an annual harvest volume ($V_{merch,t}$) based on the growing stock ($V_{gstock,t=0}$) and the area where the selective logging occurs, i.e., the annual net harvest area ($A_{NHA\_annual,t}$). The latter, if known, is the summation of the annual net harvest area at the stratum level ($A_{NHA\_annual,j,t}$). These parameters must be used in calculating the net GHG emission reductions for the baseline scenario.

3.2.3.2 Where a detailed harvesting plan is not available

In the case where the Project Proponent has obtained the approval for selective logging and also provides evidence of the preparation of the FIR or equivalent document, but this document is not complete, the annual harvest volume and annual net harvest area (at the stratum level) are calculated from the growing stock data obtained from field measurements in the PSPs (i.e. the Measured Data pathway) using the following procedure:

Step 1: The Project Proponent must select a sustainable and commonly employed method in the host country and prepare a timber harvesting plan for the selective logging in the Project Area. The Project Proponent must demonstrate that the plan is realistic and sustainable and will be implemented for selective logging if the IFM-LtPF project does not go ahead. This timber harvesting plan must provide the annual harvest volume (volume of merchantable logs to be removed) ($V_{merch,t}$) and the annual net harvest area ($A_{NHA\_annual,t}$), which, if known, is the summation of the annual net harvest area at the stratum level ($A_{NHA\_annual,j,t}$), where the harvesting would occur.

Step 2: Since the annual harvest volume and annual net harvest area are based on the measured data, the Project Proponent must obtain approval from the relevant authority in the host country and also provide the documentary evidence in the PD.

The Project Proponent must also provide evidence or documentation that the chosen method for preparing the timber harvesting plan is sustainable and a commonly employed method in the host country.

3.2.4 ANNUAL TOTAL CARBON IN THE MERCHANTABLE LOGS

The annual total carbon in the merchantable logs, $C_{merch,t}$ is calculated by multiplying the average carbon per hectare in the merchantable logs by the annual net harvest area applying Equation 3-15a. In the case where the annual net harvest area at the stratum level is known, apply Equation 3-15b:

Equation 3-15a
$$C_{merch,t} = \bar{C}_{merch,t=0} \times A_{NHA\_annual,t}$$

Equation 3-15b
$$C_{merch,t} = \sum_{j=1}^{J} \left(\bar{C}_{merch,j,t=0} \times A_{NHA\_annual,j,t} \right)$$

Parameter	Description	Unit
$C_{merch,t}$	Annual total carbon in the merchantable logs harvested in the Project Area in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\bar{C}_{merch,t=0}$	Average carbon per hectare in the merchantable logs determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	tC ha^{-1}
$\bar{C}_{merch,j,t=0}$	Average carbon per hectare in the merchantable logs in stratum *j,* (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	tC ha^{-1}
$A_{NHA\_annual,t}$	Annual net harvest area for the Project Area in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	ha
$A_{NHA\_annual,j,t}$	Annual net harvest area for the Project Area in stratum *j,* (where *j*=1,2,3 … *J* strata) in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	ha

3.2.5 ANNUAL TOTAL CARBON IN THE ABOVEGROUND BIOMASS OF THE GROWING STOCK

The annual total carbon in the AGB of the growing stock, $C_{AGB\_gstock,t}$ is calculated by multiplying the average carbon per hectare in the AGB of the growing stock by the annual net harvest area applying Equation 3-16a. In the case where the annual net harvest area at the stratum level is known, apply Equation 3-16b.

Equation 3-16a
$$C_{AGB\_gstock,t} = \bar{C}_{AGB\_gstock,t=0} \times A_{NHA\_annual,t}$$

Equation 3-16b $$C_{AGB\_gstock,t} = \sum_{j=1}^{J} \left(\bar{C}_{AGB\_gstock,j,t=0} \times A_{NHA\_annual,j,t} \right)$$

Parameter	Description	Unit
$C_{AGB\_gstock,t}$	Annual total carbon in the aboveground biomass of the growing stock harvested every year in the Project Area in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\bar{C}_{AGB\_gstock,t=0}$	Average carbon per hectare in the aboveground biomass of the growing stock determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	tC ha^{-1}
$\bar{C}_{AGB\_gstock,j,t=0}$	Average carbon per hectare in the aboveground biomass of the growing stock in stratum *j,* (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	tC ha^{-1}
$A_{NHA\_annual,t}$	Annual net harvest area for the Project Area in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	ha
$A_{NHA\_annual,j,t}$	Annual net harvest area for the Project Area in stratum *j,* (where *j*=1,2,3 … *J* strata) in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	ha

3.3 CARBON CHANGES DUE TO DEGRADATION UNDER THE BASELINE SCENARIO

The primary parameters, annual net harvest area, $A_{NHA\_annual,t}$, annual total carbon in the merchantable logs, $C_{merch,t}$,and annual total carbon in the AGB of the growing stock, $C_{AGB\_gstock,t}$, calculated in Section 3.2, are then used to calculate each of the five parameters of Equation 3-2 to determine the annual carbon lost from degradation. The procedures for calculating these five parameters are provided in the subsequent sections.

3.3.1 NET CARBON FROM THE DEADWOOD POOL

The DW pool contains carbon in coarse woody debris, standing dead trees and other dead material not included in the litter or soil carbon pools (IPCC, 2006, p. 4.73). The Methodology assumes that the proportion of DW accumulation to the DW pool and rate of decay from the pool due to natural mortality and disturbance will be the same for both the baseline and with-project scenarios, and is therefore not included.

In this Methodology, for the baseline scenario of selective logging, the additions (also referred to as inputs) to the carbon in the DW pool are:

(i) Carbon from residual stand damage

(ii) Carbon in branches and trimmings.

The carbon from DW is a function of the (delayed) decay of the combined inputs to the DW pool and is given by:

Equation 3-17

$$C_{DW_{decay},t} = f(C_{DW_{in}t}, k_{decay})$$

Parameter	Description	Unit
$C_{DW_{decay},t}$	Annual carbon leaving the deadwood pool due to the decay of deadwood in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{DW_{in},t}$	Annual total carbon input to the deadwood pool in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
k_{decay}	Rate of decay of the deadwood pool	yr^{-1}

The annual total carbon input into the deadwood pool is calculated as follows:

Equation 3-18

$$C_{DW_{in},t} = C_{RSD,t} + C_{branch\_trim,t}$$

Parameter	Description	Unit
$C_{DW_{in},t}$	Annual total carbon input to the deadwood pool in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{RSD,t}$	Annual carbon in the residual stand damage in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{branch\_trim,t}$	Annual carbon in branches and trimmings left over from harvesting in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC

3.3.1.1 Carbon from residual stand damage

In the process of selective logging, the residual stand is damaged either by being knocked down, snapped off, or due to limb breakage. The fraction of residual stand that is damaged over the amount of timber that is extracted, is denoted as the factor for residual stand damage, f_{RSD}. Data on carbon impact from damage to residual stand by selective logging is very limited (Brown et. al., 2005).

Brown et al. (2005) compiled the factor for residual stand damage (damage over extracted) for various countries and revealed a strong relationship with commercial log length (Brown et al., 2005, Figure 11, p. 16). The results have been summarised in this Methodology in Table B-3 in Appendix B. The carbon from residual stand damage can be determined using the following procedure:

Step 1: Determine the average commercial log length based on the inventory data for the Project Area.

Step 2: Select an appropriate and conservative value for f_{RSD} from publications specific to the host country. Table B-3, Section B.3, Appendix B is provided as a guidance to determine a suitable f_{RSD}.

Step 3: Apply the following equation to calculate carbon in the residual stand damage:

Equation 3-19 $$C_{RSD,t} = f_{RSD} \times C_{merch,t}$$

Parameter	Description	Unit
$C_{RSD,t}$	Annual carbon in the residual stand damage in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
f_{RSD}	Factor for residual stand damage, based on the fraction of quantity of carbon damaged in the residual stand to the quantity of carbon in total merchantable logs harvested	dimensionless
$C_{merch,t}$	Annual total carbon in merchantable logs harvested in the Project Area in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity) (See Equations 3-15a and 3-15b)	tC

3.3.1.2 Carbon in branches and trimmings

In the baseline scenario where selective logging occurs, trees are trimmed of their branches, twigs, and foliage to produce the merchantable logs intended for processing. Branches and trimmings is the term used to denote the trimmed components such as large and small branches, whose carbon will be transferred into the DW pool. Biomass from the twigs, foliage and bark are transferred into the litter pool. In accordance with the VCS rules, litter is not included as a carbon pool in this Methodology. Hence, only the fraction of branches and trimmings are accounted for in the dead wood pool.

To determine this fraction, a branch-trim factor, f_{branch_trim}, is employed (see Appendix A). The factor can be derived from the ratio of biomass of large branches and coarse woody debris over the total AGB of trees.

Determine the carbon in branches and trimmings using the following procedure:

Step 1: Find a branch-trim factor, f_{branch_trim}, from published peer reviewed literature for tropical forests of corresponding climate domain and ecological zone. If the branch-trim factor obtained from the literature does not match the forest type and climatic region of the Project Area, it will require validation via the steps outlined in Section 7.2.4.3. If a branch-trim factor can be obtained from the literature, proceed to Step 2. If a branch-trim factor cannot be obtained from the literature, it is conservative to set $C_{branch\_trim,t}$ equal to zero in Equation 3-20. Carbon from branches and trimmings is thus omitted in the ex ante calculation and must be included when a project-specific f_{branch_trim} can be derived from measurements in the first monitoring event (Section 7.2.4.3).

Step 2: Apply f_{branch_trim} in the following equation to estimate the carbon from branches and trimmings transferring into the DW pool:

Equation 3-20

$$C_{branch\_trim,t} = f_{branch\_trim} \times C_{merch,t}$$

Parameter	Description	Unit
$C_{branch\_trim,t}$	Annual carbon in branches and trimmings left over from harvesting in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{merch,t}$	Annual total carbon in the merchantable logs harvested in the Project Area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
f_{branch_trim}	The fraction of branches and trimmings in the aboveground biomass remaining after trimming of the merchantable logs transferred to the DW pool	dimensionless

Note: it is conservative to use $C_{merch,t}$ to determine $C_{branch\_trim,t}$.

3.3.1.3 Carbon emissions due to decay of the DW pool

Step 1: Select a value for the rate of decay, k_{decay}, from published peer reviewed literature, verified publication or equivalent document, for tropical forests of corresponding climate domain and ecological zone (e.g. Delaney et al., 1998) for the first year of the project.

If a range of values for the rate of decay is provided in the literature, the Project Proponent is required to provide justification for the choice of the rate of decay in the PD. If no justification can be derived, it is conservative to select the lower end of the range.

If in the subsequent monitoring events, the Project Proponent decides to estimate the project specific rate of decay, then refer to the guidance proposed by Scott and Brown (2008).

Step 2: Determine the annual fraction of DW that would remain in the DW pool in year *t* (years elapsed since the start of the IFM-LtPF project activity) by applying the rate of decay in the following equation:

Equation 3-21

$$F_{DW\_remain,t} = e^{-k_{decay} \times t}$$

Parameter	Description	Unit
$F_{DW\_remain,t}$	Annual fraction of carbon in the deadwood pool that would remain in the deadwood pool in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity) after applying the rate of decay	dimensionless
k_{decay}	Rate of decay of the deadwood pool	yr^{-1}
t	1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity	yr

Step 3: Calculate the carbon remaining and accumulating in the DW pool in year t (years elapsed since the start of the IFM-LtPF project activity). For a fixed annual harvest volume as set out in the harvesting plan or equivalent document, implying a fixed input into the deadwood pool, use Equation 3-22a. For a variable annual harvest volume as set out in the harvesting plan or equivalent document, implying a variable input into the deadwood pool, use Equation 3-22b. Where Equation 3-22b is to be used, see Appendix D for an example application.

Equation 3-22a

$$C_{DW_{pool},t} = \sum_{t=1}^{t*}\left(F_{DW\_remain,t} \times C_{DW_{in},t}\right)$$

Equation 3-22b

$$C_{DW_{pool,t}} = \left(F_{DW\_remain,t-(t-1)} \times C_{DW_{in},t}\right) + \left(F_{DW\_remain,t-(t-2)} \times C_{DW_{in},t-1}\right) + \left(F_{DW\_remain,t-(t-3)} \times C_{DW_{in},t-2}\right) + \ldots + \left(F_{DW\_remain,t-(t-t*)} \times C_{DW_{in},t-(t*-1)}\right)$$

Parameter	Description	Unit
$C_{DW_{pool},t}$	Cumulative carbon remaining in the deadwood pool in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$F_{DW\_remain,t}$	Annual fraction of carbon in the deadwood pool that would remain in the deadwood pool in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity) after applying the rate of decay	dimensionless
$C_{DW_{in},t}$	Annual total carbon input to the deadwood pool in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC

Step 4: Calculate the cumulative overall emissions leaving the DW pool in year *t* (years elapsed since the start of the IFM-LtPF project activity):

Equation 3-23

$$C_{DW_{out},t} = \sum_{t=1}^{t*} C_{DW_{in},t} - C_{DW_{pool},t}$$

Parameter	Description	Unit
$C_{DW_{out},t}$	Cumulative carbon leaving the deadwood pool and emitted into the atmosphere in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{DW_{in},t}$	Annual total carbon input to the deadwood pool in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{DW_{pool},t}$	Cumulative carbon remaining in the deadwood pool in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC

Step 5: To calculate the annual emissions leaving the DW pool in year *t* (years elapsed since the start of the IFM-LtPF project activity), apply the following equation:

Equation 3-24

$$C_{DW_{decay},t} = C_{DW_{out},t} - C_{DW_{out},t-1}$$

Parameter	Description	Unit
$C_{DW_{decay},t}$	Annual carbon leaving the deadwood pool due to the decay of deadwood in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{DW_{out},t}$	Cumulative carbon leaving the deadwood pool and emitted into the atmosphere in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{DW_{out},t-1}$	Cumulative carbon leaving the deadwood pool and emitted into the atmosphere in year *t*-1, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC

Note that for the first year of the project where *t*=1, Equation 3-24 shows that the annual carbon leaving the DW pool ($C_{DW_{decay},t}$) is equal to the cumulative carbon leaving the DW pool ($C_{DW_{out},t}$).

3.3.2 Net Carbon from the Long-term HWP Pool

Long-term HWPs (ltHWPs) are those with a half-life of over 30 years while products with a half-life of two years or less are known as short-term HWPs (stHWPs) (IPCC, 2006, Chapter 12, Section 12.2.2, Table 12-2).

The approach taken for ltHWPs is for analysis to be based on domestic harvest volume and not domestic consumption volume. In the case where a FIR is not available (see Figure 3-1) and where no other information is available to determine what quantity or ratio of the total merchantable logs' volume is classed as stHWPs, then it is conservative to assume that all the merchantable logs' volume goes into the ltHWP pool.

In order to apply this Methodology, data availability with respect to the following parameters must be determined:

- average carbon in the ltHWPs
- lumber recovery factor (see Appendix B)
- ltHWP rate of oxidation (see Appendix B).

The carbon from ltHWPs is a combination of the immediate oxidation of ltHWP residues as a result of timber processing, and the delayed oxidation of ltHWPs, as given by:

Equation 3-25

$$C_{ltHWP_{oxidation},t} = C_{ltHWP_{residues},t} + C_{ltHWP_{net\_out},t}$$

Parameter	Description	Unit
$C_{ltHWP_{oxidation},t}$	Annual carbon due to the combined delayed oxidation of long-term harvested wood products and immediate oxidation of long-term harvested wood products residues in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{ltHWP_{residues},t}$	Annual carbon due to the immediate oxidation of long-term harvested wood products residues in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{ltHWP_{net\_out},t}$	Annual net carbon due to the delayed oxidation of the long-term harvested wood products, leaving the long-term harvested wood products pool in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC

3.3.2.1 Carbon due to long-term HWP residues

Long-term HWP residues are known to be comprised of saw dust, trimmings and other conversion losses (Enters, 2001). The lumber recovery factor for merchantable log processing is required in order to determine the carbon associated with sawmill residues. This can be determined using the following procedure:

Step 1: Select a lumber recovery factor from the following data sources:

(i) National lumber recovery factors in relevant literature such as FAO (2004). Various country specific lumber recovery factors have been compiled in Table B-4 in Appendix B; or

(ii) If a national lumber recovery factor is not available, select a lumber recovery factor from a country that uses similar timber processing technology to that of the project's host country.

If a range for the lumber recovery factor is provided, the Project Proponent is required to provide justification for the choice of lumber recovery factor in the PD. If no justification can be derived, it is conservative to select the upper end of the range.

Step 2: Assuming that the sawmill residues undergo oxidation in the same year of processing, annual emissions due to ltHWP residues are determined by:

Equation 3-26

$$C_{ltHWP_{residues},t} = \overline{C}_{merch,p,t=0} \times (1 - f_{lumber\_recovery}) \times A_{NHA\_annual,t}$$

Parameter	Description	Unit
$C_{ltHWP_{residues},t}$	Annual carbon due to the immediate oxidation of long-term harvested wood products residues in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\overline{C}_{merch,p,t=0}$	Average carbon per hectare in merchantable logs of forest product type *p*=sawlog, in the Project Area determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	tC ha^{-1}
$f_{lumber\_recovery}$	Lumber recovery factor for proportion of merchantable log converted to harvested wood product	dimensionless
$A_{NHA\_annual,t}$	Annual net harvest area for the Project Area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	ha

3.3.2.2 Carbon due to oxidation of the long-term HWP pool

Calculate the average amount of carbon expected to be transferred into the HWP pool each year and stored over the long term. Wood harvested for production of paper products (and the like) and commercially harvested fuelwood, such as from pulplog (see HWPs - stHWPs in Appendix A), are not considered to be ltHWPs and are therefore accounted in Section 3.3.3 instead.

According to the IPCC's default values for oxidation of specific ltHWPs (IPCC, 2006, Chapter 12) it is noteworthy that the oxidation factors among these ltHWPs do not vary greatly. Hence, it is assumed that a single oxidation factor applied to ltHWPs would suffice.

Step 1: Select a lumber recovery factor from the data sources presented in Step 1 of Section 3.3.2.1.

Step 2: Multiply the carbon in the forest product type such as sawlog that contributes to the ltHWPs (derived in Equation 3-6) by the lumber recovery factor and annual net harvest area, as given by:

Equation 3-27

$$C_{ltHWP_{in},t} = \overline{C}_{merch,p,t=0} \times f_{lumber\_recovery} \times A_{NHA\_annual,t}$$

Parameter	Description	Unit
$C_{ltHWP_{in},t}$	Annual carbon input to the long-term harvested wood products pool from sawlog in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\overline{C}_{merch,p,t=0}$	Average carbon per hectare in merchantable logs of forest product type *p*, in the Project Area determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	tC
$f_{lumber\_recovery}$	Lumber recovery factor for proportion of merchantable log converted to harvested wood product	dimensionless
$A_{NHA\_annual,t}$	Annual net harvest area for the Project Area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	ha

Step 3: Find an appropriate rate of carbon oxidation[5] (k_{ltHWP_ox}) specific to ltHWPs. For example, if it is known that the ltHWPs are to be made into sawnwood furniture (i.e. solidwood products from sawlogs), then the rate of carbon oxidation should (closely) reflect solidwood products. The IPCC (2006) have default rates of oxidation for HWP categories (see Appendix B, Section B.5, Table B-5).

If a range of values for the carbon rate of oxidation is provided in the literature, the Project Proponent is required to provide justification for the rate of carbon oxidation in the PD. If no justification can be derived, it is conservative to select the lower end of the range.

Step 4: Determine the annual fraction of ltHWP that would remain in the ltHWP pool in year *t* (years elapsed since the start of the IFM-LtPF project activity) by applying the rate of oxidation in the following equation:

Equation 3-28

$$F_{ltHWP\_remain,t} = e^{-k_{ltHWP\_ox} \times t}$$

Parameter	Description	Unit
$F_{ltHWP\_remain,t}$	Annual fraction of ltHWP that would remain in the ltHWP pool in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity) after applying the rate of oxidation	dimensionless

[5] The term "rate of carbon oxidation" is synonymous with "rate of decay". However in this Methodology, for improved clarity to differentiate between the rates used between long-term harvested wood products (ltHWPs) and deadwood (DW), "rate of carbon oxidation" is used in association with ltHWPs while "rate of decay" is used in associated with DW.

Parameter	Description	Unit
k_{ltHWP_ox}	Rate of oxidation for long-term harvested wood products	yr^{-1}
t	1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity	yr

Step 5: Calculate the carbon remaining and accumulating in the ltHWP pool in year *t* (years elapsed since the start of the IFM-LtPF project activity). For a fixed annual harvest volume as set out in the harvesting plan or equivalent document, implying a fixed input into the ltHWP pool, use Equation 3-29a. For a variable harvest volume as set out in the harvesting plan or equivalent document, implying a variable input into the ltHWP pool, use Equation 3-29b. Where Equation 3-29b is to be used, see Appendix D for an example application:

Equation 3-29a

$$C_{ltHWP_{pool},t} = \sum_{t=1}^{t*}\left(F_{ltHWP\_remain,t} \times C_{ltHWP_{in},t}\right)$$

Equation 3-29b

$$C_{ltHWP_{pool,t}} = \left(F_{ltHWP\_remain,t-(t-1)} \times C_{ltHWP_{in},t}\right) + \left(F_{ltHWP\_remain,t-(t-2)} \times C_{ltHWP_{in},t-1}\right) + \left(F_{ltHWP\_remain,t-(t-3)} \times C_{ltHWP_{in},t-2}\right) + \ldots + \left(F_{lHWP\_remain,t-(t-t*)} \times C_{ltHWP_{in},t-(t*-1)}\right)$$

Parameter	Description	Unit
$C_{ltHWP_{pool},t}$	Cumulative carbon remaining in the ltHWP pool in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$F_{ltHWP\_remain,t}$	Annual fraction of ltHWP that would remain in the ltHWP pool in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity) after applying the rate of oxidation	dimensionless
$C_{ltHWP_{in},t}$	Annual carbon input to the long-term harvested wood products pool from sawlog in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC

Step 6: Calculate the cumulative overall emissions leaving the ltHWP pool in year t (years elapsed since the start of the IFM-LtPF project activity):

Equation 3-30

$$C_{ltHWP_{out},t} = \sum_{t=1}^{t*} C_{ltHWP_{in},t} - C_{ltHWP_{pool},t}$$

Parameter	Description	Unit
$C_{ltHWP_{out},t}$	Cumulative carbon leaving the ltHWP pool and emitted into the atmosphere from year *t*=1 to year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{ltHWP_{in},t}$	Annual carbon input to the long-term harvested wood products pool from sawlog in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{ltHWP_{pool},t}$	Cumulative carbon remaining in the ltHWP pool in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC

Step 7: To calculate the annual emissions leaving the ltHWP pool in *t* years elapsed since the start of the IFM-LtPF project activity, apply the following equation:

Equation 3-31
$$C_{ltHWP_{net\_out},t} = C_{ltHWP_{out},t} - C_{ltHWP_{out},t-1}$$

Parameter	Description	Unit
$C_{ltHWP_{net\_out},t}$	Annual net carbon due to the delayed oxidation of the long-term harvested wood products, leaving the long-term harvested wood products pool in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{ltHWP_{out},t}$	Cumulative carbon leaving the ltHWP pool and emitted into the atmosphere in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{ltHWP_{out},t-1}$	Cumulative carbon leaving the ltHWP pool and emitted into the atmosphere in year *t*-1, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC

Note, that for the first year of the project where *t*=1, Equation 3-31 shows that the annual carbon leaving the ltHWP pool ($C_{ltHWP_{net\_out},t}$) is equal to the cumulative carbon leaving the ltHWP pool ($C_{ltHWP_{out},t}$).

3.3.3 Net Carbon from the Short-term HWP Pool

Certain merchantable logs are destined to be converted into HWPs with a half-life of two years or less. These are referred to here as short-term HWPs (stHWPs; IPCC, 2006, Chapter 12, Section 12.2.2, p. 12.17). In this Methodology, the two forest product types contributing to stHWPs are pulplog (for paper products) and commercially harvested fuelwood. Similar to ltHWPs, the approach taken for stHWPs is for analysis to be based on domestic harvest volume and not domestic consumption volume.

In the case where inventory data do not distinguish the forest product types and/or where no other information is available to determine what quantity or ratio of the total merchantable logs' volume is classed into stHWPs, then it is conservative to assume that all the merchantable logs' volume goes into the ltHWP pool.

The annual carbon from stHWPs is a combination of the immediate oxidation of commercially harvested fuelwood and delayed oxidation of paper products, or solely from commercially harvested fuelwood, or solely from paper products. Equation 3-32 provides the annual carbon from the combination of both stHWPs. In the case where oxidation is attributable to only commercially harvested fuelwood, the parameter for paper products becomes zero - and vice versa.

Equation 3-32
$$C_{stHWP_{oxidation},t} = C_{stHWP_{comm\_FW},t} + C_{stHWP_{net\_out},t}$$

Parameter	Description	Unit
$C_{stHWP_{oxidation},t}$	Annual carbon due to immediate oxidation of short-term harvested wood products (commercially harvested fuelwood) and delayed oxidation of short-term harvested wood products (paper products) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{stHWP_{comm\_FW},t}$	Annual carbon due to immediate oxidation of short-term harvested wood products (commercially harvested fuelwood) leaving the project boundary in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{stHWP_{net\_out},t}$	Annual net carbon due to the delayed oxidation of short-term harvested wood products (paper products), leaving the short-term harvested wood products pool in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC

3.3.3.1 Carbon in short-term HWPs - commercially harvested fuelwood

For commercially harvested fuelwood, immediate oxidation occurs upon consumption - and therefore is regarded as an (immediate) emission in the year of harvest. The carbon from stHWPs is thus considered from the immediate oxidation of the stHWP merchantable logs.

The annual carbon from stHWPs - commercially harvested fuelwood, is calculated by multiplying the average carbon per hectare in the commercially harvested fuelwood with the annual net harvest area:

Equation 3-33
$$C_{stHWP_{comm\_FW},t} = \overline{C}_{merch,p,t=0} \times A_{NHA\_annual,t}$$

Parameter	Description	Unit
$C_{stHWP_{comm\_FW},t}$	Annual carbon due to immediate oxidation of short-term harvested wood products (commercially harvested fuelwood) leaving the project boundary in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\overline{C}_{merch,p,t=0}$	Average carbon per hectare in merchantable logs of forest product type p=pulplog, in the Project Area determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	tC ha^{-1}
$A_{NHA\_annual,t}$	Annual net harvest area for the Project Area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	ha

3.3.3.2 Carbon in short-term HWPs - pulplog

Pulplogs are mainly used for paper products. For paper products, the IPCC (2006) suggests to use a (delayed) rate of oxidation (see Appendix B). Hence, use the following procedure:

Step 1: Find an appropriate rate of carbon oxidation (k_{stHWP_ox}) specific to paper products (or see Appendix B). If a range of values for the rate of oxidation is provided in the literature, the Project Proponent is required to provide justification for the choice of the rate of oxidation in the PD. If no justification can be derived, it is conservative to select the lower end of the range. Then apply the following equation:

Equation 3-34

$$F_{stHWP\_remain,t} = e^{-k_{stHWP\_ox} \times t}$$

Parameter	Description	Unit
$F_{stHWP\_remain,t}$	Annual fraction of stHWP that would remain in the stHWP pool in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity) after applying the rate of oxidation	dimensionless
k_{stHWP_ox}	Rate of oxidation for short-term harvested wood products	yr^{-1}
t	1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity	yr

Step 2: Apply the following equation (note this is modified from Equation 3-33 because paper products are not immediately oxidized, these go into the stHWP pool).

Equation 3-35

$$C_{stHWP_{in},t} = \overline{C}_{merch,p,t=0} \times A_{NHA\_annual,t}$$

Parameter	Description	Unit
$C_{stHWP_{in},t}$	Annual carbon input to the short-term harvested wood products pool, for the specific forest product type, pulplog,in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\overline{C}_{merch,p,t=0}$	Average carbon per hectare in merchantable logs of forest product type *p*=pulplog, in the Project Area determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	tC ha^{-1}
$A_{NHA\_annual,t}$	Annual net harvest area for the Project Area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	ha

Step 3: Apply Equations 3-29a or 3-29b through to 3-31, changing the descriptions (and subscripts) from ltHWP to stHWP to calculate the annual net carbon due to the delayed oxidation of the stHWPs, leaving the stHWP pool in t years elapsed since start of the IFM-LtPF project activity.

3.3.4 CARBON IN THE GROWTH FOREGONE DUE TO SELECTIVE LOGGING

The selective logging operations removes a prescribed amount of merchantable logs after harvesting of the selected merchantable trees from the Project Area under the baseline scenario. Consequently, the carbon that would have been stored from the annual growth in these trees is forfeited. The carbon lost here is denoted as carbon in the growth foregone, $C_{growth\_foregone,t}$, and this can be calculated using the following procedure:

Step 1: Calculate the AGB in merchantable trees from height and diameter measurements of all the merchantable trees in the PSPs at the stratum level for two consecutive monitoring events using the method presented in Section 3.2.1.3.2. The procedure for establishing PSPs and tree measurements are described in Section 7.1.2.

The method to determine the annual growth parameter is based on the stock change method presented in the approved CDM Methodology for Afforestation and Reforestation project activities (CDM-EB, 2009, p. 8). The difference between the AGB of merchantable trees from data obtained in the PSP measurements at the stratum level for two consecutive monitoring events is determined and divided by the monitoring period, i.e. the time interval taken between the two monitoring events (in years), at the stratum level using Equation 3-36a and, for the Project Area using Equation 3-36b:

Equation 3-36a

$$\bar{G}_{growth\_foregone,j,t} = \frac{\bar{B}_{AGB\_merch,j,m_2} - \bar{B}_{AGB\_merch,j,m_1}}{\Delta m}$$

Equation 3-36b

$$\bar{G}_{growth\_foregone,t} = \frac{\sum_{j=1}^{J}\left(\bar{G}_{growth\_foregone,j,t} \times A_{project,j,t=0}\right)}{A_{project,t=0}}$$

Parameter	Description	Unit
$\bar{G}_{growth\_foregone,j,t}$	Average growth per hectare per year in the aboveground biomass in the merchantable trees in the Project Area in stratum *j*, (where *j*=1,2,3 … *J* strata) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	(t d.m.) ha^{-1} yr^{-1}
$\bar{B}_{AGB\_merch,j,m_2}$	Average aboveground biomass of the merchantable trees in the Project Area in stratum *j*, (where *j*=1,2,3 … *J* strata) in year, m_2 - when current monitoring event occurs	(t d.m.) ha^{-1}
$\bar{B}_{AGB\_merch,j,m_1}$	Average aboveground biomass of the merchantable trees in the Project Area in stratum *j*, (where *j*=1,2,3 … *J* strata) in year, m_1- when preceding monitoring event occurred	(t d.m.) ha^{-1}

Parameter	Description	Unit
Δm	Monitoring period, the time taken between two consecutive monitoring events	yr
$\bar{G}_{growth\_foregone,t}$	Average growth per hectare per year in the aboveground biomass in the merchantable trees in the Project Area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	(t d.m.) ha^{-1} yr^{-1}
$A_{project,j,t=0}$	Project Area within each stratum *j*, (where *j*=1,2,3 … *J* strata) where the IFM-LtPF project activity will be implemented; determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	ha
$A_{project,t=0}$	Project Area where the IFM-LtPF project activity will be implemented; determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	ha

Step 2: Calculate the carbon in the growth foregone due to the selective logging using Equation 3-37a. In the case where the annual net harvest area at the stratum level is known, apply Equation 3-37b:

Equation 3-37a

$$C_{growth\_foregone,t} = CF_{AGB} \times \bar{G}_{growth\_foregone,t} \times \sum_{t=1}^{t*} A_{NHA\_annual,t}$$

Equation 3-37b

$$C_{growth\_foregone,t} = CF_{AGB} \times \sum_{j=1}^{J} \left(\bar{G}_{growth\_foregone,j,t} \times \sum_{t=1}^{t*} A_{NHA\_annual,j,t} \right)$$

Parameter	Description	Unit
$C_{growth\_foregone,t}$	Annual carbon lost due to growth foregone in the aboveground biomass in the Project Area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\bar{G}_{growth\_foregone,t}$	Average growth per hectare per year in the aboveground biomass in the merchantable trees in the Project Area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	(t d.m.) ha^{-1} yr^{-1}
$\bar{G}_{growth\_foregone,j,t}$	Average growth per hectare per year in the aboveground biomass in the merchantable trees in the Project Area in stratum *j*, (where *j*=1,2,3 … *J* strata) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	(t d.m.) ha^{-1} yr^{-1}

Parameter	Description	Unit
CF_{AGB}	Carbon fraction in the aboveground biomass of trees for the tropical forest (see Appendix B)	tC (t d.m.)$^{-1}$
$A_{NHA\_annual,j,t}$	Annual net harvest area for the Project Area in stratum *j*, (where *j*=1,2,3 … *J* strata) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	ha

3.3.5 Carbon in the Regrowth after Selective Logging

It is good practice to account for regrowth in the gaps following logging. The IPCC (2006) suggested approach for estimating the regrowth is based on the mean annual growth in the AGB after logging, denoted here as $\bar{G}_{regrowth,t}$.

This Methodology applies a conservative approach for area of regrowth by considering that the entire annual net harvest area would permit regrowth each year. The annual net harvest area for the selective logging is calculated in Section 3.2.3.

Determine carbon in the regrowth after selective logging using the following procedure:

Step 1: Select the factor for the annual average growth in the aboveground biomass after selective logging, or a time-dependent growth model from the following sources:

(i) Local growth tables or growth models

(ii) National growth tables or growth models (e.g., from National GHG Inventory)

(iii) Published peer reviewed studies for growth models/tables from previous logged tropical forests with corresponding age, climate region and ecological zone.

Step 2: Determine the carbon due to regrowth by multiplying the annual net harvest area(s) and the average growth rate per hectare per year by the carbon fraction:

Equation 3-38

$$C_{regrowth,t} = \left(\bar{G}_{regrowth,t} \times CF_{AGB}\right) \times \sum_{t=1}^{t*} A_{NHA\_annual,t}$$

Parameter	Description	Unit
$C_{regrowth,t}$	Annual carbon increase in the biomass due to regrowth following logging in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\bar{G}_{regrowth,t}$	Average regrowth per hectare per year of the aboveground biomass after logging in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	(t d.m.) ha^{-1} yr^{-1}

Parameter	Description	Unit
CF_{AGB}	Carbon fraction in the aboveground biomass of trees for the tropical forest (see Appendix B)	tC (t d.m.)$^{-1}$
$A_{NHA\_annual,t}$	Annual net harvest area for the Project Area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)^^	ha

3.4 Baseline Activity Emissions

A number of emission sources are associated with the implementation of the baseline (selective logging) activity. Omission of any or all of the associated emission sources is conservative. The Project Proponent intending to calculate baseline activity emissions must select data required in the calculations on a conservative basis.

The stages of operation for timber harvesting include, but are not limited to, the process steps outlined in Figure 3-2 below:

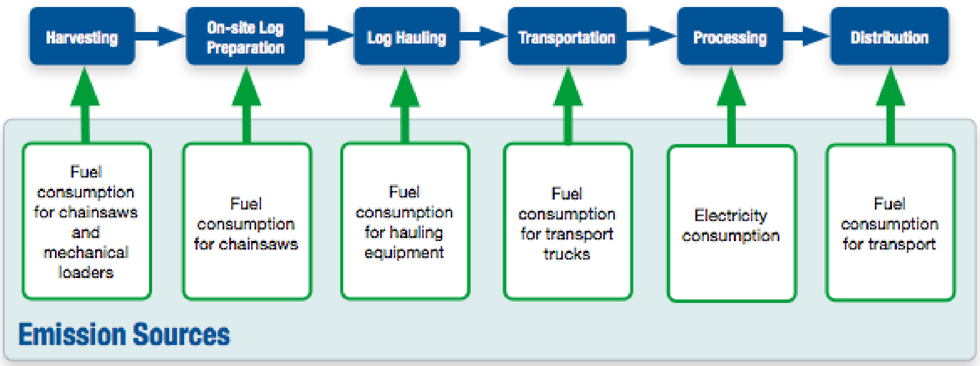

Figure 3-2. An outline of timber harvesting operations and the associated emission sources

The total emissions due to the baseline activity ($C'_{emissions,t}$) is determined from the summation of all the emission sources presented in Figure 3-2 using the following equation:

Equation 3-39

$$C'_{emissions,t} = E_{harvest,t} + E_{onsiteprep,t} + E_{hauling,t} + E_{transport,t} + E_{processing,t} + E_{distribution,t}$$

Parameter	Description	Unit
$C'_{emissions,t}$	Annual total carbon emissions associated with the baseline activity of selective logging operations in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$E_{harvest,t}$	Annual emissions due to harvesting operations such as felling and snigging in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

Parameter	Description	Unit
$E_{onsiteprep,t}$	Annual emissions due to on-site preparation such as trimming of tree heads, butts, branches and defective components in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$E_{hauling,t}$	Annual emissions due to log hauling in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$E_{transport,t}$	Annual emissions due to log transport from collection depot to processing plant in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$E_{processing,t}$	Annual emissions due to electricity consumption in sawmill in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$E_{distribution,t}$	Annual emissions due to transport of the sawn product from the mill to the wharf for export or to the depot for local usage in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

Ex ante baseline activity emissions $C'_{emissions,t}$ will be made using default emission factor data and activity data based on common practice in the area. The Project Proponent must ensure that the default values and activity data used are conservative.

3.4.1 Emissions Due to Harvesting Operations

Mechanical harvesting operations ($E_{harvest,t}$) of merchantable logs contributes to GHG emissions. This operation in countries containing tropical forests commonly employs chainsaws, while in other regions harvesters are commonly employed. Emissions from log harvesting are determined using the following procedure:

Step 1: For the common practice in the host country, select the typical equipment type, size and type of fuel consumed that is employed for harvesting. Information on harvesting practices can be found from reports on previous and existing harvesting practices in the host country.

Step 2: Find the fuel consumption (kL m^{-3}) of the selected equipment from the following data sources:

Reports on common practice for harvesting in the host country and/or manufacturers specifications

Published peer reviewed studies on harvesting operations (e.g. Klvac and Skoupy (2009) in Table B-6, Appendix B).

If a range for fuel consumption is provided, the Project Proponent is required to provide justification for their choice of fuel consumption in the PD. If no justification can be derived, it is conservative to select the lower end of the range.

Step 3: Select the emission factor associated with the fuel employed for harvesting from IPCC default emission factors for CO_2, CH_4 and N_2O emissions for Off-Road Mobile Sources and Machinery for the Forestry Sector (IPCC, 2006, Volume 2, Chapter 3, Section 3.3.1, Table 3.3.1, p. 3.36). Guidance for converting the emission factors to a CO_2 equivalent (CO_2-e) emission factor (EF_{fuel}) is provided in Appendix C.2. Guidance for unit conversions of fuel emission factors is provided in Appendix C.3.

Step 4: Emissions from harvesting of $V_{merch,t}$ are then determined by applying the following equation:

Equation 3-40

$$E_{harvest,t} = FC_{harvest} \times EF_{fuel} \times V_{merch,t}$$

Parameter	Description	Unit
$E_{harvest,t}$	Annual emissions due to harvesting operations such as felling and snigging in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$FC_{harvest}$	Fuel consumption of equipment employed for felling and snigging per m^3 of merchantable log harvested	$kL\ m^{-3}$
EF_{fuel}	Fuel emission factor	tCO_2-e kL^{-1}
$V_{merch,t}$	Annual volume of merchantable logs in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity) (see Section 3.2.3)	m^3

3.4.2 Emissions Due to On-site Preparation

Emissions due to on-site preparation ($E_{onsiteprep,t}$) such as trimming of tree heads, butts, branches and defective components are estimated using the following procedure:

Step 1: Select the typical equipment type, size and type of fuel consumed that is employed for trimming based on common practice for harvesting in the host country. For example, in tropical countries, chainsaws are commonly employed. Information on harvesting practices can be found from reports on previous and existing harvesting practices in the host country.

Step 2: Find the fuel consumption (kL m^{-3}) of the selected equipment from reports on common practice for harvesting in the host country and/or manufacturers specifications.

If a range for fuel consumption is provided, the Project Proponent is required to provide justification for their choice of fuel consumption factor in the PD. If no justification can be derived, it is conservative to select the lower end of the range.

Step 3: Select the emission factor associated with CO_2, CH_4 and N_2O emissions for the fuel employed from IPCC default emission factors for Off-Road Mobile Sources and Machinery for the Forestry Sector (IPCC, 2006, Volume 2, Chapter 3, Section 3.3.1, Table 3.3.1, p 3.36). Guidance for converting the emission factors to a CO_2 equivalent (CO_2-e) emission factor (EF_{fuel}) is provided in Appendix C.2. Guidance for unit conversions of fuel emission factors is provided in Appendix C.3.

Step 4: Choose the most applicable wood density for a forest with corresponding climate region and ecological zone, and choose the most applicable carbon fraction of wood from the data sources presented in Step 4 of Section 3.2.1.2.1,A. Then determine the volume of trimmings and branches using the following equation:

Equation 3-41

$$V_{branch\_trim,t} = \frac{C_{branch\_trim,t}}{CF_{wood} \times D}$$

Parameter	Description	Unit
$V_{branch\_trim,t}$	Annual volume of the trimmings and branches produced from harvesting in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	m^3
$C_{branch\_trim,t}$	Annual carbon in branches and trimmings left over from harvesting in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
CF_{wood}	Carbon fraction of wood for the tropical forest (see Appendix B)	tC (t d.m.)$^{-1}$
D	Wood density for the tropical forest with corresponding climate region and ecological zone (see Appendix B)	(t d.m.) m^{-3}

Step 5: Emissions from on-site preparation is then determined by applying the following equation:

Equation 3-42 $$E_{onsiteprep,t} = FC_{trim\_equip} \times EF_{fuel} \times V_{branch\_trim,t}$$

Parameter	Description	Unit
$E_{onsiteprep,t}$	Annual emissions due to on-site preparation such as trimming of tree heads, butts, branches and defective components in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
FC_{trim_equip}	Fuel consumption of equipment employed for trimming per m^3 of trimmed material	kL m^{-3}
EF_{fuel}	Fuel emission factor	tCO_2-e kL^{-1}
$V_{branch\_trim,t}$	Annual volume of the trimmings and branches produced from harvesting in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	m^3

3.4.3 Emissions Due to Log Hauling

Emissions associated with log hauling ($E_{hauling,t}$) to the collection depot are calculated using the following procedure:

Step 1: Select the typical equipment type, size and type of fuel consumed that is employed for hauling based on common practice for harvesting in the host country. Information on harvesting practices can be found from reports on previous and existing harvesting practices in the host country.

Step 2: Find the fuel consumption (kL m^{-3}) of the selected equipment from reports on common practice for harvesting in the host country and/or manufacturers specifications.

If a range for fuel consumption is provided, the Project Proponent is required to provide justification for the choice of fuel consumption factor in the PD. If no justification can be derived, it is conservative to select the lower end of the range.

Step 3: Select the emission factor associated with CO_2, CH_4 and N_2O emissions for the fuel employed from IPCC default emission factors for Off-Road Mobile Sources and Machinery for the Forestry Sector (IPCC, 2006, Volume 2, Chapter 3, Section 3.3.1, Table 3.3.1, p. 3.36). Guidance for converting the emission factors to a CO_2 equivalent (CO_2-e) emission factor (EF_{fuel}) is provided in Appendix C.2. Guidance for unit conversions of fuel emission factors is provided in Appendix C.3.

Step 4: Emissions from log hauling are then determined by applying the following equation:

Equation 3-43

$$E_{hauling,t} = FC_{hauling} \times EF_{fuel} \times V_{merch,t}$$

Parameter	Description	Unit
$E_{hauling,t}$	Annual emissions due to log hauling in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$FC_{hauling}$	Fuel consumption of equipment for hauling one m^3 of merchantable log	kL m^{-3}
EF_{fuel}	Fuel emission factor	tCO_2-e kL^{-1}
$V_{merch,t}$	Annual volume of merchantable logs in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity) (see Section 3.2.3)	m^3

3.4.4 Emissions Due to Log Transport

Emissions associated with log transport ($E_{transport,t}$) from the collection depot to the processing plant are calculated using the following procedure:

Step 1: Select the vehicle: type, load capacity (m^3 $truck^{-1}$) and type of fuel consumed for log transport based on common practice for transport in the host country. Information on harvesting practices can be found from reports on previous and existing harvesting practices in the host country.

Step 2: Determine the number of trucks required using the following equation:

Equation 3-44

$$N_{trucks\_transport,t} = \frac{V_{merch,t}}{Cap_{truck}}$$

Parameter	Description	Unit
$N_{trucks\_transport,t}$	Number of truck trips required for log transport from collection depot to processing plant in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	truck
$V_{merch,t}$	Annual volume of merchantable logs in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity) (see Section 3.2.3)	m^3
Cap_{truck}	Truck load capacity	m^3 $truck^{-1}$

Step 3: Find the fuel efficiency (km kL^{-1}) of the selected vehicle from the following data sources:

(i) Manufacturers specifications

(ii) Published peer reviewed studies on harvesting operations (e.g. Kinjo et al., 2005).

If a range for fuel efficiency is provided, the Project Proponent is required to provide justification for the choice of fuel efficiency factor in the PD. If no justification can be derived, it is conservative to select the upper end of the range.

Step 4: Select the emission factor associated with CO_2, CH_4 and N_2O emissions for the fuel employed from IPCC default emission factors for Road Transport (IPCC, 2006, Volume 2, Chapter 3, Section 3.2.1.2, Table 3.2.1-2, p. 3.16-3.21). Guidance for converting the emission factors to a CO_2 equivalent (CO_2-e) emission factor (EF_{fuel}) is provided in Appendix C.2. Guidance for unit conversions of fuel emission factors is provided in Appendix C.3.

Step 5: Estimate the transport distance from the collection depot to the processing plant ($KM_{transport,t}$) using the digital maps of the Project Area. If transport route(s) for the baseline scenario must be hypothesised, the Project Proponent is required to provide justification for their derivation of the transport route in the PD. In addition, to be conservative, the transport route proposed must be the minimum possible route.

The total log transport distance can be determined by the following:

Equation 3-45 $$KM_{transport\_total,t} = KM_{transport,t} \times N_{trucks\_transport,t} \times 2$$

Parameter	Description	Unit
$KM_{transport\_total,t}$	Annual total log transport distance in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	km
$KM_{transport,t}$	Annual log transport distance from collection depot to processing plant in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	km truck^{-1}
$N_{trucks\_transport,t}$	Number of truck trips required for log transport from collection depot to processing plant in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	truck
2	Constant, indicating return trip	dimensionless

Step 6: Emissions due to log transport are then determined by applying the following equation:

Equation 3-46 $$E_{transport,t} = \frac{KM_{transport\_total,t}}{Eff_{vehicle}} \times EF_{fuel}$$

Parameter	Description	Unit
$E_{transport,t}$	Annual emissions due to log transport haulage from felling location to the collection depot/ sawmill in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$KM_{transport\_total,t}$	Annual total log transport distance in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	km
$Eff_{vehicle}$	Fuel efficiency for vehicle type	km kL^{-1}
EF_{fuel}	Fuel emission factor	tCO_2-e kL^{-1}

3.4.5 Emissions Due to Timber Processing

Emissions as a result of processing ($E_{processing,t}$), where the processing plant is situated in the Project Area, depend on the electricity source available at the processing site. Electricity can be supplied via the national grid, or where this is not available, supplied via on-site generators. In addition, mill residue/waste may also be used as an energy source during timber processing.

To avoid double accounting, if a processing plant utilises mill residue/waste as an electricity source, then the emissions from electricity generated by mill residue/waste must not be considered here - as these emissions have already been accounted for in Section 3.3.2.1.

3.4.5.1 Emissions from processing where grid electricity is available

If grid electricity is available, then emissions due to processing will be calculated using the following procedure:

Step 1: Select an electricity demand factor (e_{demand}) for the timber processing facility from the following data sources:

(i) National electricity demand factors in relevant literature for timber processing. Various country specific electricity demand factors have been compiled in Table B-7 in Appendix B

(ii) If a national electricity demand factor is not available, select an electricity demand factor from a country that uses similar timber processing technology to that of the project's host country.

If a range for the electricity demand factor is provided, the Project Proponent is required to provide justification for the choice of electricity demand factor in the PD. If no justification can be derived, it is conservative to select the lower end of the range.

Step 2: Using the volume of merchantable logs, determine the electricity consumption required for the processing mill:

Equation 3-47 $$Q_{processing,t} = V_{merch,t} \times e_{demand}$$

Parameter	Description	Unit
$Q_{processing,t}$	Annual quantity of electricity consumption for processing in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	kWh
$V_{merch,t}$	Annual volume of merchantable logs in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity) (see Section 3.2.3)	m^3
e_{demand}	Electricity demand for processing per volume processed	kWh m^{-3}

Step 3: Select an emission factor for electricity for the host country from IEA (2009), CO_2 emissions per kWh from electricity and heat generation, pp. 101-103.

Step 4: Apply the following equation to determine the emissions due to processing:

Equation 3-48 $$E_{processing,t} = Q_{processing,t} \times EF_{electricity}$$

Parameter	Description	Unit
$E_{processing,t}$	Annual emissions due to electricity consumption in sawmill in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$Q_{processing,t}$	Annual quantity of electricity consumption for processing in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	kWh
$EF_{electricity}$	Electricity emission factor for the host country	tCO_2-e kWh^{-1}

3.4.5.2 Emissions from processing where a generator is required

If grid electricity is not available, and an on-site generator is required to power the processing facility, then calculation of processing emissions is determined from the emissions associated with fuel consumption of the generator. Apply Steps 1 and 2 of Section 3.4.5.1 to determine the electricity consumption involved for processing ($Q_{processing,t}$). Then use the following procedure:

Step 1: Select the typical load capacity (1/4, 1/2, full load), type of fuel consumed and operating time of the generator employed to power the processing facility. Such data can be obtained from the following data sources:

(i) National reports from the relevant national forestry authority

(ii) Published peer reviewed literature on timber processing for cases of equivalent volumes and processing modes and of a country that uses similar timber processing technology to that of the project's host country.

Step 2: Determine the power rating of the generator from the electricity required for processing and the operating hours required:

Equation 3-49

$$PR_{generator,t} = \frac{Q_{processing,t}}{t_{generator,t}}$$

Parameter	Description	Unit
$PR_{generator,t}$	Power rating of generator or generator size in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	kW
$Q_{processing,t}$	Annual quantity of electricity consumption for processing in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	kWh
$t_{generator,t}$	Annual operating time of generator in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	h

Step 3: Using a fuel consumption chart for the generator selected for the baseline case, apply the power rating (kW) and an appropriate load capacity (1/4, 1/2, full) to determine the fuel consumption

(kL h^{-1}) of the generator. Fuel consumption charts can be found from manufacturers of generators (see Table B-8, Appendix B for an example).

Step 4: Select an emissions factor for the fuel employed in the generator from IPCC (2006), Volume 2, Chapter 2 Stationary Combustion, Table 2.5, p. 2.22.

Step 5: Apply the following equation to determine emissions due to processing:

Equation 3-50
$$E_{processing,t} = FC_{generator} \times t_{generator,t} \times EF_{fuel}$$

Parameter	**Description**	**Unit**
$E_{processing,t}$	Annual emissions due to electricity consumption in sawmill in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$FC_{generator}$	Fuel consumption per hour of operation of generator	kL h^{-1}
$t_{generator,t}$	Annual operating time of generator in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	h
EF_{fuel}	Fuel emission factor	tCO_2-e kL $^{-1}$

3.4.6 Emissions Due to Log Distribution

Emissions due to distributing logs ($E_{distribution,t}$) are calculated using the following procedure:

Step 1: Select the vehicle type, load capacity (for e.g. m^3 $truck^{-1}$) and type of fuel consumed, for log distribution based on common practice in the host country.

Step 2: Calculate the annual total volume of ltHWP to be distributed per year from the input of carbon in ltHWP pool as determined from Equation 3-27 in Section 3.3.2.2, and the most applicable density and carbon fraction of wood for a forest with corresponding climate region and ecological zone (see Section B-1 and B-2 of Appendix B).

Equation 3-51
$$V_{ltHWP,t} = \frac{C_{ltHWP_{in},t}}{D \times CF_{wood}}$$

Parameter	**Description**	**Unit**
$V_{ltHWP,t}$	Annual volume of long-term harvested wood products in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	m^3
$C_{ltHWP_{in},t}$	Annual carbon input to the long-term harvested wood products pool from sawlog in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC

Parameter	Description	Unit
CF_{wood}	Carbon fraction of wood for the tropical forest (see Appendix B)	tC (t d.m.)$^{-1}$
D	Wood density for the tropical forest with corresponding climate region and ecological zone (see Appendix B)	(t d.m.) m^{-3}

Step 3: Determine the number of trucks required for distribution by dividing the long-term HWP volume by the load capacity of the vehicle:

Equation 3-52

$$N_{trucks\_distrib,t} = \frac{V_{ltHWP,t}}{Cap_{truck}}$$

Parameter	Description	Unit
$N_{trucks\_distrib,t}$	Annual number of truck trips required for log distribution from processing plant to distribution/export point in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	truck
$V_{ltHWP,t}$	Annual volume of long-term harvested wood products in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	m^3
Cap_{truck}	Truck load capacity	m^3 truck^{-1}

Step 4: Find the fuel efficiency (km kL^{-1}) of the selected vehicle from the following data sources:

(i) Manufacturers specifications

(ii) Published peer reviewed studies on harvesting operations (e.g. Kinjo et al., 2005).

If a range for fuel efficiency is provided, the Project Proponent is required to provide justification for the choice of fuel efficiency factor in the PD. If no justification can be derived, it is conservative to select the upper end of the range.

Step 5: Select the emission factor associated with CO_2, CH_4 and N_2O emissions for the fuel employed from IPCC default emission factors for Road Transport (IPCC, 2006, Volume 2, Chapter 3, Section 3.2.1.2, Table 3.2.1-2, p 3.16-3.21). Guidance for converting the emission factors to a CO_2 equivalent (CO_2-e) emission factor (EF_{fuel}) is provided in Appendix C.2. Guidance for unit conversions of fuel emission factors is provided in Appendix C.3.

Step 6: Estimate the distance for distribution from the processing plant to the distribution/export point ($KM_{distrib,t}$) using digital maps. If distribution route(s) for the baseline scenario must be hypothesised, the Project Proponent is required to provide justification for the derivation of a distribution route in the PD. In addition, to be conservative, the distribution route proposed must be the minimum possible route.

The total distance for distribution can be determined by the following:

Equation 3-53 $$KM_{distribtotal,t} = KM_{distrib,t} \times N_{trucks\_distrib,t} \times 2$$

Parameter	Description	Unit
$KM_{distribtotal,t}$	Annual total distribution distance in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	km
$KM_{distrib,t}$	Annual distance of transport from point of processing to distribution/export point in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	km $truck^{-1}$
$N_{trucks\_distrib,t}$	Annual number of truck trips required for log distribution from processing plant to distribution/export point in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	truck
2	Constant, indicating return trip	dimensionless

Step 7: Apply the following equation to determine the emissions due to log distribution:

Equation 3-54 $$E_{distribution,t} = \frac{KM_{distribtotal,t}}{Eff_{vehicle}} \times EF_{fuel}$$

Parameter	Description	Unit
$E_{distribution,t}$	Annual emissions due to transport of the sawn product from the mill to the wharf for export or to the depot for local usage in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$KM_{distribtotal,t}$	Annual total distribution distance in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	km
$Eff_{vehicle}$	Fuel efficiency for vehicle type	km kL^{-1}
EF_{fuel}	Fuel emission factor	tCO_2-e kL^{-1}

4 Actual Project Activity Emissions

The project activity is the introduction of forest protection without selective logging (i.e. no emissions from harvesting) - Improved Forest Management (Logged Forest to Protected Forest). However, implementing the IFM-LtPF project activity will incur quantifiable emissions. In addition, the forest in the Project Area is likely to be disturbed by natural causes such as fires, landslides, volcanoes etc. and may also be harvested illegally. The Project Proponent must take all possible measures to prevent carbon emissions from such causes and must keep detail and accurate records of emissions associated with the project activities including the monitoring of the Project Area for natural disturbances. Such records and data must be submitted along with the monitoring report to the Verifier.

Emissions associated with the actual project implementation is given by Equation 4-1, and include, but are not limited to:

- administration and planning (electricity and fuel consumption) ($E_{projplan,t}$)
- travel for design and set up (e.g. consultation and education) (fuel consumption) ($E_{design,t}$)
- travel for implementing monitoring plan (e.g. from on-the-ground forest surveillance) ($E_{monitoring,t}$)
- natural disturbances such as forest fires ($C_{natdisturb,t}$)
- illegal harvesting ($C_{illegal\_harvest,t}$) .

Equation 4-1 $$C'_{actual,t} = E_{projplan,t} + E_{design,t} + E_{monitoring,t} + \left[\left(C_{natdisturb,t} + C_{illegal\_harvest,t} \right) \times \frac{44}{12} \right]$$

Parameter	Description	Unit
$C'_{actual,t}$	Annual total carbon emissions associated with the project activity in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$E_{projplan,t}$	Annual emissions due to administration and project planning in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$E_{design,t}$	Annual emissions from travel for design and set up in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$E_{monitoring,t}$	Annual emissions due to monitoring for field work in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$C_{natdisturb,t}$	Annual carbon losses due to natural disturbance(s) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC

Parameter	Description	Unit
$C_{illegal\_harvest,t}$	Annual carbon losses due to illegal harvesting in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
44/12	The ratio of molecular weight of carbon dioxide to carbon, *see* Appendix C	tCO_{2}-e tC^{-1}

The Project Proponent must use the guidelines established by The Greenhouse Gas Protocol (WBCSD and WRI, 2005) to determine the boundary for accounting of the activities of the above emission sources.

Omission of any of the above emissions sources must follow the significance guidelines outlined in Section 1.2.3.

Ex ante actual project activity emissions $C'_{actual,t}$ will be made using default emission factor data and projected activity data for planning, design and monitoring based on the project implementation requirements. The Project Proponent must ensure that the default values and activity data used are conservative.

4.1 Emissions Due to Project Planning

Project planning involves administrative activities and travel. Emissions associated with project planning are calculated as follows:

Equation 4-2

$$E_{projplan,t} = E_{admin,t} + E_{plan\_travel,t}$$

Parameter	Description	Unit
$E_{projplan,t}$	Annual emissions due to administration and project planning in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$E_{admin,t}$	Annual emissions due to electricity consumption required for administration of the project activity in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$E_{plan\_travel,t}$	Annual emissions due to travel for project planning in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

4.1.1 Emissions Due to Administration

Where administration and planning operations are conducted in the project's host country, emissions from these operations will be accounted for. Emissions from such activities including data processing are estimated using the following procedure:

Step 1: Determine annual electricity consumption from the following:

(i) Electricity bills summated to determine the annual electricity consumption

(ii) Derived from logged hours of operation for electrical equipment employed for administration and planning multiplied by the power rating of the equipment, as per the following equation:

Equation 4-3

$$Q_{admin,t} = \sum_{ee=1}^{EE} PR_{equip,ee,t} \times t_{op\_equip,ee,t}$$

Parameter	Description	Unit
$Q_{admin,t}$	Annual electricity consumption due to administration of the project activity in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	kWh
$PR_{equip,ee,t}$	Power rating for electrical equipment, *ee* (where e*e*=1,2,3 … *EE* pieces of equipment), in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	kW
$t_{op\_equip,ee,t}$	Annual hours of operation per year of electrical equipment, e*e* (where *ee*=1,2,3 … *EE* pieces of equipment) in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	h

If administration activities occur outside the host country, they are not considered in the project accounting.

Step 2: Select an emission factor for electricity for the project's host country from data sources such as IEA (2009), CO_2 emissions per kWh from electricity and heat generation, pp. 101-103.

Step 3: Determine the emissions due to electricity consumption required for administration and planning by the following equation:

Equation 4-4

$$E_{admin,t} = Q_{admin,t} \times EF_{electricity}$$

Parameter	Description	Unit
$E_{admin,t}$	Annual emissions due to electricity consumption required for administration of the project activity in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$Q_{admin,t}$	Annual electricity consumption due to administration of the project activity in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	kWh

Parameter	Description	Unit
$EF_{electricity}$	Electricity emission factor for the host country	tCO_2-e kWh^{-1}

4.1.2 Emissions Due to Travel

Emissions as a result of travel depend on the mode of transport. For project planning this will typically and principally be either aircraft or ground transportation in the equation below.

Equation 4-5

$$E_{plan\_travel,t} = E_{plan\_flight,t} + E_{plan\_ground,t}$$

Parameter	Description	Unit
$E_{plan\_travel,t}$	Annual emissions due to travel for project planning in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$E_{plan\_flight,t}$	Annual emissions due to flights in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$E_{plan\_ground,t}$	Annual emissions due to ground transportation in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

Note: If transportation occurs outside the host country, it will not be considered in the project accounting.

4.1.2.1 Emissions due to flights

A flight log must be maintained throughout the project lifetime to provide the information required for the emission calculations. A flight log must have the following information:

(i) Departure and destination location, or airport codes for arrival and departure

(ii) Number of passengers per trip

(iii) Type of aircraft

(iv) Date of travel.

Emissions due to flights are calculated using the following procedure:

Step 1: From the travel log, determine in year *t*, for each trip *y*, the distance required for each trip and the number of passengers.

Step 2: Using distance and/or aircraft information, select an appropriate flight emission factor from the following data sources:

(i) Published peer-reviewed studies for air transportation (e.g. Miyoshi and Mason, 2009; Babikian et al., 2002)

(ii) Relevant studies from international industry experts (e.g. Ross, 2009; DEFRA, 2008).

Step 3: Calculate the total emissions due to flights for project planning using the emission factor (with units of tCO_2-e per passenger.km) by the following equation:

Equation 4-6

$$E_{plan\_flight,t} = \sum_{y=1}^{Y} \left(KM_{plan\_flight,y,t} \times N_{plan\_flight,y,t} \times EF_{flight,y} \right)$$

Parameter	Description	Unit
$E_{plan\_flight,t}$	Annual emissions due to flights in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$N_{plan\_flight,y,t}$	Annual number of passengers per trip *y,* (where *y=1*,2,3 … *Y* trips) in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	passenger
$EF_{flight,y}$	Flight emission factor for trip, *y* (where *y*=1,2,3 … *Y* trips)	tCO_2-e (passenger.km)$^{-1}$
$KM_{plan\_flight,y,t}$	Annual distance travelled per trip *y,* (where *y*=1,2,3 … *Y* trips), in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	km

4.1.2.2 Emissions due to ground transport

A ground transport log must be maintained throughout the project lifetime to provide the information required for the emission calculations. A ground travel log must have the following information for each trip taken:

(i) Departure and arrival points, or volume of fuel consumed

(ii) Type of vehicle employed

(iii) Type of fuel consumed

(iv) Date of travel.

Emissions due to ground transport are calculated using the following procedure:

Step 1: If volume of fuel consumed per trip has been recorded in the travel log, go to Step 4. If the departure and arrival destinations have been provided, determine the distance travelled for each trip, *y* ($KM_{plan\_ground,y,t}$).

Step 2: For the vehicle employed and fuel consumed, select the fuel efficiency of the vehicle from the following data sources:

(i) Manufacturers' specifications for vehicle employed

(ii) National database for vehicle specifications (e.g. Greenvehicle Guide, Australia, 2010)

Step 3: Calculate the volume of fuel consumed per trip by the following equation:

Equation 4-7

$$V_{fuel\_plan\_ground,y,t} = \frac{KM_{plan\_ground,y,t}}{Eff_{vehicle}}$$

Parameter	Description	Unit
$V_{fuel\_plan\_ground,y,t}$	Annual volume of fuel consumed per trip *y*, (where *y*=1,2,3 … *Y* trips), in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	kL
$Eff_{vehicle}$	Fuel efficiency for vehicle type	km kL^{-1}
$KM_{plan\_ground,y,t}$	Annual distance travelled per trip *y*, (where *y*=1,2,3 … *Y* trips) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	km

Step 4: From the type of fuel consumed, select the fuel emission factor(s) from the following sources:

(i) National country-specific fuel emission factors

(ii) Global fuel emission factors (e.g. IPCC (2006), Volume 2, Chapter 3, Table 3.2.1, p. 3.16 for CO_2 and Table 3.2.2, p. 3.21 for CH_4 and N_2O). Guidance for converting the emission factors to a CO_2 equivalent (CO_2-e) emission factor (EF_{fuel}) is provided in Appendix C.2. Guidance for unit conversions of fuel emission factors is provided in Appendix C.3.

Step 5: Calculate the total emissions due to ground transport for project planning by the following equations:

Equation 4-8

$$E_{plan\_ground,t} = \sum_{y=1}^{Y} \left(V_{fuel\_plan\_ground,y,t} \times EF_{fuel} \right)$$

Parameter	Description	Unit
$E_{plan\_ground,t}$	Annual emissions due to ground transportation in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$V_{fuel\_plan\_ground,y,t}$	Annual volume of fuel consumed per trip *y*, (where *y*=1,2,3 … *Y* trips), in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	kL
EF_{fuel}	Fuel emission factor	tCO_2-e kL^{-1}

4.2 Emissions Due to Design

Project design involves travel to the host country for stakeholder consultation(s), thus emissions associated with project design are calculated from both ground and air travel emissions:

Equation 4-9

$$E_{design,t} = E_{design\_ground,t} + E_{design\_flight,t}$$

Parameter	Description	Unit
$E_{design,t}$	Annual emissions from travel for design and set up in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$E_{design\_ground,t}$	Annual emissions due to ground travel for the design stage in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$E_{design\_flight,t}$	Annual emissions due to air travel for the design stage in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

4.2.1 Emissions Due to Flights

Determine the distance, number of passengers and emission factor per trip for project design using Steps 1 to 3 in Section 4.1.2.1. Emissions from flights for project design and aerial surveillance for monitoring the Project Area can be determined as below:

Equation 4-10

$$E_{design\_flight,t} = \sum_{y=1}^{Y}\left(KM_{design\_flight,y,t} \times N_{design\_flight,y,t} \times EF_{flight,y}\right)$$

Parameter	Description	Unit
$E_{design\_flight,t}$	Annual emissions due to air travel for the design stage in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$N_{design\_flight,y,t}$	Annual number of passengers per trip *y*, (where *y=1*,2,3 … *Y* trips) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	passenger
$EF_{flight,y}$	Flight emission factor for trip, *y* (where *y*=1,2,3 … *Y* trips)	tCO_2-e (passenger.km)$^{-1}$
$KM_{design\_flight,y,t}$	Annual distance travelled per trip *y*, (where *y*=1,2,3 … *Y* trips) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	km

4.2.2 Emissions Due to Ground Transport

Determine the distance, vehicle fuel efficiency and fuel emission factor per trip for project design using Steps 1 to 3 in Section 4.1.2.2. Emissions from ground transport for project design and ground patrolling for monitoring the Project Area can be determine as below:

Equation 4-11 $$E_{design\_ground,t} = \sum_{y=1}^{Y}\left(\frac{KM_{design\_ground,y,t}}{Eff_{vehicle}} \times EF_{fuel}\right)$$

Parameter	Description	Unit
$E_{design\_ground,t}$	Annual emissions due to ground travel for the design stage in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$Eff_{vehicle}$	Fuel efficiency for vehicle type	km kL^{-1}
EF_{fuel}	Fuel emission factor	tCO_2-e kL^{-1}
$KM_{design\_ground,y,t}$	Annual distance travelled per trip *y*, (where *y*=1,2,3 … *Y* trips) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	km

4.3 Emissions Due to Monitoring

Project monitoring requires travel to the Project Area for field work, thus emissions associated with project monitoring including the aerial surveillance and ground patrolling are deduced from travel emissions:

Equation 4-12 $$E_{monitoring,t} = KM_{monitoring\_ground,t} + KM_{monitoring\_flight,t}$$

Parameter	Description	Unit
$E_{monitoring,t}$	Annual emissions due to monitoring for field work in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$KM_{monitoring\_ground,t}$	Annual emissions due to ground travel for monitoring team in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$KM_{monitoring\_flight,t}$	Annual emissions due to air travel for monitoring team in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

4.3.1 Emissions Due to Flights

Determine the distance, number of passengers and emission factor per trip for monitoring using Steps 1 to 3 in Section 4.1.2.1. Emissions from flights including aerial surveillance for monitoring can be determined as below:

Equation 4-13 $$E_{monitoring\_flight,t} = \sum_{y=1}^{Y}\left(KM_{monitoring\_flight,y,t} \times N_{monitoring\_flight,y,t} \times EF_{flight,y}\right)$$

Parameter	Description	Unit
$E_{monitoring\_flight,t}$	Annual emissions due to air travel for monitoring team in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$N_{monitoring\_flight,y,t}$	Annual number of passengers per trip *y*, (where *y*=*1*,2,3 … *Y* trips) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	passenger
$EF_{flight,y}$	Flight emission factor for trip, *y* (where *y*=1,2,3 … *Y* trips)	tCO_2-e $(passenger.km)^{-1}$
$KM_{monitoring\_flight,y,t}$	Annual distance travelled per trip *y*, (where *y*=1,2,3 … *Y* trips) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	km

4.3.2 Emissions Due to Ground Transport

Determine the distance, vehicle fuel efficiency and fuel emission factor per trip for monitoring using Steps 1 to 3 in Section 4.1.2.2. Emissions from ground transport including ground patrolling for monitoring can be determined as below:

Equation 4-14

$$E_{monitoring\_ground,t} = \sum_{y=1}^{Y}\left(\frac{KM_{monitoring\_ground,y,t}}{Eff_{vehicle}} \times EF_{fuel}\right)$$

Parameter	Description	Unit
$E_{monitoring\_ground,t}$	Annual emissions due to ground travel for monitoring team in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$KM_{monitoring\_ground,y,t}$	Annual distance travelled per trip *y*, (where *y*=1,2,3 … *Y* trips) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	km
EF_{fuel}	Fuel emission factor	tCO_2-e kL^{-1}
$Eff_{vehicle}$	Fuel efficiency for vehicle type	km kL^{-1}

4.4 Emissions Due to Natural Disturbances

Natural disturbances caused by fire (including human induced), windstorms, landslides or volcanoes can have impacts on both the extent of the forest area and the carbon. As a consequence, emissions from such disturbance must be measured and factored out of the estimation of the ex post net anthropogenic GHG emission reductions. Events due to natural disturbances will be identified using the following procedures:

- Regular familiarisation with meteorological reports of the Project Area - the frequency of monitoring is dependent on the susceptibility of the region to natural disturbances
- Analysis of best available satellite imagery to monitor the Project Area, specifically to identify and estimate the areas that have been disturbed within the Project Area
- Aerial surveillance and/or ground patrolling followed by field checking to verify the extent (area) of the damage and quantification of the GHG emissions.

Once an event has been identified, emissions attributed to that naturally disturbed area must be monitored annually over the project crediting period and must be estimated using the following procedure:

Step 1: Identify the naturally disturbed areas, $A_{nd,t}$, using satellite data and locate them at the strata level. The satellite data analysis must follow a standard procedure for remote sensing, and must be verified by a field team (e.g. Fagan and DeFries, 2009).

Step 2: Calculate the area of natural disturbance in each stratum, $A_{nd,j,t}$, using satellite data and employ a field team to conduct on-ground verification of the damaged areas by measuring the area and extent of damage.

Step 3: Obtain the growing stock per hectare for the respective stratum, *j*, where the natural disturbance has occurred and also select appropriate BCEF at the stratum level (see Step 1 of Section 3.2.1.2.2) and carbon fraction (see Step 4 of Section 3.2.1.2.1,A) and then apply the following equation to obtain the annual carbon in the naturally disturbed area(s):

Equation 4-15

$$C_{AGB\_nd,j,t} = \left[\overline{V}_{gstock,j,t=0} \times BCEF_j \times \left(\sum_{nd=1}^{ND} A_{nd,j,t} \right) \right] \times CF_{AGB}$$

Parameter	Description	Unit
$C_{AGB\_nd,j,t}$	Annual carbon in the aboveground biomass of the growing stock in the naturally disturbed area in stratum *j*, (where *j*=1,2,3 … *J* strata) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\overline{V}_{gstock,j,t=0}$	Average growing stock per hectare for stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	m^3 ha^{-1}
$A_{nd,j,t}$	Annual area of natural disturbance *nd*, (where *nd*=1,2,3 … *ND* naturally disturbed areas) in stratum *j*, (where *j*=1,2,3 … *J* strata) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	ha

Parameter	Description	Unit
$BCEF_j$	Biomass conversion and expansion factor for converting growing stock to carbon in the aboveground biomass for stratum *j*, (where *j*=1,2,3 … *J* strata)	(t d.m.) m^{-3}
CF_{AGB}	Carbon fraction in the aboveground biomass of trees for the forest (see Appendix B)	tC (t d.m.)$^{-1}$

Step 4: Using direct observations of the area(s) damaged, the field team must provide an estimate of the fraction of the growing stock naturally disturbed based on a comparison with an adjacent representative undisturbed forest ($f_{natdisturb,j,t}$) within the stratum, then apply the following equation:

Equation 4-16

$$C_{AGB\_nd,t} = \sum_{j=1}^{J}\left(C_{AGB\_nd,j,t} \times f_{natdisturb,j,t}\right)$$

Parameter	Description	Unit
$C_{AGB\_nd,t}$	Annual carbon losses in the aboveground biomass of the growing stock due to natural disturbance(s) in the Project Area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{AGB\_nd,j,t}$	Annual carbon in the aboveground biomass of the growing stock in the naturally disturbed area in stratum *j*, (where *j*=1,2,3 … *J* strata) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$f_{natdisturb,j,t}$	Fraction of the growing stock naturally damaged in stratum *j* (where *j* = 1,2,3 … *J* strata) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	dimensionless

Step 5: After a natural disturbance, regrowth is likely to occur in the naturally disturbed area and hence, acts as a carbon sink. Note that the rate of regrowth in the naturally disturbed area is not the same as the rate of regrowth in the gaps created after selective harvesting under the baseline scenario. The annual carbon increase due to the regrowth in the naturally disturbed area will be calculated via Equation 4-17a.

This Methodology has accounted for the carbon in the AGB of trees (see Table 2-3 in Section 2.2.3) which conservatively estimates the carbon due to regrowth. The annual average regrowth in the AGB in the naturally disturbed area is derived by direct measurement of all trees, i.e. trees with a minimum diameter at breast height as specified by the relevant authority in the host country (see footnote ## under Table 2-3 in Section 2.2.3 of this Methodology), in the sample plots, s_{nd}, established in the naturally disturbed stratum during the monitoring event. The procedure for establishing the sample plots and the measurement techniques are described in Section 7.1.2. Number of sample plots within a stratum for regrowth measurement is determined in accordance with Pearson et al (2005) (see pp. 15-17).

The annual average regrowth post natural disturbance ($\bar{G}_{regrowth\_nd,j,t}$) is calculated based on the AGB in the naturally disturbed area estimated using Step 3 of Section 3.2.1.3.2, as follow:

(i) when the regrowth is measured for the first time in a monitoring event, the AGB at the stratum level obtained from the measurement is divided by the number of years of regrowth post natural disturbance

(ii) in subsequent monitoring events, the difference in the AGB at the stratum level between the two consecutive monitoring events are divided by the monitoring period as presented in Equation 4-17b.

Equation 4-17a

$$C_{regrowth\_nd,t} = CF_{AGB} \times \sum_{j=1}^{J} \left[\sum_{nd=1}^{ND} \left(A_{nd,j,t} \right) \times \bar{G}_{regrowth\_nd,j,t} \right]$$

Equation 4-17b

$$\bar{G}_{regrowth\_nd,j,t} = \frac{\bar{B}_{AGB\_nd,j,m_2} - \bar{B}_{AGB\_nd,j,m_1}}{\Delta m}$$

Parameter	Description	Unit
$C_{regrowth\_nd,t}$	Annual carbon increase due to the regrowth in the naturally disturbed area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\bar{G}_{regrowth\_nd,j,t}$	Average regrowth per hectare per year in the aboveground biomass after natural disturbance in stratum *j*, (where *j*=1,2,3 … *J* strata) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	(t d.m.) ha^{-1} yr^{-1}
CF_{AGB}	Carbon fraction in the aboveground biomass of trees for the forest (see Appendix B)	tC (t d.m.)$^{-1}$
$A_{nd,j,t}$	Annual area of natural disturbance *nd*, (where *nd*=1,2,3 … *ND* naturally disturbed areas) in stratum *j*, (where *j*=1,2,3 … *J* strata) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)^^	ha
$\bar{B}_{AGB\_nd,j,m_2}$	Average aboveground biomass of the trees in the area of natural disturbance *nd*, (where *nd*=1,2,3 … *ND* naturally disturbed areas) in stratum *j*, (where *j*=1,2,3 … *J* strata) in year, m_2 - when current monitoring event occurs	(t d.m.) ha^{-1}

Parameter	Description	Unit
$\bar{B}_{AGB\_nd,j,m_1}$	Average aboveground biomass of the trees in the area of natural disturbance *nd*, (where *nd*=1,2,3 … *ND* naturally disturbed areas) in stratum *j*, (where *j*=1,2,3 … *J* strata) in year, m_1- when preceding monitoring event occurred	(t d.m.) ha^{-1}
Δm	Monitoring period, the time taken between two consecutive monitoring events	yr

Step 6: In the case of a natural disturbance such as fire, CH_4, N_2O and CO_2 gases are generated. The emissions of the non-CO_2 gases can be estimated based on the total carbon emitted, as suggested by the IPCC GPG for LULUCF (IPCC, 2003, Chapter 3, Equation 3.2.19, p. 3.49). Emission ratios for CH_4 and N_2O can be obtained from IPCC (2003) in Table 3A.1.15 and an appropriate ratio for nitrogen-to-carbon ($R_{N/C}$) for the material burnt must be used. If the specific $R_{N/C}$ cannot be found, a default value of 0.01 that applies to leaf litter can be used instead, noting that lower values would be appropriate for woody material (IPCC, 2003, Chapter 3, p. 3.50). The emissions of both CH_4 and N_2O are then estimated by applying the following equations:

Equation 4-18a $$E_{CH_4,t} = C_{AGB\_nd,t} \times R_{CH_4} \times \frac{16}{12}$$

Equation 4-18b $$E_{N_2O,t} = C_{AGB\_nd,t} \times R_{N/C} \times R_{N_2O} \times \frac{44}{28}$$

Parameter	Description	Unit
$E_{CH_4,t}$	Annual emissions due to CH_4 in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCH_4
$C_{AGB\_nd,t}$	Annual carbon losses in the aboveground biomass of the growing stock due to natural disturbance(s) in the Project Area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
R_{CH_4}	Emission ratio for CH_4	dimensionless
$E_{N_2O,t}$	Annual emissions due to N_2O in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tN_2O
$R_{N/C}$	Ratio of nitrogen to carbon	tN tC^{-1}
R_{N_2O}	Emission ratio for N_2O	dimensionless

Parameter	Description	Unit
$16/12$	The ratio of molecular weight of CH_4 to carbon	tCH_4 tC^{-1}
$44/28$	The ratio of molecular weight of N_2O to N	tN_2O tN^{-1}

Step 7: Select the most current Global Warming Potentials (GWPs) for CH_4 and N_2O from UNFCCC documents and apply the GWPs in the following equation to aggregate the carbon emissions from the non-CO_2 gases. See also Section 2.2.4.1 Table 2.4 for more information. Then apply the following equation:

Equation 4-19

$$C_{CH_4N_2O,t} = \left(E_{CH_4,t} \times GWP_{CH_4} + E_{N_2O,t} \times GWP_{N_2O} \right) \times \frac{12}{44}$$

Parameter	Description	Unit
$C_{CH_4N_2O,t}$	Annual carbon from CH_4 and N_2O emissions in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$E_{CH_4,t}$	Annual emissions due to CH_4 in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCH_4
GWP_{CH_4}	Global warming potential of CH_4	tCO_2-e tCH_4^{-1}
$E_{N_2O,t}$	Annual emissions due to N_2O in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tN_2O
GWP_{N_2O}	Global warming potential of N_2O	tCO_2-e tN_2O^{-1}
$12/44$	The ratio of molecular weight of carbon to carbon carbon dioxide, see Appendix C	tC tCO_2-e^{-1}

Step 8: Calculate the total carbon emissions due to natural disturbances by using the outputs from Equations 4-16, 4-17a and 4-19. If natural disturbance is caused by an event other than fire, non-CO2 gases (CH_4 and N_2O) would not be produced. Hence the terms from Equations 4-17a and 4-19 would be zero. The regrowth in the naturally disturbed area is subtracted because it is considered as a carbon sink in this equation.

Equation 4-20

$$C_{natdisturb,t} = \sum_{t=1}^{t*} \left(C_{AGB\_nd,t} - C_{regrowth\_nd,t} + C_{CH_4N_2O,t} \right)$$

Parameter	Description	Unit
$C_{natdisturb,t}$	Annual total carbon losses due to natural disturbance(s) in the Project Area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{AGB\_nd,t}$	Annual carbon losses in the aboveground biomass of the growing stock due to natural disturbance(s) in the Project Area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{regrowth\_nd,t}$	Annual carbon increase due to the regrowth in the naturally disturbed area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$C_{CH_4N_2O,t}$	Annual carbon from CH_4 and N_2O emissions in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC

Ex ante estimations for natural disturbances will be made based on the likely scenario in the Project Area. The Project Proponent must justify the likely scenario of natural disturbances using the historical data from satellite imagery or regional/local documentation from the relevant authority.

4.5 Emissions Due to Illegal Harvesting

Under the IFM-LtPF project scenario, the Project Area is completely protected and the Project Proponent must stop selective harvesting operation as well as harvesting by other agents of deforestation. All harvesting operations in the Project Area during the Project Crediting Period are considered as illegal harvesting. Ex ante estimations for illegal harvesting will be made based on the likely scenario in the Project Area. The Project Proponent must justify the likely scenario of illegal harvesting using the historical data from satellite imagery or regional/local documentation from the relevant authority. Ex post calculation for emissions due to illegal harvesting is described below for two different scenarios depending upon the method of data collected: the field inventory method or using satellite data must be used.

4.5.1 Field Inventory Method

Where field teams are able to collect data on the quantity of wood illegally harvested from the Project Area through observation or interviews based on Participatory Rural Appraisal techniques (e.g. see Surhone et al., 2010) carbon losses are quantified using the following procedure:

Step 1: Quantify the total volume of wood illegally harvested in the Project Area through field surveys ($V_{illegal\_harvest,t}$) by measuring the stump diameter and developing species specific model to predict tree volumes based on the relevant peer reviewed literature (e.g. Corral-Rival et al., 2007)

Step 2: Choose the most applicable biomass expansion factor (BEF) value from the following data sources:

(i) National factor (e.g. from National GHG Inventory)

(ii) Default IPCC factor (see IPCC, 2003, Table 3A.1.10; and IPCC, 2006, Table 4.5)

It is noteworthy that the BEF values in IPCC literature and national GHG inventory are usually applicable to closed canopy forest. If applied to individual trees growing in an open field, the selected BEF value be increased by a further 30 percent (CDM-EB, 2009, p. 24).

Step 3: Choose the most applicable wood density for a forest with corresponding climate region and ecological zone (see Appendix B, Section B.1, Table B-1).

Step 4: Find the appropriate factor for residual stand damage (f_{RSD}), and carbon fraction (Step 4 of Section 3.2.1.2.1,A) and apply the following equation (which has been based on IPCC (2003), Equation 3.2.7, p. 3.27) to obtain the total carbon due to illegal harvesting in the Project Area:

Equation 4-21

$$C_{illegal\_harvest,t} = V_{illegal\_harvest,t} \times \left(1 + f_{RSD}\right) \times BEF \times D \times CF_{AGB}$$

Parameter	Description	Unit
$C_{illegal\_harvest,t}$	Annual carbon losses due to illegal harvesting in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$V_{illegal\_harvest,t}$	Annual volume of wood sold as determined from field surveys in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	m^3
BEF	Biomass expansion factor for converting volume of extracted roundwood to total aboveground biomass (including bark)	(t d.m.) m^{-3}
D	Wood density for the tropical forest with corresponding climate region and ecological zone (see Appendix B)	(t d.m.) m^{-3}
CF_{AGB}	Carbon fraction in the aboveground biomass of trees for the tropical forest (see Appendix B)	tC (t d.m.)$^{-1}$
f_{RSD}	Factor for residual stand damage, based on the fraction of quantity of carbon damaged in the residual stand to the quantity of carbon in the total merchantable logs harvested	dimensionless

4.5.2 Using Satellite Data

Where high resolution satellite data are used, carbon losses are quantified by:

Step 1: Identify and calculate the illegally harvested areas ($A_{illegal\_harvest,t}$) using satellite data and locate them at the strata level. The satellite data analysis must follow a standard procedure (e.g. Skole et al., 1998), and must be verified by a field team or teams.

Step 2: Verify the areas by sending a field team or teams.

Step 3: Obtain the growing stock per hectare for the respective stratum, *j*, where the illegal harvesting has occurred and also select appropriate BCEF (Step 1 of Section 3.2.1.2.2) and carbon fraction (Step 4 of Section 3.2.1.2.1,A) and then apply the following equation to obtain the total carbon per year due to illegal harvesting:

Equation 4-22

$$C_{illegal\_harvest,t} = \sum_{j=1}^{J}\left[\overline{V}_{gstock,j,t=0} \times BCEF_j \times \left(\sum_{il=1}^{IL} A_{illegal\_harvest,j,t}\right)\right] \times CF_{AGB}$$

Parameter	Description	Unit
$C_{illegal\_harvest,t}$	Annual carbon losses due to illegal harvesting in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\overline{V}_{gstock,j,t=0}$	Average growing stock per hectare for stratum *j*, (where *j*=1,2,3 … *J* strata) determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	$m^3\ ha^{-1}$
$A_{illegal\_harvest,j,t}$	Annual area of illegal harvest *il* (where *il*=1,2,3 … *IL* illegal harvested areas) in stratum *j*, (where *j*=1,2,3 … *J* strata) in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	ha
$BCEF_j$	Biomass conversion and expansion factor for converting growing stock to the aboveground biomass for stratum *j*, (where *j*=1,2,3 … *J* strata)	(t d.m.) m^{-3}
CF_{AGB}	Carbon fraction in the aboveground biomass of trees for the tropical forest (see Appendix B)	tC (t d.m.)$^{-1}$

5 Leakage Assessment and Management

5.1 Identifying Leakage

The objective of leakage assessment and management is to provide an ex post estimate of the actual decrease in carbon and increase in GHG emissions (other than carbon changes) that arise as a result of the implementation of the project activity. Where an increase in GHG emissions occurs outside a project's boundary but is measurable and attributable to the project activity, this is known as project leakage and the associated emissions in tonnes of CO_2-e per year are termed $C'_{leakage,t}$.

For an IFM-LtPF project activity, there are two sources of leakage that need to be considered and addressed in this Methodology:

(i) Carbon from degradation due to shifting of the baseline activity, $CL_{activityshifting,t}$ i.e. removal of harvested wood products including sawlog, pulplog and commercially harvested fuel wood and emissions from the associated activities outside the Project Area, $CL'_{emissions,t}$

(ii) Carbon from market leakage $CL_{market,t}$, due to shifts in supply and demand of the products and services affected by the project activity, which in this case is the supply and demand of timber.

On this basis, project leakage is the combined total of the above leakage parameters:

Equation 5-1

$$C'_{leakage,t} = (CL_{activityshifting,t} + CL_{market,t}) \times \frac{44}{12} + CL'_{emissions,t}$$

Parameter	Description	Unit
$C'_{leakage,t}$	Annual total carbon emissions associated with leakage in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$CL_{activityshifting,t}$	Annual carbon losses due to baseline activity shifting in other lands managed or operated by the Project Proponent in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$CL_{market,t}$	Annual carbon due to market leakage effects in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$CL'_{emissions,t}$	Annual emissions due to implementation of the shifted baseline activity in other lands managed or operated by the Project Proponent in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
44/12	The ratio of molecular weight of carbon dioxide to carbon, *see* Appendix C	tCO_2-e tC^{-1}

The emissions determined in $C'_{leakage,t}$ are subsequently accounted for in the net anthropogenic GHG emissions for the IFM-LtPF project (Equation 1-1).

5.2 Leakage Due to Activity Shifting

Any activity shifting due to selective logging which includes removal of harvested wood projects comprising sawlog, pulplog and commercially harvested fuel wood by the Project Proponent must be assessed as a component of leakage.

Activity shifting leakage situations become evident where the Project Proponent has:

(i) Intensified operations for selective logging, i.e. has legal authorisation for selective logging and increase logging operations in other owned and/or operated lands to recover the harvesting loss due to the IFM-LtPF project; or

(ii) Shifted operations for selective logging from the Project Area to another forest area within the host country.

The Project Proponent must provide documentation for the potential leakage areas due to activity shifting i.e. other lands owned and/or operated by the Project Proponent, including geo-referenced or digital maps illustrating the physical location(s) and their boundaries, existing land uses and management plans at each verification period. When this documentation has been provided, the carbon losses from activity shifting, $CL_{activityshifting,t}$, can be assessed as described in the following sections.

Equation 5-2 $$CL_{activityshifting,t} = CL_{IH\_activityshifting,t} + CL_{SH\_activityshifting,t}$$

Parameter	Description	Unit
$CL_{activityshifting,t}$	Annual carbon losses due to baseline activity shifting in other lands managed or operated by the Project Proponent in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$CL_{IH\_activityshifting,t}$	Annual carbon losses from activity shifting due to intensification of harvest volumes in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$CL_{SH\_activityshifting,t}$	Annual carbon losses from activity shifting due to shifting of harvest to new area in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC

5.2.1 Intensification of Logging Operations

Activity shifting leakage through intensification of logging operations including removal of sawlog, pulplog and commercially harvested fuel wood is considered where the actual merchantable logs' volume in lands currently owned and/or operated by the Project Proponent (but not part of the Project Area) since the commencement date of the IFM-LtPF project activity, exceeds the common practice volumes. To identify and determine the carbon due to the intensification of logging operations, use the following procedure:

Step 1: Assign a historical reference period of five years (Refer to Section 2.2.2.3) where the harvesting operations have occurred over five years. In the case where harvesting operations have been conducted for less than five years, the harvest volume data from the forest with comparable situations and conditions at the local or regional or national level (with conservative value) shall be used. The Project Proponent shall provide the data source and collection method for the common harvest volume from the forest comparable situations and conditions to the Verifier along with the monitoring report for verification.

Step 2: Obtain the annual volume of harvest for each land *l*, currently owned and/or operated by the Project Proponent or the forest land with comparable situations and conditions at the local or regional or national level (with conservative value), for each historical reference year *k*, over the historical reference period *K*.

Step 3: Determine the average volume of harvest for each land *l*, currently owned and/or operated by the Project Proponent using the following equation:

Equation 5-3 $$V_{historical\_harvest,l,t=0} = \frac{\sum_{k=1}^{K} V'_{historical\_harvest,l,k}}{K}$$

Parameter	Description	Unit
$V_{historical\_harvest,l,t=0}$	Average volume of harvest for land *l*, (where *l*=1,2,3 … *L* lands), that is owned and/or operated by the Project Proponent or the forest with comparable situations and conditions at local or regional or national level over the historical reference period *K*, determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	m^3 yr^{-1}
$V'_{historical\_harvest,l,k}$	Total volume of harvest for land *l*, (where *l*=1,2,3 … *L* lands), that is owned and/or operated by the Project Proponent during the historical reference year *k*, (where *k*=1,2,3 … *K* historical reference years)	m^3
K	Historical reference period (see Section 2.2.2.3) or actual number of years of harvesting operation	yr

Step 4: Compare the annual actual volume of harvest in year *t* (years elapsed since the start of the IFM-LtPF project activity) with the average volume of harvest over the historical reference period determined ex ante, for each land *l*.

One of the following three situations would occur:

Equation 5-4 $V_{historical\_harvest,l,t=0} > V_{actual\_harvest,l,t}$ $\Rightarrow$ **No Leakage**

Equation 5-5 $V_{historical\_harvest,l,t=0} = V_{actual\_harvest,l,t}$ $\Rightarrow$ **No Leakage**

Equation 5-6 $V_{historical\_harvest,l,t=0} < V_{actual\_harvest,l,t}$ $\Rightarrow$ **Leakage**

Parameter	Description	Unit
$V_{historical\_harvest,l,t=0}$	Average volume of harvest for land *l*, (where *l*=1,2,3 … *L* lands), that is owned and/or operated by the Project Proponent over the historical reference period *K*, determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	$m^3\ yr^{-1}$
$V_{actual\_harvest,l,t}$	Annual actual volume of harvest for land *l*, (where *l*=1,2,3 … *L* lands), that is owned and/or operated by the Project Proponent in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	$m^3\ yr^{-1}$

Step 5: If there is leakage (i.e. Equation 5-6 is true), the total leakage in terms of the merchantable logs' volume is calculated as follows:

Equation 5-7 $$V_{IH\_activityshifting,t} = \sum_{l=1}^{L}\left(V_{actual\_harvest,l,t} - V_{historical\_harvest,l,t=0}\right)$$

Parameter	Description	Unit
$V_{IH\_activityshifting,t}$	Annual total intensification of harvest volume per year in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	m^3
$V_{actual\_harvest,l,t}$	Annual actual volume of harvest for land *l*, (where *l*=1,2,3 … *L* lands), that is owned and/or operated by the Project Proponent in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	$m^3\ yr^{-1}$
$V_{historical\_harvest,l,t=0}$	Average volume of harvest for land *l*, (where *l*=1,2,3 … *L* lands), that is owned and/or operated by the Project Proponent over the historical reference period *K*, determined ex ante - before the start of the IFM-LtPF project activity, hence *t*=0 year	$m^3\ yr^{-1}$

Step 6: Choose the most applicable BEF value from the data sources presented in Step 2 of Section 4.5.1

Step 7: Choose the most applicable wood density for a forest with corresponding climate region and ecological zone (see Appendix B, Section B.1, Table B-1).

Step 8: Select an appropriate factor for residual stand damage (f_{RSD}) (use Table B-3, section B.3, Appendix B) and carbon fraction (see Step 4 of Section 3.2.1.2.1,A) and apply the following equation to get the carbon loss due to intensification of harvest volumes:

Equation 5-8 $$CL_{IH\_activityshifting,t} = V_{IH\_activityshifting,t} \times \left(1 + f_{RSD}\right) \times BEF \times D \times CF_{AGB}$$

Parameter	Description	Unit
$CL_{IH\_activityshifting,t}$	Annual carbon losses from activity shifting due to intensification of harvest volumes in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$V_{IH\_activityshifting,t}$	Annual total intensification of harvest volume per year in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	m^3
f_{RSD}	Factor for residual stand damage, based on the fraction of quantity of carbon damaged in the residual stand to the quantity of carbon in the total merchantable logs harvested	dimensionless
BEF	Biomass expansion factor for converting volume of extracted roundwood to total aboveground biomass (including bark)	dimensionless

Parameter	Description	Unit
D	Wood density for the tropical forest with corresponding climate region and ecological zone (see Appendix B)	(t d.m.) m^{-3}
CF_{AGB}	Carbon fraction in the aboveground biomass of trees for the tropical forest (see Appendix B)	tC (t d.m.)$^{-1}$

5.2.2 Shifted Logging Operations

Activity shifting leakage due to shifted harvesting to a new forest area can be confirmed where documentation of the management plans and/or land-use designations reveal that the Project Proponent has commenced harvesting operation in any new land logged during the crediting period after the start date of the IFM-LtPF project. When this is the case, the carbon losses due to harvest shifting can be determined using the following procedure:

Step 1: Obtain the volume of harvest in the new area from management plans ($V_{SH\_activityshifting,t}$)

Step 2: Choose the most applicable BEF value from the data sources presented in Step 2 of Section 4.5.1

Step 3: Choose the most applicable wood density for a forest with corresponding climate region and ecological zone (see Appendix B, Section B.1, Table B-1)

Step 4: Select an appropriate factor for residual stand damage (f_{RSD}) (use Table B-3, Section B.3, Appendix B) and carbon fraction (see Step 4 of Section 3.2.1.2.1,A) and apply the following equation to get the carbon loss due to shifted logging operations:

Equation 5-9

$$CL_{SH\_activityshifting,t} = V_{SH\_activityshifting,t} \times \left(1 + f_{RSD}\right) \times BEF \times D \times CF_{AGB}$$

Parameter	Description	Unit
$CL_{SH\_activityshifting,t}$	Annual carbon losses from activity shifting due to shifting of harvest to new area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$V_{SH\_activityshifting,t}$	Annual shifted harvest volume for new area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	m^3
f_{RSD}	Factor for residual stand damage, based on the fraction of quantity of carbon damaged in the residual stand to the quantity of carbon in the total merchantable logs harvested	dimensionless
BEF	Biomass expansion factor for converting volume of extracted roundwood to total aboveground biomass (including bark)	dimensionless
D	Wood density for the tropical forest with corresponding climate region and ecological zone (see Appendix B)	(t d.m.) m^{-3}
CF_{AGB}	Carbon fraction in the aboveground biomass of trees for the tropical forest (see Appendix B)	tC (t d.m.)$^{-1}$

5.2.3 Shifted Baseline Activity Emissions

Following Section 5.2.1.1, if Equation 5-6 is true, implying that harvesting has intensified, and/or shifted operations for logging have been confirmed in Section 5.2.1.2, it implies leakage due to activity shifting of the baseline scenario has occurred. Consequently, emissions associated with implementation of the shifted baseline activity must be accounted for and determined using the same approach as presented in Section 3.4 for determining baseline activity emissions. In this case, the parameters *E* are replaced with *L* in Equation 3-54 to distinguish between the baseline and leakage scenarios:

Equation 5-10

$$CL'_{emissions,t} = L_{harvesting,t} + L_{onsiteprep,t} + L_{hauling,t} + L_{transport,t} + L_{processing,t} + L_{distribution,t}$$

Parameter	Description	Unit
$CL'_{emissions,t}$	Annual emissions due to implementation of the shifted baseline activity in other lands managed or operated by the Project Proponent in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$L_{harvesting,t}$	Annual shifted emissions due to harvesting operations such as felling and snigging in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$L_{onsiteprep,t}$	Annual shifted emissions due to on-site preparation such as trimming of tree heads, butts, branches and defective components in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$L_{transport,t}$	Annual shifted emissions due to log transport from collection depot to processing plant in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$L_{hauling,t}$	Annual shifted emissions due to log hauling in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$L_{processing,t}$	Annual shifted emissions due to electricity consumption in sawmill in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$L_{distribution,t}$	Annual shifted emissions due to transport of the sawn product from the mill to the wharf for export or to the depot for local usage in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

5.3 Market Leakage

Market effects due to the presence of an IFM-LtPF project could occur in two main ways:

(i) Intensification of existing harvest practices

(ii) Formation of new enterprises and hence new (or modified existing) FIRs for sanctioned selective logging.

The Project Proponent must demonstrate how market leakage has been accounted for in accordance with the most recent version of applicable VCS rules.

6 Uncertainty Assessment

The assessment of uncertainty is a required component of quality management procedures for the management of data and information (see Section 7.3). It is considered necessary that the Project Proponent identify the parameters that significantly affect the accuracy of the calculated emission reductions in order to reduce uncertainties related to the quantification of GHG emission reductions or removal enhancements. A procedure for the estimation of uncertainty of the GHG emission reductions arising from an IFM-LtPF project is presented in this section.

6.1 Identifying Uncertainty

In general, estimations of emission reductions that are a result of emissions and removals from IFM activities have various sources of uncertainties. Typically these uncertainties are associated with sample data, such as height and diameter measurements from PSPs, biomass growth and rates of decay, activity data, emission factors, and other coefficients (e.g. lumber recovery factor).

The values of the uncertainties associated with these parameters are derived from a number of different sources:

(i) IPCC (2006) default data and guidelines

(ii) Statistical sampling

(iii) Expert judgement with justification.

Where the uncertainty of a parameter is not known, the value of the parameter will be assigned a value that is indisputably conservative, eliminating the corresponding uncertainty.

6.1.1 Calculating Uncertainty

In accordance with IPCC best practice, the methodology requires the use of 95% confidence interval for quantification of random errors (IPCC, 2006, Volume 1, Chapter 3, p. 3.6 and 3.9).

A simple approach to determine the uncertainty value of the overall emission reductions from the uncertainties of the individual components, is based on the basic error propagation rule set outlined below:

Rule 1

The uncertainty or absolute error for a function, z = x + y, where σ_x and σ_y represent the absolute error for x and y, respectively, is determined by the following:

Equation 6-1

$$\sigma_z = \sqrt{\sigma_x^2 + \sigma_y^2}$$

Rule 2

The uncertainty or absolute error for a function, $fn = x \times y \times z$, where σ_x, σ_y and σ_z represent the absolute error for x, y and z, respectively, is determined by the following:

Equation 6-2

$$\sigma_{fn} = \sqrt{\left[\frac{\partial f}{\partial x}\sigma_x\right]^2 + \left[\frac{\partial f}{\partial y}\sigma_y\right]^2 + \left[\frac{\partial f}{\partial z}\sigma_z\right]^2}$$

The relative error, or percentage error (U) is determined, for function, *fn*, as an example, via the following:

Equation 6-3

$$U_{fn} = \frac{\sigma_{fn}}{fn} \times 100$$

Project Proponents seeking more detailed guidance for combining uncertainties will find it provided in IPCC (2006), Volume 1, Chapter 3, Section 3.2.3, p. 3.27. The above method has been presented for the parameters specific to the IFM-LtPF project in the subsequent sections.

6.2 Overall IFM-LtPF Project Uncertainty

The net anthropogenic GHG emission reductions of the IFM-LtPF project activity, is deduced from the subtraction of the actual project emissions ($C'_{actual,t}$) and the leakage emissions ($C'_{leakage,t}$) from the proposed baseline emissions ($C'_{baseline,t}$), as presented in Equation 1-1 in Section 1.2.1.

An estimation of the overall uncertainty for the IFM-LtPF project is deduced by error propagation using the following equation:

Equation 6-4

$$\sigma_{IFM-LtPF,t} = \sqrt{(\sigma_{baseline,t})^2 + (\sigma_{actual,t})^2 + (\sigma_{leakage,t})^2}$$

Parameter	Description	Unit
$\sigma_{IFM-LtPF,t}$	Annual uncertainty (absolute error) for the overall IFM-LtPF project in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$\sigma_{baseline,t}$	Annual uncertainty in the annual total GHG emissions as a result of the baseline scenario in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$\sigma_{actual,t}$	Annual uncertainty in the actual (project) activity in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$\sigma_{leakage,t}$	Annual uncertainty in leakage in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

To track the changes in uncertainty associated with the IFM-LtPF activity, it is appropriate to use the relative uncertainty instead of the absolute. The relative error, or percentage error is expressed using the following equation:

Equation 6-5

$$U_{IFM-LtPF,t} = \frac{\sigma_{IFM-LtPF,t}}{C'_{IFM\_LtPF,t}} \times 100$$

Parameter	Description	Unit
$U_{IFM-LtPF,t}$	Annual uncertainty (relative error) for the overall IFM-LtPF project in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	%
$\sigma_{IFM-LtPF,t}$	Annual uncertainty (absolute error) for the overall IFM-LtPF project in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$C'_{IFM\_LtPF,t}$	Annual net anthropogenic GHG emission reductions in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

6.3 Uncertainty in Baseline Accounting

The total uncertainty related to the baseline scenario (see Equation 3-1) is a propagation of error associated with the uncertainty of the degradation plus the uncertainty in the estimation of emission sources due to the implementation of the baseline case, and is expressed using the following equation:

Equation 6-6

$$\sigma_{baseline,t} = \sqrt{\left(\sigma_{degradation,t}\right)^2 + \left(\sigma_{emissions,t}\right)^2}$$

Parameter	Description	Unit
$\sigma_{baseline,t}$	Annual uncertainty in the annual total GHG emissions as a result of the baseline scenario in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$\sigma_{degradation,t}$	Annual uncertainty in the annual emissions produced from degradation due to the baseline activity: selective logging in the Project Area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$\sigma_{emissions,t}$	Annual uncertainty in the annual emissions from the baseline activity: selective logging operations in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

6.3.1 Degradation Uncertainty

The uncertainty associated with degradation in the baseline scenario (see Equation 3-2) is a propagation of errors of the individual components contributing to degradation and is expressed using the following equation:

Equation 6-7

$$\sigma_{degradation,t} = \left[\left(\sqrt{\left(\sigma_{DW_{decay},t}\right)^2 + \left(\sigma_{ltHWP_{oxidation},t}\right)^2 + \left(\sigma_{stHWP_{oxidation},t}\right)^2 + \left(\sigma_{growth\_foregone,t}\right)^2 + \left(\sigma_{regrowth,t}\right)^2} \right) \times \frac{44}{12} \right]$$

Parameter	Description	Unit
$\sigma_{degradation,t}$	Annual uncertainty in the annual emissions produced from degradation due to the baseline activity: selective logging in the Project Area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$\sigma_{DW_{decay},t}$	Annual uncertainty in carbon from the deadwood (DW) pool due to decay in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\sigma_{ltHWP_{oxidation},t}$	Annual uncertainty in carbon from the long-term harvested wood products (ltHWP) pool due to oxidation in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\sigma_{stHWP_{oxidation},t}$	Annual uncertainty in carbon from the short-term harvested wood products (stHWP) pool due to oxidation in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\sigma_{growth\_foregone,t}$	Annual uncertainty in the carbon lost due to growth foregone in the annual net harvest area in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\sigma_{regrowth,t}$	Annual uncertainty in the carbon increase in the biomass due to regrowth following logging in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
44/12	The ratio of molecular weight of carbon dioxide to carbon, *see* Appendix C	tCO_2-e tC^{-1}

6.3.2 Baseline Emission Sources Uncertainty

The uncertainty due to emissions from the implementation of the baseline case is determined as follows:

Equation 6-8 $$\sigma_{emissions,t} = \sqrt{\sum_{g=1}^{G} \sigma^2_{baseline\_source,g,t}}$$

Parameter	Description	Unit
$\sigma_{emissions,t}$	Annual uncertainty in the annual emissions from the baseline activity: selective logging operations in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$\sigma_{baseline\_source,g,t}$	Annual uncertainty in the greenhouse gas emissions sources *g*, (where *g*=1,2,3 … *G* emission sources) associated with the baseline activity in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

6.4 Uncertainty in Actual Project Accounting

The uncertainty associated with the emissions due to the implementation of the actual project activity can be tracked through error propagation related to the individual project activity emission sources as outlined by the following:

Equation 6-9 $$\sigma_{actual,t} = \sqrt{\sum_{g=1}^{G} \sigma^2_{proj\_source,g,t}}$$

Parameter	Description	Unit
$\sigma_{actual,t}$	Annual uncertainty in the actual project activity in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$\sigma_{proj\_source,g,t}$	Annual uncertainty in the greenhouse gas emissions sources *g*, (where *g*=1,2,3 … *G* emission sources) associated with the actual project activity in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

6.5 Uncertainty in Leakage Accounting

The uncertainty associated with leakage takes into account uncertainty in the estimations of emissions due to activity shifting ($CL_{activityshifting,t}$), illegal harvesting ($CL_{illegal\_harvest,t}$), natural disturbances ($CL_{natural\_disturb,t}$) implementation of the shifted baseline activity ($CL'_{emissions,t}$), and market effects ($CL_{market,t}$).

Equation 6-10

$$\sigma_{leakage,t} = \left(\sqrt{(\sigma_{activityshifting,t})^2 + (\sigma_{market,t})^2 + (\sigma_{illegal\_harvest,t})^2 + (\sigma_{natural\_disturb,t})^2 + \left(\sigma_{CL'\_emissions,t} \times \frac{12}{44}\right)^2} \right) \times \frac{44}{12}$$

Parameter	Description	Unit
$\sigma_{leakage,t}$	Annual uncertainty in leakage in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$\sigma_{activityshifting,t}$	Annual uncertainty associated with carbon due to activity shifting in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\sigma_{market,t}$	Annual uncertainty associated with carbon due to market effects in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\sigma_{illegal\_harvest,t}$	Annual uncertainty associated with carbon due to illegal harvesting in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\sigma_{natural\_disturb,t}$	Annual uncertainty associated with carbon due to natural disturbances in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$\sigma_{CL'\_emissions,t}$	Annual uncertainty associated with emissions due to implementation of the shifted baseline activity in other lands managed or operated by the Project Proponent in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity); this parameter has been multiplied by 12/44 for conversion into tC	tCO_2-e
44/12	The ratio of molecular weight of carbon dioxide to carbon, *see* Appendix C	tCO_2-e tC^{-1}

6.6 Uncertainty Deduction

Upon establishing the uncertainty percentage using Equation 6-5, apply the following procedure:

Step 1: If $U_{IFM-LtPF,t} \leq 10\%$, then no deduction will be applied for uncertainty. The Project Proponent shall proceed to Section 6.7 to further reduce uncertainty associated with parameters.

Step 2: If $U_{IFM-LtPF,t} > 10\%$, then apply the following equation:

Equation 6-11

$$CC_{IFM-LtPF,t} = \frac{100 - (U_{IFM-LtPF,t} - 10)}{100} \times C'_{IFM-LtPF,t}$$

Parameter	Description	Unit
$CC_{IFM-LtPF,t}$	Annual carbon credits post uncertainty deduction in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$U_{IFM-LtPF,t}$	Annual uncertainty (relative error) for the overall IFM-LtPF project in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	%
$C'_{IFM\_LtPF,t}$	Annual net anthropogenic GHG emission reductions in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

After applying Equation 6-11, the Project Proponent proceeds to Section 6.7 to further reduce uncertainty associated with parameters, so as to maximise the estimates of carbon credits.

6.7 Reducing Uncertainty

Reducing the uncertainty associated with the net anthropogenic GHG emission reductions of the IFM-LtPF project activity can be achieved by identifying the parameters contributing the greatest to the uncertainty and conducting appropriate procedures to reduce the uncertainty of these parameters. This will be achieved using the following procedure:

Step 1: For each parameter used to calculate the net anthropogenic GHG emission reductions, e.g. $C'_{baseline,t}$, $C'_{actual,t}$, and $C'_{leakage,t}$, derive the ratio of the uncertainty of each contributing parameter over the main parameter. For example, to determine the ratio of the uncertainty of the individual components of the baseline scenario: degradation and baseline activity emissions, the following ratios must be derived:

Equation 6-12

$$R_{degradation,t} = \frac{\sigma_{degradation,t}}{\sigma_{baseline,t}}$$

Equation 6-13

$$R_{emissions,t} = \frac{\sigma_{emissions,t}}{\sigma_{baseline,t}}$$

Parameter	Description	Unit
$R_{degradation,t}$	Annual ratio of uncertainty of emissions due to degradation over uncertainty of the annual total GHG emissions of the baseline scenario in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	dimensionless
$\sigma_{degradation,t}$	Annual uncertainty in the annual emissions produced from degradation due to the baseline activity: selective logging in the Project Area in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

Parameter	Description	Unit
$\sigma_{baseline,t}$	Annual uncertainty in the annual total GHG emissions as a result of the baseline scenario in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e
$R_{emissions,t}$	Annual ratio of uncertainty of emissions due to implementation of baseline activity over uncertainty of the annual total GHG emissions of the baseline scenario in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	dimensionless
$\sigma_{emissions,t}$	Annual uncertainty in the annual emissions from the baseline activity: selective logging operations in year *t,* (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tCO_2-e

Step 2: Identify the parameters with the highest ratios and using the same procedure as in Step 1, investigate the parameters contributing to the identified parameter. Continue this process for all calculated/derived parameters until only sourced/measured parameters remain.

Step 3: For the sourced parameters identified as the greatest contributors to uncertainty from Step 2, analyse the source of the parameter value and the associated uncertainty.

If the parameter is either a default IPCC value or sourced from literature:

(i) Can the accuracy of the parameter and hence the range of the uncertainty be reduced by selecting another appropriate data source? If yes, provide justification and new data source

(ii) If no, can a project-specific parameter be measured? If yes, provide a description of the procedure and incorporate into the Monitoring Plan

(iii) If no, summarise justification on why the uncertainty of the parameter cannot be improved upon.

If the parameter is a project-specific measured value:

(i) Can the accuracy of the parameter and hence the range of the uncertainty be reduced by increasing the statistical sampling? If yes, provide statistical requirements and incorporate into Monitoring Plan

(ii) If no, summarise justification on why the uncertainty of the parameter cannot be improved upon.

Step 4: Once uncertainty revisions have been conducted, re-calculate the net anthropogenic emission reductions, $C'_{IFM-LtPF}$, and follow Sections 6.2 to 6.5 to calculate the revised uncertainty for the net anthropogenic GHG emission reductions of the IFM-LtPF project activity using Equations 6-4 and 6-5. Compare revised percentage with the previous.

Step 5: Follow Steps 1 and 2 in Section 6.6 and where required, account for uncertainty deduction using Equation 6-11.

7 Monitoring

7.1 Monitoring Methodology

This section provides the methodology for monitoring the parameters employed to calculate carbon changes due to forest degradation, as well as emissions due to implementation of the project and baseline activities, plus emissions as a result of leakage.

In addition, the procedures for establishing Permanent Sample Plots (PSPs) and data collection presented herein also apply to the Measured Data pathway, i.e., the case where the preparation of FIR or equivalent document, is in progress (see Section 3.2.2).

After monitoring has been implemented, the results are consequently applied to revise the net anthropogenic GHG emission reductions for the subsequent reporting period.

7.1.1 Monitoring Plan

The Project Proponent is required to submit a detailed monitoring plan in accordance with the most recent version of applicable VCS rules.

Standard Operating Procedures (SOPs), training, and capacity building will be provided by the Project Proponent to the identified responsible entity as specified in the PD. This is to ensure that accurate data is collected as required. The data, its source, the entity responsible, the frequency of collection and the equation it applies to, is detailed in the monitoring tables provided in the following sections (Tables 7-1 to 7-3).

7.1.2 Procedure for Establishing the Permanent Sample Plots (PSPs) and Measurement

Forest inventory obtained in the PSPs that are established in the Project Area is required for:

(i) The Measured Data pathway, ex ante estimation for the baseline degradation calculations (see Section 3.2.2)

(ii) Monitoring of the carbon change throughout the crediting period to obtain ex post estimations of growth foregone (see Section 3.3.4) and emissions due to natural disturbances (see Section 4.4).

Sample plots are either permanent or temporary in nature. For measuring the carbon change under the IFM-LtPF project, Permanent Sample Plots (PSPs) are more suitable than Temporary Sample Plots, as they are statistically more accurate and efficient in estimating changes in forest carbon. The measurements collected within the same plots under the PSPs approach throughout the crediting period allows the monitoring of the growth of individual trees, survivors, mortality, and growth of new trees at specific time intervals. In addition, the PSPs also permit the verification body to find, measure at random, and to verify in quantitative terms, the design and implementation of the carbon monitoring plan. The following sections describe the procedures for establishing PSPs in the Project Area.

7.1.2.1 Stratification of the Project Area

To facilitate the field work and increase the accuracy and precision of the parameters that are to be measured, the Project Area is to be divided into sub-populations or "strata" that form relatively homogeneous units. This makes monitoring more cost effective because it decreases the sampling and monitoring efforts, whilst maintaining the same level of confidence. Stratification of the Project Area is presented in more detail Section 2.2.1.1.1.

7.1.2.2 Shape and size of plots

The measurement of tree parameters in a PSP requires the determination of the size and shape of the PSPs. Circular or rectangular plots with varying sizes can be used for measuring different diameter class trees. Nesting of plots is possible - a smaller size plot is established inside a larger plot for measuring small diameter class trees. Figure 7-1 shows an example of nested circular sample plots for measuring different diameter classes in a specified circular plot. The sample plot has three circular plots: a small plot with 4 m radius to measure trees with DBH between 5-20 cm, an intermediate plot with 14 m radius to measure trees with DBH between 20-50 cm, and a large plot with 20 m radius for measuring trees with DBH above 50 cm.

The Project Proponent must decide on the appropriate size and shape of the PSP based on the common practices employed for forest inventory in the host country.

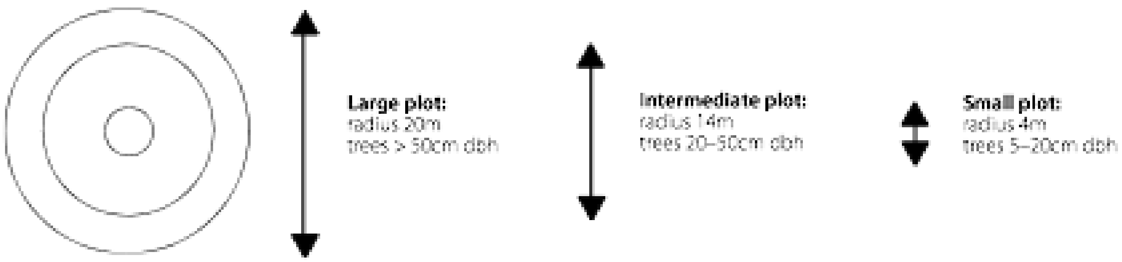

Figure 7-1 Circular three-nest sample plot sizes (Pearson et al. 2005)

7.1.2.3 Determining the number of PSPs

The number of PSPs in each stratum is determined by taking measurements in preliminary sample plots randomly laid in each stratum to achieve the desired level of precision using the following procedure:

Step 1: Select the number of preliminary sample plots (*sp*) to be established (between 6 and 10 for each stratum).

Step 2: Set the geographic location of the preliminary sample plots in each stratum by employing, for example, a random function available in the Geographic Information System (GIS) platform (e.g. ArcGIS).

Step 3: Locate the preliminary sample plot on the ground using GPS and maps.

Step 4: Establish the sample plot of specific size and shape as discussed in the Section 7.1.2.2.

Step 5: Measure the DBH and tree height of all trees as defined by the relevant authority of the host country. Use the standard forestry techniques and equipment such as DBH tape and clinometer for measuring DBH and tree height, respectively. See Pearson et al. (2005) for details.

Step 6: Use field data to calculate the carbon in the AGB in each preliminary sample plot and stratum as per the calculation in Section 3.2.1.2, and employ the following equation to estimate the standard deviation for each stratum (sd_j):

Equation 7-1

$$sd_j = \sqrt{\frac{\sum_{sp=1}^{SP} (\overline{C}_{AGB\_gstock,sp,j} - \overline{C}_{AGB\_gstock,j})}{N_j - 1}}$$

Parameter	Description	Unit
sd_j	Standard deviation for carbon in the aboveground biomass in the stratum *j*, (where *j*=1,2,3, … *J* strata)	tC ha^{-1}
$\overline{C}_{AGB\_gstock,sp,j}$	Average carbon per hectare in the aboveground biomass of the growing stock in the preliminary sample plot *sp (where sp*=1,2,3 … *SP* preliminary sample plots), of the stratum *j*, (where *j*=1,2,3, … *J* strata)	tC ha^{-1}
$\overline{C}_{AGB\_gstock,j}$	Average carbon per hectare in the aboveground biomass of the growing stock in the stratum *j*, (where *j*=1,2,3, … *J* strata)	tC ha^{-1}
N_j	Total number of sampling units in the stratum *j*, (where *j*=1,2,3, … *J* strata)	dimensionless

Step 7: Apply the precision level of 10% of the true value of the mean at the 95% confidence interval for accurate estimation of net change in the carbon stock (Pearson et al., 2005) in the project area.

Step 8: Apply the equation below to estimate the total number of PSPs, *N*, in all strata for the entire Project Area (Pearson et al., 2005):

Equation 7-2

$$N = \frac{\left(\sum_{j=1}^{J} N_j \times sd_j\right)^2}{\left(\frac{N_j^2 \times err^2}{t_{stat}^2}\right) + \left(\sum_{j=1}^{J} N_j \times sd_j^2\right)}$$

Parameter	Description	Unit
N	Total number of Permanent Sample Plots in the Project Area	Number
N_j	Number of sampling units in stratum *j* (where *j* = 1,2,3 … *J* strata)	Number
sd_j	Standard deviation of carbon density for the stratum *j*, (where *j*=1,2,3, … *J* strata)	tC ha^{-1}

Parameter	Description	Unit
t_{stat}	Sample statistic from the t-distribution for the 95% confidence level	dimensionless
err	Allowable error (calculated by mean carbon density by desired precision)	dimensionless

Step 9: The following equation is then used to calculate the number of PSPs in each individual stratum (Pearson et al. 2005):

Equation 7-3

$$n_j = N \times \frac{N_j \times sd_j}{\sum_{j=1}^{J} N_j \times sd_j}$$

Parameter	Description	Unit
n_j	Number of Permanent Sample Plots in stratum *j*, (where *j*=1,2,3, … *J* strata)	Number
N	Total number of Permanent Sample Plots in the Project Area	Number
N_j	Total number of sampling units in the stratum *j*, (where *j*=1,2,3, … *J* strata)	Number
sd_j	Standard deviation of carbon density for the stratum *j*, (where *j*=1,2,3, … *J* strata)	tC ha^{-1}

Equation 7-3 determines the number of PSPs for each stratum based on the variability in the stratum. A stratum with higher variability will require a higher number of sample plots than a stratum with less variability.

In the case of the natural disturbances, the sample plots, s_{nd}, are established in the naturally disturbed stratum during the monitoring event for estimating the carbon increased in the AGB pool due to regrowth in the naturally disturbed areas (see Step 5 of Section 4.4).

7.1.2.4 Sampling design for the PSPs

Different sampling design approaches are available for laying out the ground location of the PSPs in each stratum. Some of the commonly used sampling designs in forestry are random sampling, stratified sampling, stratified random sampling, stratified systematic sampling and cluster sampling. A suitable sampling design for establishing the PSPs is required and is important to avoid bias, such as locating PSPs along a road for example, in order to maintain the statistical rigour and validity of the calculations.

7.1.2.5 Parameter measurement in the PSPs

After determining the number of PSPs in each stratum, and the sampling design for on the ground location of the PSPs, field measurements will be conducted. The field team should have sound knowledge and experience in forest inventory, measurement procedures and equipment. Before the field work commences, the field team must prepare the following:

- A plan of the data collection procedures including the specification of merchantable tree in terms of species, minimum DBH and tree form, rules for borderline trees, locating trees during the following monitoring period, and measurement techniques for the DBH and tree height
- A plan of the data recording procedures and resources, such as paper forms or handheld PDAs
- Documentation of quality control and quality assurance procedures
- Documentation of data archiving methods
- Details of the responsibilities of the parties involved.

The Project Proponent will develop Standard Operating Procedures (SOPs) for each of the above steps and include these in the PD.

After establishing a PSP on the ground, all trees as defined by the relevant authority in the host country will be measured for their DBH and tree height (H) using appropriate equipment. The equipment employed must have been calibrated before taking to the field for measurements.

This Methodology has provided guidance on establishment of the PSPs and the measurement in the Section 7.1.2. However, the Project Proponent will be required to use methods that adhere to good practice internationally as well as locally in the host country. A detail of the chosen methods for the Project Area stratification, sampling design, intensity and the actual tree measurement must be provided in the PD. Some of the specific resource materials for monitoring the net GHG emissions are provided by the following literature: Pearson et al. (2005); Pearson et al. (2007); IPCC (2003); Hoover (2008).

7.1.3 Monitoring Frequency

Under this methodology, the Project Proponent should undertake measurement in the PSPs at intervals not exceeding five years. Parameters associated with the Project Area and leakage must be monitored annually.

7.2 Monitoring Implementation

The Project Proponent must prepare a monitoring plan for estimating carbon changes under the baseline scenario, project implementation and leakage. This section provides guidance on the specific parameters to be monitored under these scenarios, their reference in this Methodology, their sources, monitoring frequency and the relevant equation where the new value is to be applied for ex post calculations of net anthropogenic GHG emission reductions.

The data and the parameters associated with the calculation of the annual change in carbon due to degradation from selective logging ($C'_{degradation,t}$ in Equation 3-2) have been categorised into three groups:

(i) parameters obtained from the literature or reports (not monitored)

(ii) parameters measured once (not monitored)

(iii) parameters that require monitoring.

Tables 7-1 through 7-3 summarise the specific parameters, the source(s) of each data or parameter, and the equation(s) in which each of the parameters are applied.

7.2.1 Parameters Obtained from the Literature/Reports to be Reviewed/Verified (Not Monitored)

Table 7-1 provides a list of parameters to be monitored during the project lifetime and used for updating the net anthropogenic GHG emissions calculation. Section 7.3.2 provides QA/QC procedures for selecting the most appropriate value. The Project Proponent must select the value which does not lead to an over-estimation of the net anthropogenic GHG emission reductions.

Table 7-1 Parameters obtained from the literature or reports to be reviewed or verified

Parameter	Summary of Description	Unit	Source of the parameter	Review frequency or validation	Application of the Parameter in Equation(s)
$BCEF_j$	Biomass conversion and expansion factor in stratum *j*	(t d.m.) m^{-3}	literature value or derive a local value	Review the literature or where required, verify or derive local value	3-8; 4-15; 4-22
BEF	Biomass expansion factor for converting volume of extracted roundwood to total aboveground biomass (including bark)	dimensionless	literature value or derive a local value	Review the literature or where required, verify or derive local value	4-21; 5-8; 5-9
CF_{wood}	Carbon fraction of wood for the tropical forest	tC (t d.m.)$^{-1}$	literature value	Review the literature for appropriate value during the monitoring event	3-3; 3-5; 3-41; 3-51;
CF_{AGB}	Carbon fraction in the aboveground biomass of trees for the tropical forest	tC (t d.m.)$^{-1}$	literature value	Review the literature for appropriate value during the monitoring event	3-8; 3-14; 3-37a; 3-37b; 3-38; 4-15; 4-17a; 4-21; 4-22; 5-8; 5-9
D	Wood density for the tropical forest with corresponding climate region and ecological zone	(t d.m.) m^{-3}	literature value or derive a local value	Review the literature or where required, verify or derive local value	3-3; 3-5; 3-41; 3-51; 4-21; 5-8; 5-9
D_i	Species-specific density of wood,	(t d.m.) m^{-3}	literature value	Review the literature or where required, verify or derive local value	3-12

Parameter	Summary of Description	Unit	Source of the parameter	Review frequency or validation	Application of the Parameter in Equation(s)
$f_V(DBH_{n,i,s,j,t=0}, H_{n,i,s,j,t=0})$	Volume allometric equation as a function of diameter at breast height and height; t=0 year	dimensionless	obtained from literature	Review the literature or where required, verify or derive local value	3-10; 3-11
$f_B(DBH_{n,i,s,j,t=0}, H_{n,s,i,j,t=0}, D_i)$	Biomass allometric equation as a function of diameter at breast height and height; t=0 year	dimensionless	obtained from literature	Review the literature or where required, verify or derive local value	3-12
k_{decay}	Rate of decay of the deadwood pool	yr^{-1}	literature value	Review the literature for appropriate value during the monitoring event	3-17, 3-21
f_{RSD}	Factor for residual stand damage	dimensionless	literature value	Review the literature for appropriate value during the monitoring event	3-19; 4-21; 5-8, 5-9
f_{branch_trim}	Branch-trim factor	dimensionless	literature value or derive a local value	Review the literature or where required, verify or derive local value	3-20
$f_{lumber\_recovery}$	Lumber recovery factor	dimensionless	literature value	Review the literature for appropriate value during the monitoring event	3-26, 3-27
k_{ltHWP_ox}	Rate of oxidation for long-term harvested wood products	yr^{-1}	literature value	Review the literature for appropriate value during the monitoring event	3-28
k_{stHWP_ox}	Rate of oxidation for short-term harvested wood products	yr^{-1}	literature value	Review the literature for appropriate value during the monitoring event	3-34
$\bar{G}_{regrowth,t}$	Average regrowth per hectare per year of the aboveground biomass after logging in year, t	(t d.m.) ha^{-1} yr^{-1}	literature value	Review the literature for appropriate value during the monitoring event	3-38

Parameter	Summary of Description	Unit	Source of the parameter	Review frequency or validation	Application of the Parameter in Equation(s)
EF_{fuel}	Fuel emission factor	tCO_2-e kL^{-1}	literature value	Review the literature for appropriate value during the monitoring event	3-40; 3-42; 3-43; 3-46; 3-50; 3-54; 4-8; 4-11; 4-14
$FC_{harvest}$	Fuel consumption of equipment employed for felling and snigging per m^3 of merchantable log harvested	kL m^{-3}	Manufacturer's specification/literature value	Review the literature for appropriate value during the monitoring event	3-40
FC_{trim_equip}	Fuel consumption of equipment employed for trimming per m^3 of trimmed material	kL m^{-3}	Manufacturer's specification	Review the literature for appropriate value during the monitoring event	3-42
$FC_{hauling}$	Fuel consumption of equipment for hauling one m^3 of merchantable log	kL m^{-3}	Manufacturer's specification	Review the literature for appropriate value during the monitoring event	3-43
Cap_{truck}	Truck load capacity	m^3 $truck^{-1}$	literature value	Review the literature for appropriate value during the monitoring event	3-44; 3-52
$Eff_{vehicle}$	Fuel efficiency for vehicle type	km kL^{-1}	Manufacturer's specification/National Database	Review the literature for appropriate value during the monitoring event	3-46; 3-52; 3-54; 4-7; 4-11; 4-14
e_{demand}	Electricity demand for processing per volume processed	kWh m^{-3}	literature value	Review the literature for appropriate value during the monitoring event	3-47
$EF_{electricity}$	Emission factor for electricity in the host country	tCO_2-e kWh^{-1}	Country-specific data from International Energy Agency	Annually revised for the specific value	3-48; 4-4
$t_{generator,t}$	Total operating time of generator in year t	h	National reports on harvesting practice	Review the literature for appropriate value during the monitoring event	3-49; 3-50

Parameter	Summary of Description	Unit	Source of the parameter	Review frequency or validation	Application of the Parameter in Equation(s)
$FC_{generator}$	Fuel consumption per hour of operation of generator	kL h^{-1}	Manufacturer's fuel consumption chart	Review the literature for appropriate value during the monitoring event	3-50
$PR_{equip,ee,t}$	Power rating for electrical equipment, *ee*, in year *t*	kW	Manufacturer's power rating for the equipment	Review the value during the monitoring event	4-3
$EF_{flight,y}$	Flight emission factor for trip y	tCO_2-e (passenger.km)$^{-1}$	literature value	Annually revised for the specific value	4-6, 4-10; 4-13
R_{CH_4}	Emission ratio for CH_4	dimensionless	literature value	Review the literature for appropriate value during the monitoring event	4-18a
R_{N_2O}	Emission ratio for N_2O	dimensionless	literature value	Review the literature for appropriate value during the monitoring event	4-18b
$R_{N/C}$	Ratio of nitrogen to carbon	dimensionless	literature value	Review the literature for appropriate value during the monitoring event	4-18b
GWP_{CH_4}	Global warming potential of CH_4	tCO_2-e tCH_4^{-1}	literature value	Review the literature for appropriate value during the monitoring event	4-19
GWP_{N_2O}	Global warming potential of N_2O	tCO_2-e tN_2O^{-1}	literature value	Review the literature for appropriate value during the monitoring event	4-19

7.2.2 Parameters to be Measured Once (Not Monitored)

Table 7-2 provides a list of parameters measured ex ante and used in the calculation for the net anthropogenic GHG emission reductions. These parameters and data are validated or verified but not monitored.

Table 7-2 Parameters to be measured once but not monitored

Parameter	Summary of Description	Unit	Source of the parameter	Measurement Frequency	Application of the Parameter in Equation(s)
$A_{project,t=0}$	Project Area at time, *t*=0	ha	GPS data, GIS maps and satellite data	Validated/Verified before the IFM-LtPF project start date	2-1; 3-4; 3-6; 3-9; 3-13; 3-36b;
$A_{project,j,t=0}$	Project Area within each stratum, *j*, at time, *t*=0	ha	GPS data, GIS maps and satellite data	Validated/Verified before the IFM-LtPF project start date	2-1; 3-4; 3-6; 3-9; 3-13
$A_{s,j,t=0}$	Total area of sample plots, *s*, in stratum, *j*, *t*=0 year	ha	Ex ante field measurement in the sample plots	Validated/Verified before the IFM-LtPF project start date	3-10; 3-11; 3-12
$DBH_{n,i,s,j,t=0}$	Diameter at breast height *t*=0 year	cm	Ex ante field measurement in the sample plots	Validated/Verified before the IFM-LtPF project start date	3-10; 3-11; 3-12
$H_{n,i,s,j,t=0}$	Height for individual tree, *t*=0 year	m	Ex ante field measurement in the sample plots	Validated/Verified before the IFM-LtPF project start date	3-10; 3-11; 3-12
$A_{NHA\_annual,t}$	Annual net harvest area for the Project Area in year, *t*	ha	Ex ante, obtained from the harvesting plan	Validated/Verified before the IFM-LtPF project start date	3-15a; 3-16a; 3-26; 3-27; 3-33; 3-35; 3-37a; 3-38
$A_{NHA\_annual,j,t}$	Annual net harvest area at the stratum level in year, *t*	ha	Ex ante, obtained from the harvesting plan	Validated/Verified before the IFM-LtPF project start date	3-15b; 3-16b; 3-37b
$KM_{transport,t}$	Annual log transport distance from collection depot to processing plant	km $truck^{-1}$	Digital maps	Validated/Verified before the IFM-LtPF project start date	3-45
$KM_{distrib,t}$	Annual distance of transport from point of processing to distribution/export point	km $truck^{-1}$	Digital maps	Validated/Verified before the IFM-LtPF project start date	3-53
$V'_{historical\_harvest,l,k}$	Total volume of harvest for land *l* that is owned and/or operated by the Project Proponent over the historical reference period	m^3	Project Proponent records	Validated/Verified before the IFM-LtPF project start date	5-3

7.2.3 Parameters to be Monitored

Table 7-3 provides a list of parameters to be monitored during the project lifetime which are then employed to update the net anthropogenic GHG emission reductions calculation.

Table 7-3 Parameters to be monitored in the Project Area

Parameter	Summary of Description	Unit	Source of the parameter	Measurement Frequency	Application of the Parameter in Equation(s)
$DBH_{n,i,s,j,t}$	Diameter at breast height for individual tree *n*, of species *i*, in sample plot *s*, of stratum *j*, in year *t*	cm	Measured using DBH tape	At intervals not exceeding five years after the first monitoring event	3-12
$DBH_{tree\_nd,n,i,s_{nd},j,t}$	Diameter at breast height for individual tree *n*, of species *i*, in sample plot in the naturally disturbed area s_{nd}, of stratum *j*, in year *t*	cm	Measured using DBH tape	At intervals not exceeding five years after the first monitoring event	3-12
$H_{n,i,s,j,t}$	Height for individual tree *n*, of species *i*, in sample plot *s*, of stratum *j*, in year *t*	m	Measured using tree height measurement equipment	At intervals not exceeding five years after the first monitoring event	3-12
$H_{tree\_nd,n,i,s_{nd},j,t}$	Height for individual tree n, of species i, in sample plot in the naturally disturbed area s_{nd}, of stratum i, in year *t*	m	Measured using tree height measurement equipment	At intervals not exceeding five years after the first monitoring event	3-12
$t_{op\_equip,ee,t}$	Hours of operation of electrical equipment *ee*, in year *t*	h	Electrical equipment time log book	Annual	4-3
$KM_{plan\_flight,y,t}$	Distance travelled per trip *y*, for a total of Y trips in year *t*	km	Flight travel log	Annual	4-6
$N_{plan\_flight,y,t}$	Number of passengers per trip *y* in year *t*	Number	Flight travel log	Annual	4-6
$KM_{plan\_ground,y,t}$	Distance travelled per trip *y*, for a total of Y trips in year *t*	km	Vehicle travel log	Annual	4-7

Parameter	Summary of Description	Unit	Source of the parameter	Measurement Frequency	Application of the Parameter in Equation(s)
$V_{fuel\_plan\_ground,y,t}$	Annual volume of fuel consumed per trip *y* in year *t*	kL	Vehicle travel log	Annual	4-8
$KM_{design\_flight,y,t}$	Distance travelled per trip *y*, for a total of Y trips in year *t*	km	Flight travel log	Annual	4-10
$N_{design\_flight,y,t}$	Number of passengers per trip *y* in year *t*	Number	Flight travel log	Annual	4-10
$KM_{design\_ground,y,t}$	Distance travelled per trip *y*, for a total of Y trips in year *t*	km	Vehicle travel log	Annual	4-11
$KM_{monitoring\_flight,y,t}$	Distance travelled per trip *y*, for a total of Y trips in year *t*	km	Flight travel log	Annual	4-13
$N_{monitoring\_flight,y,t}$	Number of passengers per trip *y*, in year *t*	passenger	Flight travel log	Annual	4-13
$KM_{monitoring\_ground,y,t}$	Distance travelled per trip *y*, for a total of Y trips in year *t*	km	Vehicle travel log	Annual	4-14
$A_{nd,j,t}$	Area of natural disturbance *nd*, in stratum *j* in year *t*	ha	Satellite imagery and field measurement	Annual	4-15; 4-17a
$f_{natdisturb,j,t}$	Fraction of the forest naturally damaged in stratum *j*, in year *t*	dimensionless	Field survey	Annual	4-16
$V_{illegal\_harvest,t}$	Volume of wood sold as determined from field surveys in year *t*	m^3	Field survey	Annual	4-21
$A_{illegal\_harvest,j,t}$	Area of illegal harvest in stratum *j*, in year *t*	ha	Satellite data	Annual	4-22

Parameter	Summary of Description	Unit	Source of the parameter	Measurement Frequency	Application of the Parameter in Equation(s)
$V_{actual\_harvest,l,t}$	Annual actual volume of harvest for land l that is owned and/or operated by the Project Proponent or the forest with comparable situations and condition in local or regional or nation level in year t	m^3 yr^{-1}	Project Proponent records	Annual	5-4 to 5-7

7.2.4 Validating or Deriving the Parameters

To calculate the annual change in carbon due to degradation, the carbon in merchantable logs and AGB must be calculated. Good practice (IPCC, 2003) suggests the use of locally derived species-specific or group of species-specific default values for the net anthropogenic GHG emission reductions calculation. However, the application of default parameters available in the IPCC literature, national inventory reports or published peer-reviewed studies is acceptable if the parameter is applicable to a forest type and climatic region similar to the Project Area (CDM-EB, 2009, p. 26). Where the default parameter does not match the forest type and climatic region of the Project Area, it is required to validate the parameters using the destructive sampling approach described in the following section.

7.2.4.1 Validating or deriving the wood density

Where the default value for wood density is not obtained from the forest type and climatic region similar to the Project Area, validate or derive the wood density using the following procedures based on Pearson et al. (2005) and CDM-EB (2009):

Step 1: Select 20-30 trees[6] representing all DBH classes found in the Project Area during the first monitoring event (within five years from the project start date).

Step 2: Measure the DBH and height of all trees.

Step 3: Fell the trees and separate each tree into the following components: merchantable log, large branches, small branches (less than 10 cm diameter), and foliage.

Step 4: Cut the merchantable logs into at least five sections, and the large branches into at least three sections.

Step 5: To determine the total volume of the merchantable logs and large branches, measure the length and the diameter at both ends of each section of the logs/branches; and calculate the total volume as in Pearson et al. (2005), Appendix B, Method 1, step 6a, p. 40.

[6] According to the CDM at least five trees representing all DBH classes, is sufficient for the destructive sampling method for verifying default values or equations. However, this Methodology suggests using at least 20 trees, which provides a greater representation of the trees in the Project Area.

Step 6: Obtain a complete cross-sectional sample from each log and large branch and measure the fresh weight and calculate the volume of each sample. Oven-dry the samples at 70 degrees for 24 hours and measure the dry weight. Estimate the wood density (D) for the forest types as well as species-specific wood density (D_j) by dividing the dry weight by the volume.

Step 7: Select the wood density.

If the wood density for the forest types and the species-specific wood density in the Project Area derived from the direct measurement are within ± 10% (CDM-EB, 2009, p. 26) of the corresponding default wood densities or lower than the measured value, it is conservative to use the selected default values for wood densities.

If the default wood densities are greater than the measured wood densities by 10% or more, it is conservative to use the wood densities derived from the samples.

If the default wood densities are lower than the measured wood densities by 10% or more, it is conservative to use the default wood densities.

7.2.4.2 Validating or deriving the volume and biomass allometric equations

Where the default volume and biomass allometric equations do not match the forest type and climatic region of the Project Area, it is required to validate or derive the allometric equations using the following destructive sampling procedure:

Step 1: Follow Steps 1 to 5 in Section 7.2.4.1 to calculate the total volume of the merchantable logs and large branches.

Step 2: Measure the fresh weight and oven dry weight of the small branches and foliage of all the felled trees.

Step 3: Estimate the biomass of the logs and large branches using the total volume and wood density (see Section 7.2.4.1) (biomass = volume x wood density). Derive the total AGB by adding the oven dry biomass of the leaves and small branches to the biomass of the large branches and logs.

Step 4: Apply the volume and biomass allometric equations to the measured data for 20-30 trees and obtain the mean volume and AGB for these trees.

Step 5: Select the equations.

If the volumes and AGB of the harvested trees derived from the direct measurement are within ± 10% of the mean values predicted by the default allometric equations, or the prediction is lower than the measured value, it is conservative to use the selected default allometric equation.

If the default allometric equations overestimate the prediction compared with the measured volume or AGB, develop a project-specific volume and/or AGB allometric equation by applying regression to tree volume and/or AGB as an independent variable to DBH and height. The wood density is also used as an independent variable for the biomass allometric equation.

7.2.4.3 Validating or deriving the branch-trim factor

If a branch-trim factor, f_{branch_trim}, cannot be obtained from the literature, or the branch-trim factor obtained from the literature does not match the forest type and climatic region of the Project Area, it is required to derive or validate, respectively, a project-specific branch-trim factor in the first monitoring event using the following the procedure:

Step 1: Follow Steps 1 to 3 in Section 7.2.4.2 and obtain the biomass of large and small branches and the total AGB.

Step 2: Calculate the branch-trim factor as the ratio of biomass of large branches to the AGB of the tree via the following equation:

Equation 7-4

$$f_{branch\_trim} = \frac{B_{branch\_trim,m_1}}{B_{AGB\_trees,m_1}}$$

Parameter	Description	Unit
f_{branch_trim}	The fraction of branches and trimmings in the aboveground biomass remaining after trimming of the merchantable logs transferred to the DW pool	dimensionless
B_{branch_trim,m_1}	Biomass in large and small branches in year m_1 of first monitoring event	t d.m.
B_{AGB_trees,m_1}	Biomass in the aboveground biomass of sample trees in year m_1 of first monitoring event	t d.m.

Step 3: If a branch-trim factor was employed in ex ante estimations, compare the project-specific branch-trim factor and the estimated branch-trim factor. If the estimated branch-trim factor is within ± 10% of the branch-trim factor value, or the value is lower than the estimated value, it is conservative to use the selected branch-trim factor.

Step 4: If the branch-trim factor value is higher than the estimated value, use the estimated value for the project.

7.2.5 Non-Permanence Risk Assessment

7.2.5.1 Buffer determination

The amount of credits a project must allocate for buffer reserves in the AFOLU Pooled Buffer Account, $CC_{NPbuffer,t}$, is based on the project's potential for future carbon loss. The method to calculate $CC_{NPbuffer,t}$ has been presented in Section 1.2.4, Equation 1-2.

To obtain the project's non-permanence buffer withholding percentage, $NP_{buffer,t}\%$, a risk rating in relation to its potential for reversal of the sequestered/protected carbon will be determined using the most recent version of VCS tool for AFOLU Non-Permanence Risk Analysis and Buffer Determination. The risk assessment must be clearly documented and substantiated in the PD and/or monitoring report.

Once the amount of credits to be deposited in the buffer account is determined, the tradeable carbon credits, VCU_t, can be calculated using Equation 1-3, Section 1.2.4.

7.3 Quality Assurance and Quality Control

Quality assurance (QA) and quality control (QC) are important for verifying and certifying carbon changes throughout the crediting period. The Project Proponent must have QA and QC systems in place at the project development stage in order to provide enough confidence to all the stakeholders on the reliability, accuracy and precision of the measurement. Accurate and precise data collection and analysis requires a trained field team, appropriate equipment, standard data collection procedures and recording, analysis and storage of data.

The PD must describe the QA and QC approach for the IFM-LtPF project and must contain Standard Operating Procedures (SOPs) for:

(i) Conducting field measurement

(ii) Selecting literature values

(iii) Data entry, maintenance and archiving

(iv) Contract procurement.

To ensure good practice in monitoring and inventory a comprehensive QA and QC system will be implemented. The procedures will be based on ISO 9001 and encompass the elements as defined in the relevant sections of the IPCC 2006 Guidelines for National Greenhouse Gas Inventories. Applying the framework proposed by ISO 9001 will ensure that all procedures and systems will be subjected to internal audits as well as being independently verified.

The QA/QC and verification system will adopt a continuous improvement model with a particular emphasis on the key parameters within the Methodology that will be monitored.

7.3.1 QA/QC for Conducting Field Measurements

The capacity and skill set of field teams employed to establish and collect measurement data in PSPs associated with carbon inventory will be assessed by qualified personnel using a combination of theoretical and practical assessment. All field teams will receive extensive training so that they are fully cognisant of all procedures and understand the importance of collecting accurate data. Appropriate training will be developed encompassing a continuous improvement system. The QA/QC system will document and allow traceability of the skill sets, training and continuous improvement of all personnel associated with the project.

If the particular required skill sets are deemed unsatisfactory then the applicable personnel will be required to undergo a formal training program conducted by suitably qualified personnel. This will be recorded in the appropriate QA module.

Standard Operating Procedures (SOPs) will be developed to encompass all the steps required to establish the carbon inventory associated with the major pools, namely AGB, DW and where applicable HWPs. The SOPs will be sufficiently robust to ensure that any new person sent into the field should be able to repeat the previous measurements.

SOPs associated with the number and placement of PSPs will also be developed to ensure their appropriate implementation. SOPs associated with the use and accuracy of all equipment used to take measurements will be developed and implemented.

All PSPs and measurements will in the first instance be established under the guidance of appropriately qualified personnel. The qualifications and expertise of these authorised staff will be identified in the appropriate QA module.

An evaluation of all field teams will be conducted to identify errors in field techniques, verify the measurement process and correct any identified problems before any measurements are undertaken. All PSPs and associated personnel who established and obtained the associated measurements will be subjected to a random audit program to ensure the accuracy and precision of data collected. The audit program will initially consist of 10% of PSPs being re-measured by suitably qualified personnel. The audit program will be fluid in nature so that it targets those plots and personnel that show a significant standard deviation. SOPs will be written to encompass this as well as a system that ensures that all PSPs and or specific measurements are re-taken and re-calculated. SOPs will be written to ensure that any field data collected over time is compared to the original data and discrepancies are verified again.

7.3.2 QA/QC for Selecting Literature Values

The selection of appropriate and current data from the literature is required in order to reduce uncertainty of the net anthropogenic emission reductions of the IFM-LtPF project. Types of data required from literature for the current Methodology are:

 Emission factors

 Rate of oxidation/decay

 Forestry parameters and conversion factors, i.e. biomass expansion factor, biomass conversion and expansion factors, wood density and carbon fraction

 Forestry process factors, i.e. lumber recovery factor, residual stand damage

 Growth models

 Allometric equations.

The Project Proponent is required to choose values/models from the literature from project(s) and area(s) with features and characteristics similar to the IFM-LtPF Project Area, for example a tropical forest with corresponding climate region and ecological zone. In addition when selecting data or parameters from the literature, the Project Proponent must adopt a conservative approach in regards to the net anthropogenic GHG emission reductions. This implies that if two or more values are available for the forest types and condition in the Project Area, the value which does not lead to an over-estimation of the net GHG emission reductions must always be chosen.

Literature values must be obtained from the following sources in the order of the most preferred data source:

(i) Peer-reviewed literature values providing project-specific data

(ii) Country-specific data

(iii) Global IPCC default values.

When recording literature values, the Project Proponent is required to provide the following information in order for the data to be verified:

(1) Source of data, date, table/figure, page number, from which the data is derived
(2) Corresponding features that match with the Project Area, i.e. forest type, climate zone, etc.
(3) Corresponding uncertainty (absolute or relative)
(4) An explanation of the choice of parameter from the range, if a range is provided. The Project Proponent must choose a value that presents the net anthropogenic emission reductions as conservative.

7.3.3 QA/QC for Data Entry and Archiving

According to the guidelines published by the IPCC (2006) it is a prerequisite that all calculations leading to emission or removal estimates should be fully reproducible. As such, QC procedures must be created to address potential errors associated with input data, the conversion of algorithms of a calculation and the output. In addition, because of the relatively long term nature of the IFM-LtPF project activity, data archiving (maintenance and storage), QA procedures and SOPs will be established to ensure the traceability of data analysis and the documentation of calculations over the lifetime of the project. As such the following activities will be developed into formal SOPs.

(i) Numbers entered into spreadsheets will reference the data sources and cells containing derived data as "results" will be clearly marked
(ii) All calculations will be presented in the form of formulas so that auditing tools can be used to track back from a result to the data source, and calculations can be evaluated by analysing the formulae
(iii) All databases, spreadsheets and recording sheets will be clearly referenced by name, version, author, updates, intended use and checking procedures, so that it can be used as a data source of the derived results and referenced further as required in the inventory process
(iv) When using databases, the source of data tables must be referenced to the data source using a referencing column
(v) Wherever possible, queries are to be used when using databases as a means to track back to the data table
(vi) Where queries are not practical and new tables of data need to be generated, scripts or macros wherever used, are to be recorded and referenced in a referencing column
(vii) All data are to be archived electronically so that these can be stored and backed up and kept for at least two years after the end of the crediting period. SOPs will be developed to ensure that this occurs in a timely manner
(viii) Before any calculation is implemented it must be peer reviewed for accuracy and relevance (including unit conversion factors) by two personnel with the relevant skills and authority
(ix) All calculations must be checked by at least one appropriately skilled independent person to ensure they are accurate and consistent with applicable time series

(x) Wherever possible, estimates and calculations are to be compared with literature values. If they are considered significantly different (5%) they are to be checked for accuracy.

7.3.4 QA/QC for Contract Procurement

SOPs will be developed for the procurement of suppliers or contractors. This is to ensure that any analysis undertaken meets internationally recognised standards and that contractors if used, adopt best practice when undertaking specific tasks.

7.4 Ex post Calculation of Net Anthropogenic GHG Emission Reductions

After the completion of the monitoring plan as outlined in the previous sections, the baseline degradation, project activity, and leakage emissions and their uncertainties, must be revised and adjusted at the end of each monitoring period. The net anthropogenic GHG emission reductions on the basis of the ex post measured parameters can be recalculated via the following steps:

Step 1: Calculate annual total carbon emissions due to degradation of the baseline activity, $C'_{degradation,t}$, using procedures outlined in Sections 3.2 and 3.3.

Step 2: Calculate annual total carbon emissions due to implementation of baseline activity, $C'_{emissions,t}$, using procedures outlined in Section 3.4.

Step 3: Calculate annual total carbon emissions associated with the baseline scenario, $C'_{baseline,t}$, using Equation 3-1, Section 3.1.

Step 4: Calculate annual total carbon emissions associated with the project activity, $C'_{actual,t}$, using procedures outlined in Section 4.

Step 5: Calculate the annual total carbon emissions associated with leakage, $C'_{leakage,t}$, using procedures outlined in Section 5.

Step 6: Calculate the net anthropogenic GHG emission reductions, $C'_{IFM-LtPF,t}$, using Equation 1-1, Section 1.2.1.

Step 7: Determine the absolute uncertainties for all parameters employed in the calculation of the net anthropogenic GHG emission reductions using the process outlined in Sections 6.2 to 6.5. Using Equations 6-4 and 6-5, calculate the absolute and relative uncertainty, respectively, associated with the net anthropogenic GHG emission reductions. Follow the procedure (Steps 1 and 2) in Section 6.6 to ascertain if an uncertainty deduction must be applied. Proceed to Section 6.7 to reduce the uncertainty of the net anthropogenic GHG emission reductions. Revise the calculation of the net anthropogenic GHG emission reductions.

Step 8: Determine the non-permanence buffer withholding percentage, $NP_{buffer,t}\%$, from the Non-Permanence Risk Assessment (Section 7.2.4) and calculate the carbon credits to be deposited in the VCS buffer withholding pool, $CC_{NPbuffer,t}$, using Equation 1-2, Section 1.2.4.

Step 9: In the case where $C'_{actual,t}$ < $C'_{baseline,t}$, calculate the carbon credits that can be traded after non-permanence buffer credits have been considered, VCU_t, using Equation 1-3, Section 1.2.4.

Step 10: In the case where $C'_{actual,t}$ > $C'_{baseline,t}$, and carbon is lost from the project, the project will be subjected to procedures for cancellation of buffer credits in accordance with VCS rules.

The ex post calculation of the net GHG anthropogenic emission reductions presented in the monitoring report must be verified.

8 References

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Appendices

Appendix A: Definitions and Acronyms

Some of the important definitions of terms used throughout the proposed Methodology have been adapted from the GPG LULUCF published by the IPCC (2003). The definition of terms are presented in Appendix A.1.

The acronyms used throughout the Methodology represent internationally defined terms used widely by the Verified Carbon Standard (see VCS), the Intergovernmental Panel on Climate Change (see IPCC), the United Nations Framework Convention on Climate Change (see UNFCCC), and in the disciplines of agriculture, forestry and geography.

A.1 Definition of Terms

Aboveground Biomass, AGB	Living biomass of the trees above the ground that includes stems, stumps, branches, bark, seeds and foliage.
Wood Density, D	Ratio between oven dry biomass and fresh stem-wood volume without bark; units of (tonne of dry matter) m^{-3} ; used as a parameter in equations.
Branches and trimmings	The trimmed components such as large and small branches, whose carbon is transferred into the deadwood pool after harvesting.
Branch-trim factor	Factor accounting only for the carbon in the large and small branches that remain on the forest floor after the trimming process and whose carbon is transferred into the deadwood pool.
Biomass Conversion and Expansion Factor, BCEF	Factor converting growing stock to aboveground biomass, units of (tonne of dry matter) m^{-3} ; used as a parameter in equations.
Biomass Expansion Factor, BEF	Biomass expansion factor for converting volume of extracted roundwood to total AGB (including bark).
Carbon Fraction, CF	Ratio between quantity of carbon and dry biomass, units of (tonnes of carbon) (tonne of dry matter)$^{-1}$; used as a parameter in equations.
Carbon Pool	Reservoir that has the potential to accumulate (or lose) carbon over a period of time. In IFM-LtPF project activity, the pools to be considered are aboveground biomass, deadwood and wood products.

Commercial Log Length	The length of merchantable logs above the stump height to the minimum top diameter.
Crediting Period	Synonymous with project crediting period as defined in VCS rules
Deadwood, DW	Non-living biomass of woody vegetation not contained in the litter, either standing or lying above the soil level, and stumps larger or equal to 10 cm in diameter, or a nationally-specified diameter; used as a subscript in equations.
Dry Matter	Biomass that has been dried to an oven-dry condition, where the temperature of the oven is usually held at 70 °C.
Ex ante	Before an activity; the estimation of the net GHG emission reductions, before the start of the IFM-LtPF project activity, for the project crediting period.
Ex post	After an activity; the calculation of the actual net GHG emission reductions for the years elapsed since the start of the IFM-LtPF project activity.
Forest	Land with biomass that is defined by a minimum area, level of tree crown cover and tree height. Under the Kyoto Protocol, ranges for the three parameters are: 0.05 - 1.0 hectare with crown cover (or equivalent stocking level) of more than 10 - 30% comprising trees, with the potential of the trees to reach a height of 2 - 5 metres at maturity *in situ*.
Forest Degradation	Biomass that is lost through a measurable decrease in canopy cover, but which is not sufficient to reduce canopy cover to below the percent range specified for forest in the relevant country (Penman et al., 2003).
Forest Inventory Report, FIR	A legally approved or sanctioned document by the relevant authority of the host country that includes, but is not limited to, inventory data, forest management plan, and other forest inventory findings obtainable from the host country's forest inventory database.
Forest Product Type	Forest product type includes sawlog, pulplog and commercially harvested fuelwood. The definition of these products are obtained from the relevant authority of the host country.

Fuelwood, FW	Biomass collected for energy production purposes that includes commercial fellings and trees damaged by natural causes, but does not include wood that is produced as a by-product or residual matter from industrial processing of merchantable logs.
Growing Stock	The total volume (over bark) of all living trees with DBH larger than the minimum DBH as specified by the relevant authority in the host country.
Harvested Wood Products, HWPs	Merchantable logs that will be crafted into products, either classed as long-term or short-term products. An example of merchantable logs that will be made into long-term HWPs (ltHWPs) is sawlogs. Examples of merchantable logs that will be made into short-term HWPs (stHWPs) are pulplogs and logs commercially harvested for fuelwood.
Lumber Recovery Factor	Ratio of the volume of sawnwood products (ltHWPs) recovered from harvested sawlog volumes. Lumber recovery factor subtracted from unity results in sawmill residues from the processing of ltHWPs.
Merchantable Logs	Marketable portion of the merchantable trees as defined by the minimum diameter at breast height and tree top, as specified by the relevant authority in the host country.
Merchantable Trees	Trees with a minimum DBH and tree form as defined by the relevant authority in the host country.
Minimum DBH	The diameter at breast height used for defining a merchantable tree as specified by the relevant authority in the host country.
Monitoring event	The implementation of the monitoring activity for measuring the parameters for net GHG emission reductions after the commencement of the IFM-LtPF project.
Monitoring period	The time taken between monitoring events for collecting measurements in the PSPs in the Project Area, and for reviewing non-monitored parameters.
Non-tree	For the purpose of this Methodology, non-tree has been broadly defined as all the vegetation except the trees with the minimum DBH as specified by the relevant authority in the host country (see footnote ## on page 18). It comprises of ground vegetation (seedlings, saplings, herbs and shrubs), hanging veins and lianas and also woody climbers.

Project Area	Geographic area in which the IFM-LtPF project activity will be implemented that reduce emissions from forest degradation.
Project Boundary	Encompasses (i) geographical boundary, (ii) crediting period, (iii) sources and sinks and associated GHGs, and (iv) carbon pools. In this Methodology, on the basis that the overarching component is the geographical boundary, the Project Boundary is therefore referred to as the geographical area in which the project actions and activities will be implemented.
Residual Stand Damage, RSD	Damage to non-harvested trees due to harvesting operations. The residual stand are damaged either by being knocked down, snapped off or due to limb breakage.
Tropical Forests	Forests growing in the tropical region and comprised of the following four broad forest classes: Evergreen Tropical Rainforest, Moist Deciduous Tropical Forest, Dry Tropical Forest and Upland Tropical Forest (FAO, 1998).

A.2 List of Acronyms Used

Abbreviation	Term

A.3 General Notation of Parameters

Parameter symbol type	Description of parameter function and unit type
$\bar{X}$	a per hectare value
X	a value in any particular year
X'	a tCO_2-e value in any particular year
X''	an absolute value

Reference Notes

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Appendix B: Guidance for Parameter Selection

B.1 Wood Density

Guidance on selecting suitable wood density depends on the type of data available and its application:

Existing Inventory Data Pathway - BCEF Method: Where Less Detailed FIR is Available

Where less detailed FIR information is available and species types are not known, a mean tree density (t d.m.) m^{-3} for the tropical region most appropriate to the Project Area should be employed.

The arithmetic mean and most common wood density values (t d.m.) m^{-3} for tropical tree species in tropical Africa, America and Asia presented in Table B-1, is based on a study by Reyes et al. (1992) using approximately 1280 tree species.

Table B-1 Arithmetic mean for tropical tree species by tropical region (Reyes et al. 1992)

Tropical Region	Arithmetic Mean, (t d.m.) m^{-3}
Africa	0.50
America	0.60
Asia	0.57

Existing Inventory Data Pathway - Allometric Method: Where Detailed FIR is Available

Where species are known, species-specific or group of species-specific wood density should be selected from the following sources:

(i) National species-specific or group of species-specific densities (e.g., from National GHG inventory)

(ii) Species-specific or group of species-specific densities from neighbouring countries of a similar climate region and ecological zone

(iii) Globally species-specific densities (e.g. IPCC, 2006a, Chapter 4, Table 4.13, p. 4.64).

Such data types should be applied at either the species level, for example, in biomass allometric equations that employ species density, along with DBH and H, $f_i(DBH_i, H_i, D_i)$, or applied to determine a weighted average density, based on the dominant species measured in each volume.

A Project Area specific average density can be employed, see Section 7.2.4.1 on how to derive this value.

Measured Data Pathway - Allometric Method: Where FIR Data is not Available

Guidance on density selection is the same as for Existing Inventory Data Pathway - Allometric Method.

B.2 Carbon Fraction

Where species-specific carbon fraction data is not available, the carbon fraction should be obtained from IPCC (2006a), Chapter 4, Table 4.3, p. 4.48, presented here for the tropical and subtropical climate domain in Table B-2:

Table B-2 Carbon fraction for all of tree and wood component for tropical forests (adapted from IPCC, 2006, Chapter 4, Table 4.3, p. 4.49)

Part of Tree	Parameter	Carbon Fraction, tC (t d.m.)$^{-1}$	References
Wood	CF_{wood}	0.49	Feldpausch et al., in IPCC (2006a)
Wood, tree DBH < 10 cm	CF_{wood}	0.46	Hughes et al., in IPCC (2006a)
Wood, tree DBH ≥ 10 cm	CF_{wood}	0.49	
All of tree (AGB)	CF_{AGB}	0.47	Andreae and Merlet, Chambers et al., Lasco and Pulhin in IPCC (2006a)
Default IPCC value, All of tree	CF_{AGB}	0.47	McGroddy et al., in IPCC (2006a)

B.3 Residual Stand Damage

Brown et al. (2005) compiled the factor for residual stand damage (damage over extracted) for various countries and revealed a strong relationship with average commercial log length. The results have been summarised in this Methodology in Table B-3 below.

Table B-3 Factor for residual stand damage (compiled from Brown et. al., 2005, Figure 11, p. 16)

f_{RSD} (tCdamaged tCextracted^{-1})	Commerical Log Length (m)	Country	Reference
1.74	22	Congo	Brown et al. (2005)
2.30	17	Malaysia	Pinard and Putz (1996)
2.78	10.8	Belize	Brown et al. (2005)

f_{RSD} (tCdamaged tCextracted^{-1})	Commerical Log Length (m)	Country	Reference
3.10	9.8	Bolivia	Pearson et al. (2005)

B.4 Lumber Recovery Factor

The lumber recovery factor for sawlog processing is required in order to calculate the volume of the long-term HWP carbon pool.

This factor vary from country to country (see Table B-4), and are dependent on a number of variables that include skilled labour, equipment used, and sawmill facilities (FAO, 2004; Pulkki, 1997).

Table B-4. Country-specific lumber recovery factors

Country (and Sawmill details)	$f_{lumber\_recovery}$, (Range, Where Provided)	Reference
Conventional logging sawmills (*for comparative purposes*)	0.35	FAO (2004)
Cameroon, Malaysia - Sarawak for general use in the absence of country-specific factor	0.36-0.57, dependent on lumber market	FAO (2004)
Ghana	average of 0.40, maximum of 0.50	Loehnertz et al. (1996)
Indonesia (general)	0.45	Silitonga (1987)
Brazil, Old Amazon	0.47	Verissimo et al. (1992)
Indonesia, East Kalimantan	0.50	Muladi (1996)
Malaysia (general)	0.50	Bhargava and Kugan (1988)
Papua New Guinea	average of 0.52 (0.44-0.56)	Kilkki (1992)
Brazil, Maranhao State	0.55	Loehnertz et al. (1996)
Philippines	average value not provided (0.56-0.68)	Niedermaier (1984)

B.5 HWP Rate of Oxidation

The rate of oxidation refers to the proportion of the HWP pool(s) which is oxidized, thereby releasing carbon to the atmosphere. Three approaches can be used to establish the product decay profile for HWP (Ford-Robertson, 2003):

(i) linear decay over the lifetime - so there is nothing left at the end of that period

(ii) exponential decay with a given half-life - in order to generate an equivalent "tonne-year" impact, the half life is equivalent to half of the lifetime used for linear decay

(iii) instant decay of all emissions at the end of the product life - as with the exponential decay, the life used is half of that used for linear decay.

The IPCC default approach (IPCC, 2006b, Chapter 12, Section 12.2.2, p. 12.17) assumes that the carbon in woody material follows a first-order oxidation. It is based on the assumption that HWPs are discarded from use. Table B-5 presents the IPCC default rates of oxidation for HWP categories (ltHWPs and stHWPs).

Table B-5. Rate of oxidation for Harvested Wood Products (adapted from IPCC (2006b), Chapter 12, Table 12.2, p. 12.17)

Harvested Wood Products Category	k_{ltHWP_ox} Rate of oxidation
ltHWPs, e.g. solid wood	0.023
stHWPs, e.g. paper products	0.347

B.6 Harvester Fuel Consumption Factor

Klvac and Skoupy (2009) derived fuel consumption emission factors for equipment required for harvesting operations, as listed in Table B-6.

Table B-6. Equipment types and fuel consumption for harvesting operations (Klvac and Skoupy, 2009)

Operation	Equipment	Factor	Data	Unit
Felling	harvester	Fuel consumption, $FC_{harvest}$	1.28 - 1.73	L m^{-3}

B.7 Electricity Demand of Sawmill Processes

The electricity demand factor can be employed to determine the electricity consumption (kWh) required for a particular volume of merchantable logs. Table B-7 presents data from three international sawmill processes and shows that an approximate range for the electricity demand (e_{demand}) is 20-40 kWh m^{-3}.

Where the country specific value for the electricity demand is available, it should be used. If this is not the case, then a factor from a country that uses similar timber processing technology to that of the project's host country should be used.

Table B-7. Electricity demand for sawmill processing in various countries

Country	Electricity (kWh day $^{-1}$)	Harvest Volume (m^3 day^{-1})	e_{demand} (kWh m^{-3})	Data Source
Indonesia	600	20	30	Budiono (unknown)
Brazil	2756	136	20	Poole and Pinheiro (2003)
New Zealand	-	-	26-41	Li et al. (2006)

B.8 Fuel Consumption Charts

The fuel consumption rate of the generator can be derived from fuel consumption charts for generators. An example is shown in Table B-8 using the generator size (kW) and the anticipated load.

Table B-8 Fuel consumption chart for a diesel generator (Diesel Service and Supply, 2009)

Generator Size (kW)	1/4 Load (kL h^{-1})	Full Load (kL h^{-1})	Generator Size (kW)	1/4 Load (kL h^{-1})	Full Load (kL h^{-1})
20	0.002	0.006	500	0.042	0.135
40	0.006	0.015	750	0.062	0.202
60	0.007	0.018	1000	0.082	0.269
100	0.01	0.028	1250	0.102	0.336
125	0.012	0.034	1500	0.122	0.403
150	0.014	0.041	1750	0.142	0.47
200	0.018	0.055	2000	0.162	0.537
300	0.026	0.081	2250	0.182	0.604

B.9 Forest Product Type

Classification of forest product types into short-term and long-term harvested wood products is presented in Figure B-1 below:

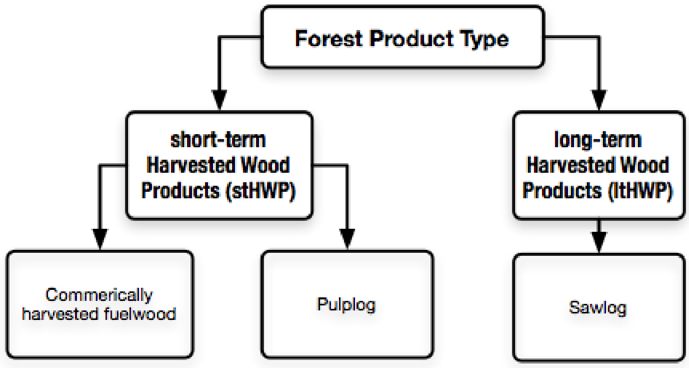

Figure B-1. Classification of forest product types into short-term and long-term harvested wood products

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Appendix C: Unit Conversion and GWP Calculations

C.1 Converting Mass of Carbon (tC) to Carbon Dioxide (tCO_2)

Mass of carbon, which is the typical unit expressed in AFOLU projects, is converted to mass of carbon dioxide gas using the following relationship:

Equation C-1

$$m_{CO_2} = m_{carbon} \times \frac{44}{12}$$

Parameter	Description	Unit
m_{CO_2}	Mass of carbon dioxide	tCO_2
m_{carbon}	Mass of carbon	tC
44/12	Molecular ratio of carbon dioxide to carbon	$tCO_2\ tC^{-1}$

C.2 Converting Other GHGs to Carbon Dioxide Equivalents (CO_2-e)

Other GHGs considered in this Methodology subject to significance as determined in Section 1.2.3, are methane (CH_4) and nitrous oxide (N_2O).

Non-CO_2 gas emission factors must be expressed in carbon dioxide equivalents by multiplying their emission factors by their corresponding global warming potentials (GWPs) and summating the results together to obtain an overall emission factor in terms of carbon dioxide equivalents:

Equation C-2

$$EF = \left(EF_{CH_4} \times GWP_{CH_4}\right) + \left(EF_{N_2O} \times GWP_{N_2O}\right)$$

Parameter	Description	Unit
EF_{CH_4}	Emission factor for methane gas, activity data-specific	tCH_4 (activity data unit#)$^{-1}$
EF_{N_2O}	Emission factor for nitrous oxide gas, activity data-specific	tN_2O (activity data unit)$^{-1}$
GWP_{CH_4}	Global warming potential of methane (*see* Table 2-4)	tCO_2-e tCH_4^{-1}
GWP_{N_2O}	Global warming potential of nitrous oxide (*see* Table 2-4)	tCO_2-e tN_2O^{-1}

activity data unit is the unit of the activity data of either the carbon source or sink, e.g. methane emissions, tCH_4 (kL of fuel)$^{-1}$

Where CH_4 and N_2O are determined to be insignificant (determined from Section 1.2.3) to the overall calculations, and HFCs, PFCs and SF_6 are not included, then CO_2 becomes the sole contributor.

Throughout this Methodology, even if CO_2 becomes the sole contributor toward GHG emissions, it is expressed as CO_2-e.

Global Warming Potentials (GWPs) for CH_4 and N_2O must be selected from the most recent UNFCCC publications (e.g. UNFCCC, 2004).

C.3 Converting Units for Fuel Emission Factor

IPCC (2006) emission factors for GHGs (CO_2, CH_4 and N_2O) are recorded in units of kg of GHG (TJ of fuel)$^{-1}$. As such, for each GHG, the emission factor must be multiplied by the fuel's heating value (in TJ kg^{-1}) and density (kg kL^{-1}) to obtain an emission factor in tGHG kL^{-1}. (e.g. tCO_2-e kL^{-1}, tCH_4 kL^{-1} and tN_2O kL^{-1}).

Equation C-3

$$E_{fuel\_GHG} = \frac{EF_{IPCCfuel\_GHG} \times HV_{fuel} \times \rho_{fuel}}{1000}$$

Parameter	Description	Unit
EF_{fuel_GHG}	Fuel emission factor for the greenhouse gas (CO_2, CH_4 or N_2O)	tGHG kL^{-1}
$EF_{IPCCfuel\_GHG}$	IPCC fuel emission factor for greenhouse gas (CO_2, CH_4 or N_2O)	kgGHG TJ^{-1}
HV_{fuel}	Heating value of fuel	TJ kg^{-1}
ρ_{fuel}	Density of fuel	kg kL^{-1}

Heating value and density of fuels can be found from the IPCC Emission Factor Database (2009).

A CO_2 equivalent (CO_2-e) fuel emission factor (EF_{fuel}) can be derived using the global warming potential (GWP) of each gas as outlined in Section C.2.

Reference Notes

IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Institute for Global Environmental Strategies, Japan.

IPCC Emission Factor Database (2009). http://www.ipcc-nggip.iges.or.jp/EFDB/find_ef_main.php

UNFCCC (2004). Information on Global Warming Potentials: Technical Paper, FCCC/TP/2004/3, pp. 12.

Appendix D: Example Solution to Equations 3-22a and 3-22b

Equation 3-22a is straight-forward and therefore will not be represented here. However, the mathematical expression of Equation 3-22b is complex and therefore warrants an order of example solution of its application. This example applies also to Equation 3-29b as the procedure to the order of solution is similar. For applying this example to Equation 3-29b, replace the subscript "DW" with "ltHWP" or/and "stHWP" as required.

Equation 3-22b

$$C_{DW_{pool,t}} = \left(F_{DW\_remain,t-(t-1)} \times C_{DW_{in},t}\right) + \left(F_{DW\_remain,t-(t-2)} \times C_{DW_{in},t-1}\right) + \left(F_{DW\_remain,t-(t-3)} \times C_{DW_{in},t-2}\right) + \mathrm{K} + \left(F_{DW\_remain,t-(t-t^*)} \times C_{DW_{in},t-(t^*-1)}\right)$$

Parameter	Description	Unit
$C_{DW_{pool,t}}$	Cumulative carbon remaining in the deadwood pool in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC
$F_{DW\_remain_t}$	Annual fraction of carbon in the deadwood pool that would remain in the deadwood pool in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity) after applying the rate of decay	dimensionless
$C_{DW_{in,t}}$	Annual total carbon input to the deadwood pool in year *t*, (where *t*=1,2,3 … *t** years elapsed since the start of the IFM-LtPF project activity)	tC

This example assumes that a specific project has a lifetime of 5 years. Hence, the application of Equation 3-22b becomes:

Year 1 $C_{DW_{pool,1}} = \left(F_{DW\_remain,1} \times C_{DW_{in},1}\right)$

Year 2 $C_{DW_{pool,2}} = \left(F_{DW\_remain,1} \times C_{DW_{in},2}\right) + \left(F_{DW\_remain,2} \times C_{DW_{in},1}\right)$

Year 3 $C_{DW_{pool,3}} = \left(F_{DW\_remain,1} \times C_{DW_{in},3}\right) + \left(F_{DW\_remain,2} \times C_{DW_{in},2}\right) + \left(F_{DW\_remain,3} \times C_{DW_{in},1}\right)$

Year 4 $C_{DW_{pool,4}} = \left(F_{DW\_remain,1} \times C_{DW_{in},4}\right) + \left(F_{ltHWP\_remain,2} \times C_{ltHWP_{in},3}\right) + \left(F_{DW\_remain,3} \times C_{DW_{in},2}\right) + \left(F_{DW\_remain,4} \times C_{DW_{in},1}\right)$

Year 5 $C_{DW_{pool,5}} = \left(F_{DW\_remain,1} \times C_{DW_{in},5}\right) + \left(F_{DW\_remain,2} \times C_{DW_{in},4}\right) + \left(F_{DW\_remain,3} \times C_{DW_{in},3}\right) + \left(F_{DW\_remain,4} \times C_{DW_{in},2}\right) + \left(F_{DW\_remain,5} \times C_{DW_{in},1}\right)$

Tables D-1 and D-2 present the application of Equations 3-21 through to 3-23, for a fixed and variable input to the deadwood pool, applying Equations 3-22a and 3-22b, respectively. For parameter descriptions, please refer to the description tables for relevant equations used in Section 3.3.1 (for deadwood pool) and Section 3.3.2 (for long-term HWP pool).

Table D-1. Numerical example for a fixed input into the deadwood pool (applying Equation 3-22a)

Assume that $C_{DW_{in},t}$ has been calculated to have a fixed annual value of 54,000 tC and k_{decay} determined to be 0.03 yr^{-1}				
Project Lifetime	Equation 3-18	Equation 3-21	Equation 3-22a	Equation 3-23
t (yr)	$C_{DW_{in},t}$ (tC)	$F_{DW\_remain,t}$ (tC)	$C_{DWpool,t}$ (dimensionless)	$C_{DW_{out},t}$ (tC)
1	54,000	0.970	52,404	1,596
2	54,000	0.942	103,259	4,741
3	54,000	0.914	152,612	9,388
4	54,000	0.887	200,505	15,495
5	54,000	0.861	246,984	23,016
* Please note that due to numerical rounding, the values presented in this table may not exactly reflect your calculated values.				

Table D-2. Numerical example for a variable input into the deadwood pool (applying Equation 3-22b)

Assume that $C_{DW_{in},t}$ has been calculated to have a variable annual value (see Column 2) and k_{decay} determined to be 0.03 yr^{-1}				
Project Lifetime	Equation 3-18	Equation 3-21	Equation 3-22b	Equation 3-23
t (yr)	$C_{DW_{in},t}$ (tC)	$F_{DW\_remain,t}$ (tC)	$C_{DWpool,t}$ (dimensionless)	$C_{DW_{out},t}$ (tC)

1	54,000	0.970	52,404	1,596
2	26,000	0.942	76,087	3,913
3	30,000	0.914	102,952	7,048
4	12,000	0.887	111,554	10,446
5	13,000	0.861	120,873	14,127
* Please note that due to numerical rounding, the values presented in this table may not exactly reflect your calculated values.				

VCS | VERIFIED CARBON STANDARD
A Global Benchmark for Carbon

Approved VCS Methodology VM0012

Version 1.2
Sectoral Scope 14

Improved Forest Management in Temperate and Boreal Forests (LtPF)

This methodology is developed by:

3GreenTree Ecosystem Services Ltd.

ERA Ecosystem Restoration Associates Inc.

The previous revision of this methodology to Version 1.2 received support from Camco Group International Inc.

Table of Contents

1 SOURCES

This document reflects an update to VM0012 Improved Forest Management on Privately Owned Properties in Temperate and Boreal Forests (LtPF) v.1.0, which was developed 3GreenTree Ecosystem Services, Ltd. and ERA Ecosystem Restoration Associates, and approved by VCS on April 19, 2011.

This update removes the applicability conditions related to fee simple ownership to become consistent with the VCS Version 3 definitions and requirements related to right of use.

The document has been reorganized to match the VCS Version 3 Project Document Template structure, without materially affecting the original content.

The following documents were used to inform and guide the creation of this methodology:

- VCS Standard 2007.1 (Voluntary Carbon Standard, 2008d)
- VCS Program Guidelines 2007.1 (Voluntary Carbon Standard, 2008e)
- VCS Guidance for AFOLU Projects (Voluntary Carbon Standard, 2008a)
- VCS Tool for AFOLU Methodological Issues (Voluntary Carbon Standard, 2008b)
- Tool for AFOLU Non-Permanence Risk Analysis and Buffer Determination - Proposed (Voluntary Carbon Standard, 2010a)
- CAR Forest Project Protocol Version 3.0 and 3.2 (Climate Action Reserve, 2010)
- VM0003 Methodology for Improved Forest Management through Extension of Rotation Age, v1.0

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology for Improved Forest Management – Logged to Protected Forest quantifies GHG emission reductions/removals from projects on land with forests remaining forests and where carbon sequestration occurs when logging in the baseline scenario is avoided in the project scenario.

2.1 Baseline and Project Scenario Steps:

1. Determine project eligibility and applicability of this methodology.
2. Establish the project area (= private property boundary).
3. Establish a project time horizon.
4. Determine multiple credible and realistic baseline scenarios.
5. Select the baseline scenario
6. Test for additionality using designated tools and requirements.
7. Select the applicable carbon pools and emission sources for the project area.
8. Create detailed baseline scenario and project scenario assumptions:
    a. Spatially stratify the current land cover and land use conditions by area, if necessary:
    b. Determine the timber harvesting land base area(s)
    c. Project the baseline and project scenario forest management schedule, including forest regeneration practices, for a minimum of one rotation. Include spatially located harvestable volume and area by analysis unit and year, identify stand level harvesting methods and assumptions, and identify additional relevant scenario modeling information.
    d. Project the net annual ecosystem carbon stock changes over time under the baseline and project scenarios, including changes due to harvest removals, regeneration, stand growth, mortality, and any additional factors that materially affect carbon balance.
9. Calculate annualized and project total ex-ante carbon pool flows and GHG Emissions for the baseline and project scenarios.

10. Calculate the net change in GHG emissions between the ex-ante ecosystem carbon projections for the baseline and project scenarios, on an annualized basis.
11. Assess leakage risks to determine a leakage factor to be applied to the net annual GHG emission changes.
12. Calculate and estimate the expected net VCU's, including calculating VCS permanence buffer requirements.
13. Calculate and apply an uncertainty factor to net GHG emission reductions.

2.2 Monitoring Steps:

1. Determine the data and assumptions to be monitored to assess ex-post carbon stock changes in the project area.
2. Determine remote sensing activities for monitoring ex-post land use changes on the project area.
3. Develop and implement a systematic field plot network for estimating and monitoring actual stand level biomass within the project boundary.
4. Develop and implement a leakage monitoring plan.
5. Develop a record-keeping procedure to record and archive monitoring activities, results, and related management actions.
6. Design a quality assurance/quality control program related to monitoring.

3 DEFINITIONS

Boreal Forest - as per FAO ecological zone definitions and mapping (FAO, 2001): "The Boreal, or subarctic, domain is found only in the higher latitudes of the Northern Hemisphere between 50-55 to 65-70 degrees. It has at least one and up to 4 month with an average temperature above 10^{o}C. Another feature is the large annual range of temperature. Rainfall is low, generally below 500 mm. The northern boundary, approximately the isotherm of 10^{o}C for the warmest month (usually July), coincides rather well with the poleward limit of tree growth."

Clear cut - Harvest removal of >90% of merchantable trees within a defined area

De minimis – carbon emissions deemed to be insignificant or immaterial to the total GHG calculations. Unless otherwise specified, *de minimis* refers to activities resulting in <5% change in the total project GHG emission reductions. See (CDM, 2007a) for further details.

Logging slash - Dead wood residues (including foliage) left on the forest floor after timber removal

Right of Use – As defined in the most recent version of the VCS Standard.

Temperate Forest – as per FAO ecological zone definitions and mapping (FAO, 2001): "The temperate domain occupies a medial position within the middle latitudes – usually between the subtropical domain equator-wards and the boreal domain pole-wards. The boundaries with the subtropical - and boreal domain are 8 months and 4 months, respectively, with average temperatures of 10°C or above. Its main distribution is in the northern hemisphere".

Timber Harvest Land Base (THLB) – a sub-set of the project area land base subject to timber harvesting, including spatially located areas or reasonable volume-based proxies within the project boundaries which are currently considered biologically and economically feasible for timber harvesting as per typical regional logging practices relevant to the project site. Removals from the THLB may include, but are not limited to: non-forest areas; non-commercial forest types; physically inoperable or inaccessible areas due to terrain, soils, etc.; current and future roads and other non-forest clearings; legally required or voluntary buffers and protected areas (i.e.

riparian zones, wildlife areas, sensitive sites, etc.), long run uneconomical stands, and other areas which are not eligible for harvesting under typical or common practices determined in the baseline and project scenarios. Examples of determining THLB can be found within British Columbia Timber Supply Analysis documentation at http://www.for.gov.bc.ca/hts/tsas.htm in Timber Supply Area (TSA) Analysis Reports (i.e. pg. 10, http://www.for.gov.bc.ca/hts/tsa/tsa13/tsr2/analysis.pdf); however, projects must use methods typical of local forest estate modeling and timber supply analyses. Note that the THLB is a primary stratification which identifies areas eligible for harvesting activities; all project requirements apply to the entire project area.

Tree - A perennial woody plant with a diameter at breast height > 5 cm and a height greater than 1.3 m.

Acronyms:

CAR – Climate Action Reserve

CDM - Clean Development Mechanism

GPG LULUCF - Intergovernmental Panel on Climate Change‘s Good Practice Guidance for Land-Use, Land Use Change and Forestry

IFM - Improved Forest Management (VCS project type)

LtPF – Logged to Protected Forest (VCS IFM project sub-type)

PD - Project Description

VCS - Verified Carbon Standard

VCU - Verified Carbon Units

4 APPLICABILITY CONDITIONS

This methodology is applicable to:

1. Projects which meet the most recent approved criteria for VCS Improved Forest Management – Logged to Protected Forest (IFM-LtPF) eligible projects, and;

2. Projects located in Temperate and Boreal Domain Global Ecological Zones (as defined by FAO (FAO, 2001)) which are forest lands remaining forest lands (as defined by IPCC (IPCC, 2003)), and which can meet IPCC GPG LULUCF Tier III inventory and data requirements (IPCC, 2003); and,

3. Projects that meet the most current approved VCS Standard requirements for ownership; and,

4. Projects on properties where the *starting* average annual illegal, unplanned, and fuelwood removals are less than 5% of total annual harvest levels (in CO_2e) in the baseline scenario[1]; and,

[1] This methodology does not provide specific equations and methods for the treatment of illegal and unplanned harvesting or fuelwood removal. Therefore, projects with non-*de minimis* levels (determined using the Tool for Testing Significance of GHG Emissions in A/R CDM Projects (CDM, 2007a)) of these activities in the starting condition (or as local common practice applicable to the project area) are ineligible. If monitoring reveals conditions change during the project duration, projects will not necessarily be rendered ineligible for this methodology, but rather must demonstrate that new non-*de minimis* illegal or unplanned harvests, and fuelwood removal net emissions reductions are accounted for in the project scenario prior to the next verification, in a manner equivalent to the terms $LB_{FELLINGS,i,t}$ and $LB_{OTHER,i,t}$ (see section 8.2.7). These additional equations and methods will constitute a methodology revision, subject to the latest approved VCS revision -approval process.

5. Projects which do not encompass managed peatland forests (peatland as defined by IPCC GPG LULUCF); and,

6. Projects where the total percentage of wetlands in the project area is not expected to change as part of project activities; and,

7. Projects that can demonstrate there will be no activity shifting to other lands owned or managed by project proponents outside the project boundary at the beginning of the project (within the first year of the project start date)[2]; and,

8. Projects that do not include non-*de minimis* application of organic or inorganic fertilizer in the project scenario.

5 PROJECT BOUNDARY

5.1 Spatial Project Boundaries:

The project boundary is to be defined by the project proponent with maps and legal land descriptions. Such properties may be contiguous or separate properties if they are located within a similar region and forest condition.

Note that all spatially relevant forest land holdings owned or managed by the project proponent will need to be considered in leakage assessments and monitoring, even if they are not included in the defined project area.

5.2 Temporal Project Boundaries

As per VCS requirements for AFOLU projects, project proponents must specify a project-crediting period as set out in the most recent version of the VCS Standard. .

5.3 Leakage Assessment Boundaries

Leakage within this methodology is assessed against a national leakage area.

5.4 Selected Carbon Pools and Emissions Sources:

Table 1 - Selection of Carbon Pools

Carbon Pool	Selected?	Justification/Explanation
Aboveground Tree Biomass	Yes	Required by VCS. Major carbon pool subject to changes from the baseline to the project scenario.
Aboveground Non-tree Biomass	No	Excluded by VCS. Minor carbon pool subject to changes from the baseline to the project scenario
Belowground Biomass Pool	Yes	Required by VCS. Major carbon pool subject to changes from the baseline to the project scenario.

[2] This methodology does not provide specific equations and methods for calculating net emissions related to activity shifting leakage. VCS requires "IFM project developers must demonstrate that there is no leakage within their operations – i.e., on other lands they manage/operate outside the bounds of the VCS carbon project" (Voluntary Carbon Standard, 2008a); and the methodology requires monitoring and reporting on evidence demonstrating no activity shifting is occurring in order to demonstrate compliance with VCS. If, during the project duration, activity shifting is found to be occurring, project should to refer the latest VCS AFOLU requirements.

Dead Wood Pool	Yes	Required by VCS. Minor carbon pool subject to changes from the baseline to the project scenario.
Litter Pool	No	Excluded by VCS for AFOLU projects. Minor carbon pool – generally considered as a transitional pool only.
Soil Carbon Pool	No	Optional in VCS AFOLU IFM projects, but excluded in this methodology. As a conservative approach, changes to soil carbon from harvesting are assumed to be *de minimis*.
Wood Products Pool	Yes	Required by VCS. All baseline scenarios involve logging.

Table 2 - Emissions Sources Included/Excluded from the Project Boundary

Emissions Sources	Gas	Selected?	Justification/Explanation
Use of Fertilizers	CO_2 CH_4 N_2O	No No No	Non-*de minimis* use of fertilizer in the project scenario is excluded. In the baseline scenario, fertilizer emissions are deemed insignificant, as per the VCS May 24th, 2010 AFOLU Program Update (Voluntary Carbon Standard, 2010c). These exclusions are conservative, and do not increase the emission reductions.
Combustion of Fossil Fuels by Vehicles / Equipment	CO_2 CH_4 N_2O	Optional[3] No No	Carbon emissions from harvesting equipment, log transport, and primary forest product manufacturing are included. CH_4 and N_2O emissions from equipment are assumed to be *de minimis*. The exclusion of these combustion gases does not increase the emissions reductions in the project.
Burning of Biomass (on site slash burning)	CO_2 CH_4 N_2O	No No No	However, carbon stock decreases due to biomass burning are accounted as a carbon stock change. These exclusion assumptions do not increase the emission reductions in the project.

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO:

This methodology utilizes a project-based baseline scenario approach.

[3] Project developer may choose to exclude this pool is it can be demonstrated that it is conservative with respect to the impact on GHG emission reductions generated.

The flow of GHG emissions over the project duration is based on the creation and projection of a reasonable, credible, and conservative baseline harvesting scenario in the absence of the carbon project. The most plausible baseline scenario is selected from a comparative assessment of the project and the baseline alternatives, including "at a minimum, a comparative assessment of the implementation barriers and net benefits faced by the project and its alternatives" (Voluntary Carbon Standard, 2008d).

This methodology will employ a 3 step process to select a most likely baseline, and is required to be consistent with the assessment and determination of additionality in Section 7[4]:

STEP 1 – Identify Plausible Alternative Baseline Scenarios to the VCS Project Activity

Project proponents must identify and document descriptions, rationale, and information sources for multiple *(at minimum 3)* realistic and credible property forest management scenarios that would have potentially occurred within the proposed project boundary in the absence of the carbon project activity.

The possible baseline scenarios to be evaluated must include, at minimum:

1. Historical Practice Baseline Scenarios: continuation of pre-project historical activity baseline or management plans;
2. Common Practice Baseline Scenarios: activity on the project area which could have been performed without the carbon project, based on evidence of comparable forest management for similar property types and situations in the region[5];

All identified baseline scenarios must, at a minimum:

1. Comply with IFM-LtPF project and eligibility requirements by only including activities and areas where forests remain forests;
2. Comply with legal requirements for forest management and land use in the area, "unless verifiable evidence can be provided demonstrating that common practice in the area does not adhere to such requirements" (Voluntary Carbon Standard, 2008d)[6];
3. Demonstrate that the "projected baseline scenario environmental practices equal or exceed those commonly considered a minimum standard among landowners in the area" (Voluntary Carbon Standard, 2008d).

Realistic and credible baseline scenarios must be based on verifiable information sources such as local or regional land, harvest, or inventory records, observable comparable regional property evidence, formal property appraisals, financial modeling compared against typical published regional industry market return rate targets, regional stakeholder feedback, accredited or certified professionals (i.e. registered professional foresters, etc.) within the regional relevant industry, and other reasonable information sources provided in a manner consistent with typical regional considerations and practices.

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[4] Although only required as part of the Additionality assessment, project proponents may find utilizing the Tool for the Demonstration and Assessment of Additionality in VCS AFOLU Project Activities (VCS, 2010b) to be useful for additional guidance for identifying and selecting baseline scenarios.

[5] Also considering the financial drivers for management activities based on verifiable market-based financial return expectations of typical market property owners and investors (i.e., IRR, NPV, cost of capital hurdle rates, etc. for data comparisons with available market financial information).

[6] Note that VCS further states: "if it can be shown that these activities result from laws, statutes, regulatory frameworks or policies implemented since 11 November 2001 that give comparative advantage to less emissions-intensive technologies or activities relative to more emissions-intensive technologies or activities they need not be taken into account and the baseline scenario could refer to a hypothetical baseline rate of avoided emissions or sequestration without the national and/or sectoral laws, statutes, regulatory frameworks or policies being in place." (Voluntary Carbon Standard, 2008d).

Project proponents may utilize tools such as the Investment Analysis (Step 2) and Barrier Analysis (Step 3) of the latest approved version of the VCS Tool for Demonstration and Assessment of Additionality as an initial filter to exclude project scenarios which are financially infeasible or face clear barriers to implementation.

The remaining baseline scenarios are then further evaluated to select the most likely baseline scenario, as follows.

STEP 2 – Selection of a Single Baseline Scenario for the Project

Project proponents must select a single baseline scenario for the project using the following steps:

STEP 2a - The Historical Baseline Scenario – based on historical operating practices on the property:

The baseline scenario based on actual property harvest history *must be selected if*:

2a.1 The project proponent has at least 5 years historical harvest level data history[7].

All other cases will utilize the Common Practice Baseline Scenario Selection steps below:

STEP 2b - The Common Practice Baseline Scenario – based on previous owner activities:

2b.1 If the current project proponent has owned the property for less than five years then the project proponent may:

- i. Choose to use the previous managers historical activities or management plan as representative of common practice, in which case the baseline scenario is selected based on the process and criteria in Step 2a; *or*,
- ii. Choose to select the baseline scenario based on common practice and investment analysis of scenarios as outlined in Step 2c below.

STEP 2c - The Common Practice Baseline Scenario – based on common practice activities:

For recent or pending changes in project property management without historical data (> 5 years) (or otherwise not selecting a historical baseline scenario as per Step 2b), the project proponent will select the baseline scenario(s) based on an assessment of regional common practice[8] supported by a financial analysis for achieving typical market returns from forest products.

The project proponent must select the baseline scenario that:

2c.1 Generates the most financial attractive return on investment from forest product returns using the assessment process outlined in Step 2 Option II and/or Option III in the most recent version of the VCS Tool for the Demonstration and Assessment of Additionality in VCS AFOLU Project Activities; and,

2c.2 Can be demonstrated to be regionally common practice and locally operationally implementable, including:

- a. Compliant with the legally required land use and forest management practices in a manner consistent with VCS requirements (see Step 1);

[7] For convenience, projects may utilize a pre-existing forward-looking forest management plan as the historical baseline data, if this management plan can be demonstrated to be consistent with the historical practices and rates, and representative of a forward projection of historical harvest practices.

[8] VCS currently defines common practice as: "Extrapolation of observed similar activities in the geographical area with similar socio-economic and ecological conditions as the project area occurring in the period beginning ten years prior to the project start date" (VCS, 2010b).

b. Consistent with local market capacity for the baseline scenario activities and products (i.e. log markets, contractor capacity, etc.);
c. Consistent with observable and verifiable[9] regional operational practices, including, at minimum:
   i. Harvest types (i.e. clearcut, selective cut, etc.),
   ii. Logging and hauling equipment types and capabilities,
   iii. Annual harvest levels (i.e. m^3/year, ha/year),
   iv. Average minimum harvest age, tree size, and/or stand volume,
   v. Average minimum economic viability (or decision criteria) by stand type,
   vi. Average minimum log utilization specifications (on average based on size and/or species), and waste/breakage assumptions,
   vii. Average tree retention practices, including hydro-riparian buffers, wildlife trees, and other single or grouped merchantable and un-merchantable tree retention,
   viii. Maximum harvest slope or other operability constraints which would limit regional logging equipment,
   ix. Reforestation and stand management practices; and
d. Operationally feasible on the project area using local harvesting and hauling technology, local infrastructure, etc. [10].

Project proponents must provide a description of the selected baseline scenario and related scenario modeling assumptions which justifies and provides supporting evidence that the baseline scenario selected under STEP 2c reflects a credible assessment of typical common practice for similar conditions, as listed above.

STEP 3 – Additionality Test

Project proponents must further ensure the selected most plausible baseline scenario is consistent with the outcome of the additionality assessment of this scenario made under Section 7 in this methodology.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

Project proponents must use the newest version of the VCS tool: "Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities". In summary, this tool employs the following steps:

Step 1 - *Identification of alternative land use scenarios to the AFOLU project activity;*

Step 2 - *Investment analysis to determine that the proposed project activity is not the most economically or financially attractive of the identified land use scenarios; or*

Step 3 - *Barriers analysis; and*

Step 4 - *Common practice analysis.*

Project proponents must insure the assessment and outcomes of additionality are consistent with the baseline selection assessment undertaken in Section 6.

[9] Demonstrated by reviewing modeled baseline scenario assumptions in comparison to: directly observable activities on other regional properties, verifiable documentation from previous or current owner/manager operational requirements, property or comparable property appraisals or valuation document assumptions, published documents reviewing regional operational practices, comparable published regional government requirements, testimony of independent local experts and professionals, and/or other verifiable sources.

[10] For example, a baseline scenario could not be selected if it involved using equipment (i.e. helicopter logging) not available regionally. A baseline could not be selected which projected a level of harvest the local mills, road infrastructure, and contractor capacity could clearly not physically handle annually without significant additional capital investment. Relevant independent local expert opinion may be used to further demonstrate the reasonableness of local capacity assumptions.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions:

The baseline emissions are calculated from the baseline scenario selected in Section 6. This baseline scenario does not change during the project duration, however, as outlined in Section 8.2.4, certain data or model parameter changes may require remodeling baseline carbon pools in future verifications.

All calculations in this methodology represent annualized net changes in carbon stocks by polygon. Results from each polygon must therefore be summed across the project activity area to determine the annual total net emissions and reductions.

Valid Starting Inventory Requirements

Project proponents must provide a valid starting forest inventory meeting the following requirements:

1. Pertaining directly to the entire project area; and,
2. Created, updated, or validated <10 years ago; and,
3. Documentation is available describing the methods used to create, update, or otherwise validate the starting inventory, including statistical analysis, field data, and/or other evidence[11,12].

Baseline Scenario Area Stratification

The process of stratifying the area represented in the baseline scenario should include two steps. The first is to divide the area (A_{BSL}) into homogeneous units (polygons) from the perspective of carbon storage and sequestration. The second step is to identify areas within the project area that are eligible for specific forest management activities within the baseline and project scenario.

STEP 1 – Stratify to create homogeneous units

If the project activity area is not homogeneous, stratification should be carried out to improve the accuracy and precision of biomass estimates[13]. Different stratifications may be required for the baseline and project scenarios in order to improve accuracy in the estimates of net GHG removal by sinks. For estimation of the baseline net GHG removals by sinks, or calculation of actual net GHG removals, homogeneous *polygons*[14] *should be defined on the basis of parameters that will be used as key entry variables in the methods used to estimate changes in biomass stocks* (for example, growth models or yield curves/tables). These include:

1. Management regime. For example, types of harvesting (clear cutting, patch retention), and land conversions for roads and landings.
2. Site index / anticipated growth rates
3. Forest species
4. Age class

Useful tools for defining polygons include ground-truthing maps from satellite imagery, aerial photos, and maps of vegetation, soils, and topography.

[11] Note that this methodology evaluates uncertainty using actual results from an ex-post plot network program (see Section 8.5.3) and hence does not mandate a starting inventory accuracy requirement. Project proponents, however, must provide evidence that the starting inventory has been validated to regional common practice minimum standards for use in ex-ante modeling.

[12] Project proponents may provide supporting evidence using local inventory validation results from outside the project area if: they are based on directly comparable inventory methods, overall average forest cover and condition are comparable, and if the data refer to comparable or larger scale properties.

[13] For further details, see http://cdm.unfccc.int/methodologies/DB/YDYGY2G5VNPKVHB7B9SU12RRWRL439/view.html

[14] At minimum, more than one polygon per project is required for the statistical calculations in Section 8.5.3.

In the case where a project area is large and spans a diverse range of forest types and ages, the area may need to be stratified into hundreds or even thousands of polygons. When the number of polygons is ≥ 25, the proponent has the option of aggregating similar polygons into "*analysis units*[15]" to facilitate modeling and monitoring. This practice is common when planning management activities over large forest management areas. The use of *analysis units allows polygons to be grouped based on similarities in the polygon criteria, including removing differences associated with stand age*. Each analysis unit is modeled from the period of stand initiation to a mature end point. The attributes (e.g. biomass and dead organic matter pools) of each analysis unit are recorded for every year of growth and stored in a database that can easily be linked back to a specific stand age.

STEP 2 – Identify areas eligible for specific management activities

To assure the project includes only eligible management activities, proponents must identify areas within the project boundary that would be subject to timber harvesting and other management activities under the baseline scenario. A timber harvesting land base (THLB) should be identified based upon harvesting plans that reflect the historical and future anticipated location and rates of timber extraction. Specific information used to define the THLB should include:

1. The spatial location and extent of forested versus non-forested areas
2. Merchantable and operable forest areas suited to economic timber extraction
3. The spatial location and extent of legal land use restrictions and legally required protected areas.

The THLB is essentially used to refine and focus baseline and project forest management activity projections and modeling, in a manner consistent with the selected scenarios and related common practice.

8.1.1 Model Selection and Use

It will be necessary to employ mathematical models to project annual carbon stock changes over time in the various carbon pools. Although it may be possible to utilize a series of spreadsheet calculations for simple forest situations, in most cases complex forest management models (both at the stand and landscape-level) will need to be employed. Regardless of the type of model used, the same model must be used for both the baseline and project scenarios to ensure consistency in the carbon projections.

A hierarchy of suitability should be applied in selecting an appropriate model, in accordance with the following criteria:

1. Well established (i.e., have been under continuous use and development for 10 years, or longer);
2. Generate values on an annual basis (preferably), or at intervals not exceeding 10 years.
3. Include a reasonable representation of mortality from stand-self thinning and natural disturbance agents that are regionally appropriate. Adjustments may need to be made by project proponents to account for these factors if they are not well represented. Rationale must be provided when making adjustments.
4. Output data are expressed in carbon units (tC/ha) or as biomass (t/ha), and are calculated for each of the required carbon pools (See Table 1). If expansion factors are used in combination with growth and yield model(s), they should be based upon regionally specific studies and applied only for the appropriate region and species.
5. Well documented and expert reviewed. In order of preference, these include (a) ongoing publications in peer-reviewed scientific journals, (b) documented reviews by expert practitioners in forestry/biology/ecology, and/or (c) approved by government for use in forest management activities;
6. Parameterized, calibrated, and tested for the specific conditions of the project.

[15] At minimum, more than one analysis unit is required for the statistical calculations in Section 8.5.3.

The following criteria are preferred but not required:

7. Documented as appropriate for simulating the ecological and management scenarios that define the baseline and project case;
8. Process-based models that simulate carbon dynamics directly (in the case of stand-level models) or in the case of landscape models (i.e. forest estate models), be driven by inputs from these stand level models. Process models that simulate all carbon pools within an ecosystem are preferred because their projections of carbon dynamics in the required and optional pools should be more accurate and easier to monitor and verify. Examples of appropriate stand-level growth models include FORECAST (Seely, Kimmins, Welham, & Scoullar, 1999), and CO2FIX (Masera & et al, 2003)
9. Growth and yield models are commonly used to project productivity in managed and unmanaged forest stands. In most cases their output is in the form of an annual merchantable timber volume increment. Examples include TASS/TIPSY, and VDYP (British Columbia Ministry of Forests and Range[16]), and the US Forest Service's Forest Vegetation Simulator (FVS) model[17]. This approach is less desirable because volume must be converted using a series of expansion factors representing each carbon pool. An example of this approach is the Carbon Budget Model of the Canadian Forest Service (CBM CFS3 (Kurz & et al., 2009), which uses volume curves as input data. For details on the use of expansion factors, see Pearson et al. 2007. This extra step in conversion introduces the potential for additional error into the pool estimates.

In addition, project proponents will make available, at validator/verifier request, documentation of:

1. The appropriateness of the selected model(s) to the particular project application;
2. A listing and explanation of all input data, output data, and model parameters/assumptions.

8.1.2 Calculating the Baseline Carbon Balance

This methodology employs the IPCC gain-loss method (IPCC, 2006a), which requires the biomass carbon loss be subtracted from the biomass carbon increment for the reporting year. This method is particularly appropriate for areas with a mix of stands of different forest types, and/or where biomass change is very small compared to the total amount of biomass. Further details can be found in (IPCC, 2006a) (Ch. 4).

The total annual carbon balance in year, t, for the baseline scenario is calculated as ($\Delta C_{BSL,t}$, in t C yr^{-1}):

$$\Delta \mathbf{C}_{\mathbf{BSL,t}} = \Delta \mathbf{C}_{\mathbf{BSL,P,t}} \qquad \mathbf{(1)}$$

where:

$\Delta C_{BSL,P,t}$ = annual change in carbon stocks in all pools in the baseline across the project activity area; t C yr^{-1} .

$$\Delta \mathbf{C}_{\mathbf{BSL,P,t}} = \Delta \mathbf{C}_{\mathbf{BSL,LB,t}} + \Delta \mathbf{C}_{\mathbf{BSL,DOM,t}} + \Delta \mathbf{C}_{\mathbf{BSl,HWP,t}} \qquad \mathbf{(2)}$$

where:

$\Delta C_{BSL,LB,t}$ = annual change in carbon stocks in living tree biomass (above- and belowground); t C yr^{-1}

$\Delta C_{BSL,DOM,t}$ = annual change in carbon stocks in dead organic matter; t C yr^{-1}

$\Delta C_{BSl,HWP,t}$ = annual change in carbon stocks associated with harvested wood products, t C yr^{-1}.

[16] http://www.for.gov.bc.ca/hre/StandDevMod/index.htm

[17] http://www.fs.fed.us/fmsc/fvs/

$$\Delta C_{BSL,LB,t} = \Delta C_{BSL,G,t} - \Delta C_{BSL,i,t} \quad (3)$$

where:

$\Delta C_{BSL,G,t}$ = annual increase in tree carbon stock from growth; t C yr^{-1}

$\Delta C_{BSL,L,t}$ = annual decrease in tree carbon stock from a reduction in live biomass; t C yr^{-1}.

If the project area has been stratified, carbon pools are calculated for each polygon, i, and then summed during a given year, t.

8.1.3 Live Biomass Gain

Live biomass gain in year, *t*, polygon, *i* ($\Delta C_{BSL,G,i.t}$) is calculated as:

$$\Delta C_{BSL,G,t} = \Sigma(A_{BSL,i} \bullet G_{BSL,i,t}) \bullet CF \quad (4)$$

where:

$A_{BSL,i,}$ = area (ha) of forest land in polygon, *i*;

$G_{BSL,i,t}$ = annual increment rate in tree biomass (t d.m. ha^{-1} yr^{-1}), in polygon, *i*, and;

CF = carbon fraction of dry matter t C t^{-1} d.m. (IPCC default value = 0.5).

$$G_{BSL,i,t} = G_{BSL,AG,i,t} + G_{BSL,BG,i,t} \quad (5a)$$

where:

$G_{BSL,AG,i,t}$ and $G_{BSL,BG,i,t}$ = annual above- and belowground biomass increment rates (t d.m. ha^{-1} yr^{-1});

$$G_{BSL,BG,i,t} = G_{BSL,AG,i,t} \bullet R_i \quad (5b)$$

where R_i is the root:shoot ratio in polygon, *i*. R_i should ideally be estimated for each polygon, but these data are difficult to derive empirically. Hence, general relationships are acceptable as long as they are appropriate for the species and region associated with the project (Cairns, 1997).

Equations 4 and 5 can be used directly to calculate $\Delta C_{BSL,G,t}$ when all tree cover within a polygon is removed by harvesting (i.e., clearfelling) and no residual structure is retained. In cases of partial harvesting and/or multiple entries into a polygon, these equations must be applied separately to each of the resulting sub-polygons (the different age classes that are created). This ensures that growth rates reflect the difference in forest age between the sub-polygons.

The ex ante calculation of $G_{BSL,i,t}$ (either directly, or from its component parts) will be derived from models that require inputs derived, in part, from forest inventory data. Criteria for model suitability are provided in 8.1.1.1. The exact form of the input data depends on the nature of the model but may include site index, species composition, and volume.

Inventory data used for this purpose must:

1. Pertain directly to the project area, and
2. Not be more than 10 years old.

Typically, inventory data provide only a generalized description of stand attributes such that only average values (versus species-specific estimates) can be used in the ex ante modeling exercise.

Some models will require estimates for parameter values not traditionally measured in typical forest inventories activities. Project proponents must make reasonable efforts to acquire sources of such data in accordance with the following priority list (best to least desirable):

1. Project area and forest-type specific
2. Regional estimates, from the same or similar ecosystems or forest types
3. National estimates that represent averages for similar forest types
4. Global estimates for generally similar forest types.

8.1.4 Live Biomass Loss

The annual decrease in live biomass tree carbon from live biomass loss ($\Delta C_{BSL,L,t}$; t C yr^{-1}) is the sum of losses from:

1. Natural mortality (i.e. insects, disease, competition, wind, etc.)
2. Commercial round wood felling
3. Incidental sources.

Losses must be specific to a given polygon; each polygon must be summed in order to calculate total annual loss across the project activity area. The live biomass losses are not emitted directly, but rather are transferred to dead organic matter pools.

$$\Delta C_{BSL,L,t} = \Sigma(LBL_{BSL,NATURALi,t} + LBL_{BSL,FELLINGS,i,t} + LBL_{BSL,OTHER,i,t}) \bullet CF \quad (6)$$

where:

$LBL_{BSL,NATURALi,t}$ = annual loss of live tree biomass due to natural mortality in polygon, *i*; t d.m. yr^{-1}

$LBL_{BSL,FELLINGS,i,t}$ = annual loss of live tree biomass due to commercial felling in polygon, *i*; t d.m. yr^{-1}

$LBL_{BSL,OTHER,i,t}$ = annual loss of live tree biomass from incidental sources in polygon, *i*; t d.m. yr^{-1}

CF = carbon fraction of dry matter; t C t^{-1} d.m. (IPCC default value = 0.5).

$$LBL_{BSL,NATURALi,t} = A_{BSL,i} \bullet LB_{BSL,i,t} \bullet f_{BSL,NATURAL,i,t} \quad (7)$$[18]

where

$A_{BSL,i}$ = area (ha) of forest land in polygon, *i*;

$LB_{BSL,i,t}$ = average live tree biomass (t d.m. ha^{-1}) in polygon, *i,* for year, *t*

$LB_{BSL,i,t}$ is calculated for year, *t*, beginning with biomass estimates in year *t*=1 (the project start year) and with annual biomass increments ($G_{BSL,i,t}$) added as per calculations in equation 5a.

$f_{BSL,NATURAL,i,t}$ = the annual proportion of biomass that dies from natural mortality in polygon , *i* (unitless; $0 \leq f_{BSL,NATURALi} \leq 1$), year, *t*. Tree mortality is an ongoing process during stand development. Trees die as a consequence of insect attack, disease, competition, or some combination thereof. Hence, mortality can be highly

[18] Note, for Equation 7, 8, and 9: **$(f_{BSL,NATURAL,i,t} + f_{BSL,HARVEST,i,t} + f_{BSL,DAMAGE,i,t}) \leq 1.0$**

variable between years. This parameter can be applied uniformly across an analysis unit, or individually to a given polygon. Sources for mortality estimates include permanent sample plots in similar stand types, literature reports, and inventory data.

$$\mathbf{LBL_{FELLINGS,i,t} = A_{BSL,i} \bullet LB_{BSL,i,t} \bullet f_{BSL,HARVEST,i,t}} \quad \mathbf{(8)}$$

where:

$A_{BSL,i}$ = area (ha) of forest land in polygon, *i*

$LB_{BSL,i,t}$ = average live tree biomass (t d.m. ha^{-1}) in polygon, *i,* for year, *t* (see equation 7 for its calculation).

$f_{BSL,HARVEST,i,t}$ = the proportion of biomass removed by harvesting from polygon, *i,* (unitless; $0 \leq f_{BSL,HARVESTIi} \leq 1$), in year, *t*. Data for this variable should be obtained from harvest schedule information. Values may be constrained by (a) the value of $f_{BSL,NATURAL,i,t}$ (i.e., $f_{BSL,HARVEST,i,t} < 1 - f_{BSL,NATURAL,i,t}$), and/or (b) the area of timber available for commercial harvest.

Incidental loss ($LBL_{BSL,OTHER,i,t}$; t d.m. yr^{-1}) is the additional live tree biomass removed for road and landing construction in the polygon, *i*, and is calculated as a proportion of biomass removed by harvesting:

$$\mathbf{LBL_{BSL,OTHER,i,t} = A_{BSL,i} \bullet LB_{BSL,i,t} \bullet f_{BSL,DAMAGE,i,t}} \quad \mathbf{(9)}$$

where:

$A_{BSL,i}$ = area (ha) of forest land in polygon, *i*;

$LB_{BSL,i,t}$ = average live tree biomass (t d.m. ha^{-1}) in polygon, *i,* for year, *t*

$f_{BSL,DAMAGE,i,t}$ = the proportion of additional biomass removed for road and landing construction in polygon, *i,* year, *t* (unitless; $0 \leq f_{BSL,DAMAGE,i,t} \leq 1$)[19]. Data for this variable should be based on regional and local comparative studies and experiential information derived from the local forest industry[20].

8.1.5 Dead Organic Matter Dynamics ($\Delta C_{BSL,DOM}$)

Dead organic matter (DOM) included in this methodology comprises three components: standing dead wood (minimum ≥ 5 cm DBH and 1.3 m height; termed snags), lying dead wood (minimum ≥ 5 cm DBH; LDW), and belowground dead wood (i.e., dead roots). Standing dead wood is < 45º of vertical, while lying dead wood is ≥ 45º of vertical. Carbon stored within dead belowground biomass and lying dead wood pools must not be assumed to be released immediately following disturbance. Rather decay must be modeled using a scientifically credible decay function (such as the exponential model referenced in Equation 13) in which a minimum of 10 years is required for complete loss of stored carbon.

The annual change in carbon stocks in DOM ($\Delta C_{BSL,DOM}$; t C yr^{-1}) is calculated as:

$$\mathbf{\Delta C_{BSL,DOM,t} = \Delta C_{BSL,LDW,t} + \Delta C_{BSL,SNAG,t} + \Delta C_{BSL,DBG,t}} \quad \mathbf{(10)}$$

[19] Projecting ex-ante road and landing removals beyond a few years is difficult and complex. As described, $f_{BSL,DAMAGE,i,t}$ functions as a proxy for estimating biomass impacts of all new roads and landings associated with annual harvesting in polygon, i. Project proponents can simulate $LBL_{BSL,OTHER,i,t}$ directly, if appropriate models are available.

[20] $f_{BSL,DAMAGE,i,t}$ may be zero or de minimis in cases where a polygon is already roaded.

where:

$\Delta C_{BSL,LDW,t}$ = change in lying dead wood (LDW) carbon stocks in year, t; t C yr^{-1}

$\Delta C_{BSL,SNAG,t}$ = change in snag carbon stock in year, t; t C yr^{-1}

$\Delta C_{BSL,DBG,t}$ = change in dead belowground biomass carbon stock in year, t; t C yr^{-1}.

$$\Delta C_{BSL,LDW,t} = \Sigma(LDW_{BSL,IN,i,t} - LDW_{BSL,OUT,i,t}) \bullet CF \quad (11a)$$

$$LDW_{BSL,i,t+1} = LDW_{BSL,i,t} + (LDW_{BSL,IN,i,t} - LDW_{BSL,OUT,i,t}) \quad (11b)$$

where:

$LDW_{BSL,,i,t}$ = The total mass of lying dead wood accumulated in polygon *i* , at time, *t* (t d.m.).

$LDW_{BSL,IN,i,t}$ = annual increase in LDW biomass for polygon *i*, year, *t* (t d.m yr^{-1}). LDW increases occur as a result of natural mortality (typically, blowdown), and as a direct or indirect result of harvesting.

$LDW_{BSL,OUT,i,t}$ = annual loss in LDW biomass through decay, for polygon *i*, year, *t*, (t d.m yr^{-1})

$LDW_{BSL,IN,i,t}$ and $LDW_{BSL,OUT,i,t}$ are summed across polygons.

CF = carbon fraction of dry matter (IPCC default value = 0.5).

$$\begin{aligned}LDW_{BSL,IN,i,t} = {} & (LBL_{BSL,NATURALi,t} - LBL_{BSL,NATURALi,t} \bullet R_i) \bullet f_{BSL,BLOWDOWN,i,t} + \\ & ((LBL_{BSL,FELLINGS,i,t} - LBL_{BSL,FELLINGS,i,t} \bullet R_i) + \\ & (LBL_{BSL,OTHER,i,t} - LBL_{BSL,OTHER,i,t} \bullet R_i)) \bullet f_{BSL,BRANCH,i,t} + \\ & ((LBL_{BSL,FELLINGS,i,t} - LBL_{BSL,FELLINGS,i,t} \bullet R_i) + \\ & (LBL_{BSL,OTHER,i,t} - LBL_{BSL,OTHER,i,t} \bullet R_i)) \bullet \\ & (1 - f_{BSL,BRANCH,i,t}) \bullet f_{BSL,BUCKINGLOSS,i,t} + SNAG_{BSL,,i,t} \bullet f_{BSL,SNAGFALLDOWN,i,t} \quad (12)\end{aligned}$$

where:

$LBL_{BSL,NATURALi,t}$, $LBL_{BSL,FELLINGS,i,t,}$ and $LBL_{BSL,OTHER,i,t}$ are as calculated in equations 7, 8, and 9, respectively.

R_i is the root:shoot ratio in polygon, *i* (see equation 5b).

$f_{BSL,BLOWDOWN,i,t}$ = the annual proportion of live aboveground tree biomass subject to blowdown in polygon, *i,* year*, t* (unitless; $0 \leq f_{BSL,BLOWDOWN,i,t} \leq 1$). Ex ante estimates must be derived preferably from regional reports in similar forest types.

$f_{BSL,BRANCH,i,t}$ = the annual proportion of aboveground tree biomass comprised of branches $\geq$ 5 cm diameter in polygon, *i* (unitless; $0 \leq f_{BSL,BRANCH,i,t} \leq 1$). Ex ante data are available from allometric equations and models (for example, (Kurz & Apps, 2006) for Canada; (Smith, Miles, Vissage, & Pugh, 2004) for the U.S.). In the event slash burning was undertaken as part of regular management activities, this parameter should be reduced accordingly to reflect the proportion of biomass remaining. Estimates should be obtained from expert opinion; as a default, assume 100% consumption if slash burning occurs.

$f_{BSL,BUCKINGLOSS,i,t}$ = the annual proportion of the log bole biomass left on site after assessing and/or merchandizing the log bole for quality, in polygon, *i* (unitless; $0 \leq f_{BSL,BUCKINGLOSS,i,t} \leq 1$). Preferably, data for this variable must be based on regional and local comparative studies and experiential information derived from the local forest industry. Otherwise, an average default value of 21% can be used, based on US national summary statistics (Smith, Miles, Vissage, & Pugh, 2004).

$SNAG_{BSL,,i,t}$ = the total mass of the snag pool in polygon, *i*, year, *t* (see equation 14b).

$f_{BSL,SNAGFALLDOWN,i,t}$ = the annual proportion of snag biomass in polygon, *i*, year, *t*, that falls over and thus is transferred to the LDW pool (unitless; $0 \leq f_{SNAGFALLDOWN,i,t} \leq 1$). Ex ante estimates for this parameter can be derived from peer reviewed literature (for example, (Parish, Antos, Ott, & Di Lucca, 2010) and forest carbon accounting models that track the rates of input and losses from dead organic matter pools (for example, (Kurz & et al, 2009).

$$\mathbf{LDW_{BSL,OUT,i,t} = LDW_{BSL,,i,t} \bullet f_{BSL,lwDECAY,i,t}} \quad \textbf{(13)}$$

where:

$LDW_{BSL,,i,t}$ = the total amount of lying deadwood mass in polygon *i,* year*, t (see equation 11b)*. $f_{BSL,lwDECAY,i,t}$ = the annual proportional loss of lying dead biomass due to decay, in polygon *i,* year*, t* (unitless; ; $0 \leq f_{BSL,lwDECAY,i,t} \leq 1$). A common approach to ex ante estimation of $f_{BSL,lwDECAY,i,t}$ is to assume mass loss occurs in proportion to the amount of mass remaining in accordance with a single exponential model, of the general form:

$$Y_t = Y_o e^{-kt}$$

where Y_o is the initial quantity of material, Y_t the amount left at time t, and k is a decay constant (Harmon, et al., 1986). Other types of exponential models are available (reviewed in (Harmon, et al., 1986)) and may be more appropriate to particular forest types (to be described and justified by the project proponent, if used). Ex ante estimates for the decay parameter appropriate for the project should be derived from peer-reviewed literature (for example, (Harmon, et al., 1986); (Laiho & and Prescott, 2004); (Harmon et al, 2008)).

The change in standing dead wood (snag) carbon stock in year, t (t C yr^{-1}) is calculated as:

$$\mathbf{\Delta C_{BSL,SNAG,t} = \Sigma(SNAG_{BSL,IN,i,t} - SNAG_{BSL,OUT,i,t}) \bullet CF} \quad \textbf{(14a)}$$

$$\mathbf{SNAG_{BSL,i,t+1} = SNAG_{BSL,i,t} + (SNAG_{BSL,IN,i,t} - SNAG_{BSL,OUT,i,t})} \quad \textbf{(14b)}$$

where:

$SNAG_{BSL,i,t}$ = The total mass of snags accumulated in polygon *i, at time t (t d.m.).*

$SNAG_{BSL,IN,i,t}$ = annual gain in snag biomass for polygon *i*, year, *t* (t d.m yr^{-1}). Snag biomass develops as a result of natural mortality. In cases where snags are created through management activities, these should be accounted for here.

$SNAG_{BSL,OUT,i,t}$ = annual loss in snag biomass through decay, or falldown (i.e, transfer to the LDW pool)(t d.m yr^{-1})

CF = carbon fraction of dry matter (IPCC default value = 0.5).

Note that $SNAG_{BSL,IN,i,t}$ and $SNAG_{BSL,OUT,i,t}$ are summed across polygons.

$$\mathbf{SNAG_{BSL,IN,i,t} = (LBL_{BSL,NATURALi,t} - LBL_{BSL,NATURALi,t} \bullet R_i) \bullet (1 - f_{BSL,BLOWDOWN,i,t})} \quad \textbf{(15)}$$

where:

$LBL_{BSL,NATURALi,t}$ is as calculated in equation 7, and

1 - $f_{BSL,BLOWDOWN,i,t}$ is the proportion of live tree aboveground biomass that dies in polygon, *i*, year, *t*, but remains as standing dead organic matter (i.e., snags) (unitless; $0 \leq f_{BSL,BLOWDOWN,i,t} \leq 1$). Ex ante default estimates for this calculation can be derived from literature values (for example (Harmon, et al., 1986); (Runkle, 2000); (Harmon et al, 2008)) and should be matched to the ecosystems that most closely characterize the project area.

$$\mathbf{SNAG_{BSL,OUT,i,t} = SNAG_{BSL,i,t} \bullet f_{BSL,SWDECAY,i,t} + SNAG_{BSL,i,t} \bullet f_{BSL,SNAGFALLDOWN,i,t}} \quad \textbf{(16)}$$

where:

$SNAG_{BSL,i,t}$ = the total amount of snag mass in polygon *i,* year*, t* (see equation 14b). $f_{BSL,SWDECAY,i,t}$ = the annual proportional loss of snag biomass due to decay, in polygon, *i*, year, *t* (unitless; $0 \leq f_{BSL,SWDECAY,i,t} \leq 1$). As with lying dead wood, a common approach to estimating $f_{BSL,SWDECAY,i,t}$ is to assume mass loss occurs in proportion to the amount of mass remaining in accordance with a single exponential model (see equation 13). Ex ante estimates for this parameter should be derived from peer reviewed literature appropriate for the project site (for example, Vanderwel et al. 2006a) and forest carbon accounting models that track the rates of input and losses from dead organic matter pools for each forest type, productivity, and age-class (see, for example, Vanderwel et al., 2006b; (Kurz & et al, 2009)).

$f_{BSL,SNAGFALLDOWN,i,t}$ = the annual proportion of snag biomass in polygon, *i*, that falls over and thus is transferred to the LDW pool (unitless; $0 \leq f_{BSL,SNAGFALLDOWN,i,t} \leq 1$). See equation 12 for parameter estimates.

The annual change in DOM derived from dead belowground biomass ($\Delta C_{BSL,DBG,\ ,t}$; t C yr^{-1}) is calculated for each polygon as per equation 17a. Calculation of $\Delta C_{BSL,DBG,t}$ is specific to a given polygon; each polygon must therefore be summed in order to calculate total annual loss across the project activity area.

$$\Delta \mathbf{C_{BSL,DBG,t}} = \mathbf{\Sigma(DBG_{BSL,IN,i,t} - DBG_{BSL,OUT,i,t}) \bullet CF} \quad \textbf{(17a)}$$

$$\mathbf{DBG_{BSL,i,t+1} = DBG_{BSL,i,t} + (DBG_{BSL,IN,i,t} - DBG_{BSL,OUT,i,t})} \quad \textbf{(17b)}$$

where:

$DGB_{BSL,i,t}$ = The total quantity of dead belowground biomass accumulated in polygon *i,* at time*, t* (t d.m.).

$DBG_{BSL,IN,i,t}$ = annual gain in dead belowground biomass for polygon *i*, year, *t* (t d.m yr^{-1}). Dead belowground biomass develops as a result of mortality through natural causes or through harvesting activities.

$DBG_{BSL,OUT,i,t}$ = annual loss in dead belowground biomass through decay, (t d.m yr^{-1})

CF = carbon fraction of dry matter (IPCC default value = 0.5).

$$\mathbf{DBG_{BSL,IN,i,t} = [(A_{BSL,i} \bullet LB_{BSL,i,t} \bullet R_i) \bullet (f_{BSL,NATURAL,i,t} + f_{BSL,HARVEST,i,t} + f_{BSL,DAMAGE,i,t})]} \quad \textbf{(17c)}$$

where:

$A_{BSL,i}$ = area (ha) of forest land in polygon, *i*;

$LB_{BSL,i,t}$ = average live tree biomass (t d.m. ha^{-1}) in polygon, *i,* for year, *t.* $LB_{BSL,i,t}$ is calculated for year, *t*, beginning with biomass estimates in year *t*=1 (the project start year) and with annual biomass increments ($G_{BSL,i,t}$) added as per calculations in equation 5 a, b. This value is then multiplied by $A_{BSL,i,}$ the area (ha) of forest land in polygon, *i*.

R_i is the root:shoot ratio in polygon, *i* (see equation 5b).

$f_{BSL,NATURAL,i,t}$ = the annual proportion of biomass that dies from natural mortality in polygon, *i* (unitless; $0 \leq f_{NATURALi} \leq 1$), year, *t* (see equation 7),

$f_{BSL,HARVEST,i,t}$ = the proportion of biomass removed by harvesting from polygon, *i,* (unitless; $0 \leq f_{HARVESTIi} \leq 1$), year, *t* (see equation 8),

$f_{BSL,DAMAGE,i,t}$ = the proportion of additional biomass removed or road and landing construction in polygon, *i* (unitless; $0 \leq f_{DAMAGE,i,t} \leq 1$), year, *t* (see equation 9)

$$\mathbf{DBG_{BSL,OUT,i,t} = DBG_{BSL,i,t} \bullet f_{BSL,dgbDECAY,i,t}} \quad \textbf{(17d)}$$

where:

$DBG_{BSL,i,t}$ = the total quantity of dead belowground in polygon *i,* year*, t* (see equation 17b).

$f_{BSL,dgbDECAY,i,t}$ = the annual proportional loss of dead belowground biomass due to decay, in polygon *i,* year*, t* (unitless; ; $0 \leq f_{BSL,lwDECAY,i,t} \leq 1$). The ex ante estimation of the decay of dead belowground biomass should be done using a similar single exponent decay function as that described above for lying deadwood biomass. Estimates for the decay parameter appropriate for specific project should be derived from peer-reviewed literature (see for example: (Moore, Trofymow, Siltanen, Prescott, & CIDET, 2005)); Melin et al. (2009); (Melin, Petersson, & Nordfjell, 2009)).

8.1.6 Harvested Wood Products

This methodology considers the net emissions and carbon storage related to:

a. Wood products created from harvested logs removed from the project site,
b. The fossil fuel emissions from equipment and facilities involved in the harvesting, transportation, and processing of wood products.

The annual change emissions associated with the production of harvested wood products (HWP), $\Delta C_{BSl,HWP,t}$, is calculated as:

$$\mathbf{\Delta C_{BSl,HWP,t} = \Delta C_{BSL,STORHWP,t} - \Delta C_{BSL,EMITFOSSIL,t,}} \quad \textbf{(18)}$$

$\Delta C_{BSL,STORHWP,t}$ = the annual change in harvested carbon that remains in storage after conversion to wood products (t C yr^{-1})

$\Delta C_{BSL,EMITFOSSIL,t}$ = the annual change in fossil fuel emissions from harvesting (logging and log transport) and processing of the various wood products.

8.1.7 Carbon storage in harvested wood products ($\Delta C_{BSL,STORHWP,t}$)

In accordance with the VCS AFOLU requirements (Version 3)[21], emissions of carbon stored within harvested wood products in IFM projects must be modeled based upon the following criteria:

a) For short-term wood products and wood waste that would decay within 3 years, all carbon must be assumed to be lost immediately.

b) For medium-term wood products that are retired between 3 and 100 years, a 20-year linear decay function must be applied.

c) For long-term wood products that are considered permanent (ie, carbon is stored for 100 years or more), it may be assumed no carbon is released.

The annual change in carbon storage in harvested wood products in year *t* ($\Delta C_{BSL,STORHWP,t}$; t C yr^{-1}) is determined based upon the following equation:

$$\Delta C_{BSL,STORHWP,t} = (C_{BSL,STORHWP,t2} - C_{BSL,STORHWP,t1}) / T \qquad (19)$$

where:

$C_{BSL,STORHWP,t2}$ = carbon storage in harvested wood products at t=2; t C

$C_{BSL,STORHWP,t1}$ = carbon storage in harvested wood products at t=1; t C

T = number of years between monitoring t1 and t2

t : 1,2,3…t years elapsed since the project start date

For applications within North America this methodology has adapted data from the Forestry Appendix of the Technical Guidelines of the US Department of Energy's Voluntary Reporting of Greenhouse Gases Program (known as Section 1605(b))[22] to calculate proportions in use for the short-term and long-term wood products, from which a remaining medium-term wood product pool can be calculated and decayed over a 20-year period. In the case where the methodology is applied outside of North America, the project proponent must utilize regionally appropriate data from a peer-reviewed source to complete the steps below. Alternatively, a globally applicable method such as that defined by Winjum et al. (1998)[23] may be utilized to estimate carbon storage in wood products..

Storage in the harvested wood products pool at a given time t ($C_{BSL,STORHWP,t}$; t C) is calculated according to the following steps for each harvest period *h*:

Step 1 (Carbon contained in harvested timber): Determine the carbon contained within harvested timber removed from the project landbase. This can be calculated from measures of total merchantable volume generated during the harvest period *h* using species-specific wood densities and standard carbon conversions or

[21] In previous versions, this methodology used the "100 Year Method" following procedures developed by Miner (Miner, 2006), which have been replaced by the updated methods outlined in this revised version to ensure compliance with version 3.2 of the *AFOLU Requirements*.

[22] http://www.eia.doe.gov/oiaf/1605/Forestryappendix[1].pdf Also available as a US Forest Service General Technical Report at: http://www.fs.fed.us/ne/durham/4104/papers/ne_gtr343.pdf

[23] Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. Forest Science 44: 272-284

estimated from live biomass removals after accounting for removal of belowground components, branches, and bucking losses (equation 20). In accordance with the 1605(b) approach, the harvested wood carbon ($C_{BSL,TIMBER,h}$) must be divided into the following product type (*k*) categories: 1) softwood saw log, 2) softwood pulpwood, 3) hardwood saw log, 4) hardwood pulpwood. This can be done using local data if available or estimated based upon region and forest type according to Table 1.4 in the 1605(b) document. Table 3 provides recommendations for analogs for areas within North America but outside of the conterminous US; however, the project proponent must justify the appropriateness of the selected analog . In the case of global project locations outside of North America, the project proponent must identify and justify the use of alternative data from peer-reviewed sources.

$$\mathbf{C_{BSL,TIMBER,h} = \Sigma[(LBL_{BSL,FELLINGS,i,h} - LBL_{BSL,FELLINGS,i,h} \bullet R_i + LBL_{BSL,OTHER,i,h} - LBL_{BSL,OTHER,i,h} \bullet R_i) \bullet (1 - f_{BSL,BRANCH,i,h}) \bullet (1 - f_{BSL,BUCKINGLOSS,i,h})] \bullet \bullet CF} \quad \mathbf{(20)}$$

where:

$C_{BSL,TIMBER,h}$= carbon contained in timber harvested in period *h* (summed for all harvested polygons, *i*); t C

$LBL_{BSL,FELLINGS,i,h}$ = annual removal of live tree biomass due to commercial felling in polygon, *i*; t d.m. (equation 8)

$LBL_{BSL,OTHER,i,h}$ = annual removal of live tree biomass from incidental sources in polygon, *i*; t d.m. (equation 9)

R_i is the root:shoot ratio in polygon, *i* (see equation 5b).

$1 - f_{BSL,BRANCH,i,h}$ the proportion of live tree biomass remaining after netting out branch biomass, in polygon *i* (unitless; $0 \leq f_{BRANCH,i,t} \leq 1$)(see equation 12)

$1 - f_{BSL,BUCKINGLOSS,i,h}$ = the proportion of the log bole remaining after in-woods log processing/bucking for quality, length, etc., in polygon, *i* (unitless; $0 \leq f_{BUCKINGLOSS,i,t} \leq 1$) (equation 12)

h = harvest period ; yr

Step 2: (Carbon contained in harvested timber after milling): Determine the total carbon in harvested timber that will enter the wood products pool by product type accounting for mill efficiencies and estimated product disposition percentages ($C_{BSL,MILL,h}$; t C). The gross quantity of carbon contained in harvested timber for each of the four product types described in Step 1 must be decremented to account for losses during processing (equation 21). These losses including bark and other milling wastes and may be determined using local data or estimated based upon region and product type according to Table 1.5 in the 1605(b) document. Table 3 provides recommendations for analogs for areas within North America but outside of the conterminous US; however, the project proponent must justify the appropriateness of the selected analog. In the case of global project locations outside of North America, the project proponent must identify and justify the use of alternative data from peer-reviewed sources.).

$$\mathbf{C_{BSL,MILL,h,k} = (C_{BSL,TIMBER,h,k} \bullet f_{RND,k} \bullet r_{RND,k})} \quad \mathbf{(21)}$$

where:

$C_{BSL,MILL,h,k}$ = carbon contained in harvested timber after milling in period h, for product type *k*; t C

$C_{BSL,TIMBER,h,k}$ = carbon contained in timber harvested in period h, for product type *k*; t C

k = wood product type – (softwood saw log, softwood pulpwood, hardwood saw log, or hardwood pulpwood; proportions determined from Table 1.4 of 1605(b) document)

$f_{RND,k}$ = fraction of growing stock volume removed as roundwood for product type *k* (default values by region in Table 1.5 of the 1605(b) document); dimensionless

$r_{RND,k}$ = ratio of industrial roundwood to growing stock volume removed as roundwood for product type *k* (default values by region in Table 1.5 of the 1605(b) document); dimensionless

Step 3: (Carbon storage in medium-term and long-term wood products): Calculate the total carbon lost in short-lived products and stored in medium-term and long-term products. For each harvest period *h*, carbon stored in harvested wood products of a defined type (k) after accounting for milling losses ($\mathbf{C_{BSL,MILL,h,k}}$) must be apportioned into one of the following categories:

a) Short lived wood products: harvested wood products and wood waste that will decay within 3 years.
b) Medium lived wood products: harvested wood products and wood waste that will be retired between 3 and 100 years from the date of harvest.
c) Long lived wood products: harvested wood products and wood waste that may be considered permanent (stored for 100 years or more).

To determine the proportion of harvested wood products (by type) that fall into each category, refer to the "In Use" column for the selected forest region in Table 1.6 in the 1605(b) document. Table 3 provides recommendations for analogs for areas within North America but outside of the conterminous UShowever,. the project proponent must justify the appropriateness of the selected analog at project validation. In the case of global project locations outside of North America, the project proponent must identify and justify the use of alternative data from peer-reviewed sourcesTable 3

Three values are then calculated from these data selected from Table 1.6 in the 1605(b) document, for each product type, *k* : the short-lived fraction ($P_{BSL,SLF,k}$), medium-lived fraction ($P_{BSL,MLF,k}$), and long-lived fraction ($P_{BSL,LLF,k}$):

$$\mathbf{P_{BSL,SLF,k} = 1 - P_{3\text{-}year}} \quad \textbf{(22a)}$$

$$\mathbf{P_{BSL,LLF,k} = P_{100\text{-}year}} \quad \textbf{(22b)}$$

$$\mathbf{P_{BSL,MLF,k} = P_{3\text{-}year} - P_{100\text{-}year}} \text{,} \quad \textbf{(22c)}$$

Each category of wood products (*k*) stores carbon according to the following rules:

i. Short-lived wood products – immediate emission of all carbon upon harvest
ii. Medium-lived wood products – no emission of carbon upon harvest, but carbon stored will decrease by 1/20th for the next 20 years after harvest, such that after 20 years the term becomes zero
iii. Long-lived wood products – no loss of carbon.

Thus, carbon storage in harvested wood products at time *t* may be calculated using a cohort approach in which medium-term and long-term wood products from each harvest period *h* are tracked independently and then summed over the project time period as indicated in equation 23.

$$C_{BSL,STORHWP,t,} = \Sigma\, \Sigma\, ((C_{BSL,MILL,h,k} \bullet P_{LLF,k}) + [(C_{BSL,MILL,h,k} \bullet P_{MLF,k}) \bullet ((20\text{-}h) / 20)]) \quad \textbf{(23)}$$

where:

$C_{BSL,STORHWP,t,}$ = carbon stored in harvested wood products in year *t* summed for all product types *k* and then over all harvest periods *h*; t C

k = wood product type – (softwood saw log, softwood pulpwood, hardwood saw log, or hardwood pulpwood; proportions determined from Table 1.4 of 1605(b) document)

h = year of harvest (the term (20-h) should not be allowed to drop below 0)

Table 3 – Recommended analogous Regional 1605b Data Substitutions for regions for North America, outside the conterminous U.S.

Region	Regional analog[1]
Coastal British Columbia and Coastal Alaska	Pacific Northwest, West
Columbia (British Columbia)	Pacific Northwest, East
Alpine and Montane (Rocky Mountain region in British Columbia and Alberta)	Rocky Mountain, North
Boreal (across Canada) and Interior Alaska	Northern Lake States
Great Lakes St-Lawrence (central Canada)	Northern Lake States
Carolinian (southwestern Ontario) and Acadian (Maritimes)	Northeast

[1] As per Table 1.6 of the 1605(b) methodology document (see text)

8.1.8 Fossil fuel emissions associated with logging, transport, and manufacture

The annual change in fossil fuel emissions from harvesting and processing of the various wood products ($\Delta C_{BSL,EMITFOSSIL,t}$) are calculated as:

$$C_{BSL,EMITFOSSIL,t} = C_{BSL,EMITHARVEST,t} + C_{BSL,EMITMANUFACTURE,t} + C_{BSL,EMITTRANSPORT,t} \quad \textbf{(24)}$$

where:

$C_{BSL,EMITHARVEST,t}$ is the annual fossil fuel emissions associated with harvesting of raw material (t C yr^{-1})

$C_{BSL,EMITMANUFACTURE,t}$ is the annual fossil fuel emissions associated with the manufacturing of raw material (t C yr^{-1})

$C_{BSL,EMITTRANSPORT,t}$ is the annual fossil fuel emissions associated with the transport of raw material (t C yr^{-1})

The simplest approach to calculating $C_{BSL,EMITFOSSIL,t}$ is to use published or derived carbon emission intensity factors. In the case of harvesting, $_{BSL,}C_{EMITHARVEST,t}$; t C yr^{-1}), can be calculated (summed across harvested polygons)as:

$$\mathbf{C_{BSL,EMITHARVEST,t} = \Sigma[(LBL_{BSL,FELLINGS,i,t} - LBL_{BSL,FELLINGS,i,t} \bullet R_i + LBL_{BSL,OTHER,i,t} - LBL_{BSL,OTHER,i,t} \bullet R_i) \bullet (1 - f_{BSL,BRANCH,i,t}) \bullet (1 - f_{BSL,BUCKINGLOSS,i,t})] \bullet CF \bullet c_{HARVEST}} \quad \mathbf{(25)}$$

where:

$c_{HARVEST}$ is the carbon emission intensity factor (t C emitted/t C raw material) associated with harvesting (see Table 4 for default values); all other terms are as defined in equation 20.

$C_{BSL,EMITTRANSPORT,t}$ must be calculated after consideration of the transport distance from harvest to processing facility, and the means of transportation. This term can be calculated as follows (after (Heath, et al., 2010)):

$$\mathbf{C_{BSL,EMITTRANSPORT,t} = \Sigma[(LBL_{BSL,FELLINGS,i,t} - LBL_{BSL,FELLINGS,i,t} \bullet R_i + LBL_{BSL,OTHER,i,t} - LBL_{BSL,OTHER,i,t} \bullet R_i) \bullet (1 - f_{BSL,BRANCH,i,t}) \bullet (1 - f_{BSL,BUCKINGLOSS,i,t})] \bullet CF \bullet \Sigma(f_{BSL,TRANSPORTk} \bullet d_{TRANSPORTk} \bullet c_{TRANSPORTk})} \quad \mathbf{(26)}$$

where:

$f_{BSL,TRANSPORTk}$ = the fraction of raw material transported by transportation type, *k*. (unitless; $0 \leq f_{BSL,TRANSPORTk} < 1$).

$d_{TRANSPORTk}$ = the distance transported by transportation type, *k*. (km);

$c_{TRANSPORTk}$ is the carbon emission intensity factor (kg C emitted/t C raw material) associated with transportation type, k (see Table 4 for default values); all other terms are as defined in equation 20.

$$\mathbf{C_{BSL,EMITMANUFACTURE,t} = \Sigma[(LBL_{BSL,FELLINGS,i,t} - LBL_{BSL,FELLINGS,i,t} \bullet R_i + LBL_{BSL,OTHER,i,t} - LBL_{BSL,OTHER,i,t} \bullet R_i) \bullet (1 - f_{BSL,BRANCH,i,t}) \bullet (1 - f_{BSL,BUCKINGLOSS,i,t})] \bullet \Sigma(f_{BSL,PRODUCTk} \bullet c_{MANUFACTUREk}) \bullet CF} \quad \mathbf{(27)}$$

$c_{MANUFACTUREk}$ is the carbon emission intensity factor (t C emitted/t C raw material) associated with manufacture of product type, *k*; all other terms are as defined in equation 19.

Default values for $c_{MANUFACTUREk}$ are provided in Table 4. Data are from a comprehensive analysis conducted in Finland (Pingoud, Perälä, Soimakallio, & Pussinen, 2003). Higher comparative values from North America are provided for harvesting and sawnwood manufacturing to illustrate inherent variability. Project proponents may use the default values in Table 4, or substitute regional data, if available.

Table 4 –Carbon emission intensity factors for harvesting, the manufacture of various product categories, k, and for various transportation categories, k.

Activity	Value	Reference	Other (for comparison)
Harvesting ($c_{HARVEST}$) (t C emitted/t C raw material)			
Clearcut harvest	0.016	(Zhang, Cormier, Lyng, Mabee, Ogino, & McLean, 2010)	
Manufacturing ($c_{MANUFACTUREk}$) (t C emitted/t C raw material)			
Sawnwood	0.04	(Pingoud & Lehtila, 2002) – Calculated from Table I & III	0.1 (western US), 0.156 (southern US) (Milota, West, & Hartley, 2005)
Veneer, plywood and structural panels	0.06	(Pingoud & Lehtila, 2002) – Calculated from Table I & III	
Non-structural panels	0.12	(Pingoud & Lehtila, 2002) – Calculated from Table I & III	
Paper		(Pingoud & Lehtila, 2002) – Calculated from Table I & III	
Mechanical pulping	0.48	(Pingoud & Lehtila, 2002) – Calculated from Table I & III	
Chemical pulping	0.13	(Pingoud & Lehtila, 2002) – Calculated from Table I & III	
Transportation ($c_{TRANSPORTk}$) (t C emitted/t C raw material ● km)			
Truck	7.0×10^{-5}	(Heath, et al., 2010) - From Supporting Information Table S16	
Rail	8.2×10^{-6}	(Heath, et al., 2010) - From Supporting Information Table S16	

8.2 Project Emissions

Net project emissions are calculated by repeating the procedures in Section 8.1 (Baseline Emissions), using the project scenario polygons, data, and modeling. Unless otherwise noted and justified by the project proponent, all modeling methods, calculations, assumptions, and data sources should be consistent in both the baseline and project scenarios, with the exception of ex-post monitoring data as outlined below. For purposes of efficacy, it may be advantageous to re-stratify the landbase for the project scenario, as compared to the baseline.

Within this methodology, it is anticipated that project scenarios may undertake ongoing low levels of management activities for forest maintenance, ecological enhancement, and/or risk mitigation (for example, pest management, salvage, etc.). In order to comply with the IFM-LtPF project type and this methodology, these activities must meet the following requirements:

1. All net GHG emissions from project activities must be modeled and accounted for in the project scenario in the same manner as the baseline scenario.
2. Project activities cannot remove > 20% of the harvesting volume projected in the baseline scenario over an equivalent 10-year period.
3. Project proponents must be able to demonstrate that activities:
    a. have a conservation benefit and are consistent with principles of managing for biodiversity, ecosystem function, and carbon retention.
    b. are related to restoration, ecological management, or emissions risk reduction

If a project scenario has no planned timber removals, then all related equations in the project emissions calculations in Section 8.2 can be set to zero.

If the project scenario has planned activities other than those involving the removal of timber that affect non-*de minimis* levels of carbon stock, the project must document these activities, reasonably calculate their carbon impacts, and include these emissions in the total carbon calculations for the project scenario.

All calculations in this methodology represent annualized net changes in carbon stocks by polygon, which must therefore be summed across the project activity area to determine the annual total net emissions and reductions.

Note, additional details for many calculations, including references and background are provided within the equivalent Baseline Emissions section.

8.2.1 Project Scenario Area Stratification

The project scenario will utilize the same methods and steps to create polygons as outlined for the baseline scenario (see Section 8.1) from $A_{PRJ,I}$. However, the project scenario may be stratified differently to accommodate different project management activities and/or changes to inventory data resulting from ex-post monitoring (if new polygons are created as the result of natural disturbance events, for example). There may be differences between the project and baseline scenarios in the areas within the landbase that are eligible for specific forest management activities (i.e., the assumptions used to determine the THLB may differ in the project scenario relative to the baseline). However, the underlying inventory and data assumptions must be the same in the baseline and project scenarios.

8.2.2 Determining Actual Onsite Carbon Stocks

Actual carbon stocks must be calculated prior to each verification, or at a maximum interval of 5 years, by updating the project's forest carbon inventory from the monitoring data.

This is done by:

1. Incorporating any new forest inventory data (including data from new or re-measured sampling plots and other monitored data, as outlined in Section 9.2 and 9.3) obtained during the previous year into the inventory estimate.
2. Updating the forest inventory for spatial monitoring results, including annual project activities and/or disturbances that have occurred during the monitoring period.
3. Using the selected model(s) to project prior-year data from the forest inventory to the current reporting year (as described in Section 8.2.5).
4. Comparing estimates of live biomass and dead organic matter in polygons and calculated from monitoring activities (Section 9.2 and 9.3) against current-year modeled values in the project scenario (see Section 8.2.4).
5. Making calibration adjustments to models and/or parameters such that the fit between the equivalent modeled and measured variables meets targets (as per Section 8.2.4).
6. If any changes are made to the model assumptions or parameters used in Section 8.2, the calculation of baseline emissions (from the current date forward) must be redone using the updated model(s) and parameter sets.
7. Calculate the error terms for use in determining the uncertainty factor (Section 8.5.3).

8.2.3 Ex-Post Calculations of Carbon Stocks

Actual (ex post) annual net carbon stocks are calculated using the equations in this section.

$$\mathbf{C_{ACTUAL,i,t} = C_{LB,i,t} + C_{DOM,i,t}} \qquad \textbf{(28a)}$$

where:

$C_{ACTUAL,i,t}$ = carbon stocks in all selected carbon pools in polygon, *i*, year, *t*; t C

$C_{LB,i,t}$ = carbon stocks in living tree biomass in polygon, *i*, year, *t*; t C

$C_{DOM,i,t}$ = carbon stocks in dead organic matter in year, *t*; t C

Live biomass

Average aboveground biomass for measured polygon, *i,* in year, *t* ($B_{AG,i,t}$) is determined by converting the aboveground, tree-level measurements (kg biomass per tree) described in Section 9.3.2 to area-based, stand-level measurements (t ha^{-1}). This is achieved by summing the aboveground biomass of all the trees within a sample plot, converting kg to t, and then dividing the sum by the plot area in ha. All plots within a particular polygon should be averaged to get an average estimate of stand-level aboveground biomass (t ha^{-1}). Once the average aboveground biomass has been determined for each measured polygon, belowground biomass is estimated by multiplying the aboveground biomass by the root:shoot ratio, R_i (equation 28d) and the two are summed to determine total stand-level live biomass for measured polygon i, time t, ($B_{TOTAL,i,t}$). R_i is described in Section 8.1.3. Finally, the average measured carbon stock in living tree biomass for measured polygon *i*, time *t*, ($C_{LB,i,t}$) is calculated as shown in equation 28c. This value of $C_{LB,i,t}$ must be compared to the equivalent calculation of live biomass ($LB_{PRJ,i,t}$) calculated in the project scenario (Section 8.2.5) (see comparison method and steps below).

$$B_{TOTAL,i,t} = (B_{AG,i,t} + B_{BG,i,t}) \quad (28b)$$

$$C_{LB,i,t} = (B_{TOTAL,i,t}) \bullet CF \quad (28c)$$

where:

$B_{AG,i,t}$ = aboveground tree biomass (t d.m. ha^{-1}) measured in polygon, *i,* year, *t*

$B_{BG,i,t}$ = belowground tree biomass (t d.m. ha^{-1}) measured in polygon, *i,* year, *t*.

$B_{TOTAL,i,t}$ = total tree biomass (t d.m. ha^{-1}) measured in polygon, *i,* year, *t*

$$B_{BG,i,t} = B_{AG,i,t} \bullet R_i \quad (28d)$$

CF = carbon fraction of dry matter (IPCC default value = 0.5)

Dead organic matter

Carbon stored in dead organic matter pools in measured polygon, *i*, year *t*, ($C_{DOM,i,t}$) is calculated as the sum of that stored in lying dead wood and standing snags.

$$C_{DOM,i,t} = (DOM_{LDW,i,t} + DOM_{SNAG,i,t}) \bullet CF \quad (28e)$$

where:

$DOM_{LDW,i,t}$ = average mass of dead organic matter contained in lying dead wood (t d.m. ha^{-1}) in measured in polygon, *i,* year, *t*

$DOM_{SNAG,i,t}$ = average mass of dead organic matter contained in standing snags (t d.m. ha^{-1}) in measured in polygon, *i,* year, *t*

The average quantity of dead organic matter contained in lying dead wood for measured polygon, *i,* in year, *t* ($DOM_{LDW,i,t}$) is calculated according to equations 60a-c in Section 9.3.2. The value of $DOM_{LDW,i,t}$ must be compared to the equivalent calculation of lying dead wood mass ($LDW_{PRJ,i,t}$) in the project scenario (Section 8.2.8) (see comparison method and steps below).

The average quantity of dead organic matter contained in standing snags for measured polygon, *i,* in year, *t* ($DOM_{SNAG,i,t}$ is calculated by summing the mass (aboveground only) of all the measured standing dead trees within a sample plot (converting kg to t) and dividing the sum by the plot area in ha (see Section 9.3.2). The belowground component of snags is treated as dead belowground biomass (see Section 8.2.8) and is not directly measured. All plots within a particular polygon should be averaged to get an average estimate of $DOM_{SNAG,i,t}$. The value of $DOM_{SNAG,i,t}$ must be compared to the equivalent calculation of standing dead tree mass ($SNAG_{PRJ,i,t}$) in the project scenario (Section 8.2.8) (see comparison method and steps below).

8.2.4 Updating the Modeled Project Carbon Balance

In this methodology, the ex ante carbon balances in the project case may be derived from computer model output. In this event, the precision of the modeled carbon stocks should be evaluated for each polygon or analysis unit (depending on the level of stratification used) using the method described for determining mean model error in Section 8.5.3 (equations 60a,b). If the model error term is too high (> 10%), proponents should attempt to improve the model fit by re-evaluating and adjusting model parameters until model error term is < 10%. Model error terms greater than 10% (after model adjustments) will be penalized according the calculation of the uncertainty factor described in Section 8.5.3. If changes in model assumptions or parameters are made, the baseline scenario (from the next year forward) must be recalculated using the revised model.

8.2.5 Calculating the Project Carbon Balance

The total annual carbon balance in year, t, for the project scenario is calculated as ($\Delta C_{PRJ,t}$, in t C yr^{-1}):

$$\Delta C_{PRJ,t} = \Delta C_{PRJ,P,t} \quad (29)$$

where:

$\Delta C_{PRJ,P,t}$ is the annual change in carbon stocks in all pools in the project across the project activity area; t C yr^{-1} .

$$\Delta C_{PRJ,P,t} = \Delta C_{PRJ,LB,t} + \Delta C_{PRJ,DOM,t} + \Delta C_{PRJ,HWP,t} \quad (30)$$

$\Delta C_{PRJ,LB,t}$ = annual change in carbon stocks in living tree biomass (above- and belowground); t C yr^{-1}

$\Delta C_{PRJ,DOM,t}$ = annual change in carbon stocks in dead organic matter; t C yr^{-1}

$\Delta C_{PRJ,HWP,t}$ is the annual change in carbon stocks associated with harvested wood products, t C yr^{-1}.

$$\Delta C_{PRJ,LB,t} = \Delta C_{PRJ,G,t} - \Delta C_{PRJ,L,t} \quad (31)$$

where:

$\Delta C_{PRJ,G,t}$ = annual increase in tree carbon stock from growth; t C yr^{-1}

$\Delta C_{PRJ,L,t}$ = annual decrease in tree carbon stock from a reduction in live biomass; t C yr^{-1}.

If the project area has been stratified, carbon pools are calculated for each polygon, i, and then summed during a given year, t.

8.2.6 Live Biomass Gain

Live biomass gain in year, *t*, polygon, *i* ($\Delta C_{PRJ,G,i.t}$) is calculated as:

$$\Delta \mathbf{C_{PRJ,G,t} = \Sigma(A_{PRJ,i} \bullet G_{PRJ,i,t}) \bullet CF} \quad (32)$$

where:

$A_{PRJ,i,}$ = area (ha) of forest land in polygon, *i*;

$G_{PRJ,i,t}$ = annual increment rate in tree biomass (t d.m. ha^{-1} yr^{-1}), in polygon, *i*, and;

CF = carbon fraction of dry matter t C t^{-1} d.m. (IPCC default value = 0.5).

$$\mathbf{G_{PRJ,i,t} = G_{PRJ,AG,i,t} + G_{PRJ,BG,i,t}} \quad (33a)$$

where $G_{PRJ,AG,i,t}$ and $G_{PRJ,BG,i,t}$ are the annual above- and belowground biomass increment rates (t d.m. ha^{-1} yr^{-1});

$$\mathbf{G_{PRJ,BG,i,t} = G_{PRJ,AG,i,t} \bullet R_i} \quad (33b)$$

where R_i is the root:shoot ratio in polygon, *i*. R_i should ideally be estimated for each polygon, but these data are difficult to derive empirically. Hence, general relationships are acceptable (Cairns, 1997).

Equations 32 and 33 can be used directly to calculate $\Delta C_{PRJ,G,t}$ when all tree cover within a polygon is removed by harvesting (i.e., clearfelling) and no residual structure is retained. In cases of partial harvesting and/or multiple entries into a polygon, these equations must be applied separately to each of the resulting sub-polygons (the different age classes that are created). This ensures that growth rates reflect the difference in forest age between the sub-polygons.

The ex ante and ex post calculation of $G_{PRJ,i,t}$ (either directly, or from its component parts) will be derived from models that require inputs derived, in part, from forest inventory data updated from monitoring sample plots (see Sections 9.3.2 and 8.2.2). Criteria for model suitability are provided in 8.1.1. The exact form of the input data depends on the nature of the model but may include site index, species composition, and volume (see notes in Section 8.1).

8.2.7 Live Biomass Loss

The annual decrease in aboveground tree carbon from live biomass loss (ΔC_{PRJ},L,t; t C yr^{-1}) is the sum of losses from:

1. Natural mortality (i.e. insects, disease, competition, wind, etc.)
2. Commercial round wood felling
3. Incidental sources.

Losses must be specific to a given polygon; each polygon must be summed in order to calculate total annual loss across the project activity area. The live biomass losses are not emitted directly, but rather are transferred to dead organic matter pools.

$$\Delta \mathbf{C_{PRJ,L,t} = \Sigma(LBL_{PRJ,NATURALi,t} + LBL_{PRJ,FELLINGS,i,t} + LBL_{PRJ,OTHERi,t})} \bullet CF \quad (34)$$

where:

$LBL_{PRJ,NATURALi,t}$ = annual loss of live tree biomass due to natural mortality in polygon, *i*; t d.m. yr^{-1}

$LBL_{PRJ,FELLINGS,i,t}$ = annual loss of live tree biomass due to commercial felling in polygon, *i*; t d.m. yr^{-1}

$LBL_{PRJ,OTHER,i,t}$ = annual loss of live tree biomass from incidental sources in polygon, *i*; t d.m. yr^{-1}

CF = carbon fraction of dry matter; t C t^{-1} d.m. (IPCC default value = 0.5).

$$\mathbf{LBL_{PRJ,NATURALi,t} = A_{PRJ,i} \bullet LB_{PRJ,i,t} \bullet f_{PRJ,NATURAL,i,t}} \qquad \textbf{(35)}$$ [24]

where

$A_{PRJ,i}$ = area (ha) of forest land in polygon, *i*;

$LB_{PRJ,i,t}$ = average live tree biomass (t d.m. ha^{-1}) in polygon, *i,* for year, *t*

$LB_{PRJ,i,t}$ is calculated for year, *t*, beginning with biomass estimates in year *t*=1 (the project start year) and with annual biomass increments ($G_{PRJ,i,t}$) added as per calculations in equation 33a.

$f_{PRJ,NATURAL,i,t}$ = the annual proportion of biomass that dies from natural mortality in forest type , *i* (unitless; $0 \leq f_{PRJ,NATURALi} \leq 1$), year, *t*. Tree mortality is an ongoing process during stand development. Trees die as a consequence of insect attack, disease, competition, or some combination thereof. Hence, mortality can be highly variable between years. This parameter can be applied uniformly across an analysis unit, or individually to a given polygon. Ex post estimates from regional data sources in corresponding stand types are preferred. Sources for mortality estimates include permanent sample plots in similar stand types, literature reports, and inventory data. Some models (the FORECAST model, for example) simulate annual background mortality rates directly and can accommodate variable age structures following partial harvesting.

$$\mathbf{LBL_{PRJ,FELLINGS,i,t} = A_{PRJ,i} \bullet LB_{PRJ,i,t} \bullet f_{PRJ,HARVEST,i,t}} \qquad \textbf{(36)}$$

where:

$A_{PRJ,i}$ = area (ha) of forest land in polygon, *i*

$LB_{PRJ,i,t}$ = average live tree biomass (t d.m. ha^{-1}) in polygon, *i,* for year, *t* (see equation 7 for its calculation).

$f_{PRJ,HARVEST,i,t}$ = the proportion of biomass removed by harvesting from polygon, *i,* (unitless; $0 \leq f_{PRJ,HARVESTIi} \leq 1$), in year, *t*. Data for this variable should be obtained from harvest schedule information. Values may be constrained by (a) the value of $f_{PRJ,NATURAL,i,t}$ (i.e., $f_{PRJ,HARVEST,i,t} < 1 - f_{PRJ,NATURAL,i,t}$), and/or (b) the area of timber available for commercial harvest.

Incidental loss ($LBL_{PRJ,OTHER,i,t}$; t d.m. yr^{-1}) is the additional live tree biomass removed for road and landing construction in the polygon, *i*, and is calculated as a proportion of biomass removed by harvesting:

$$\mathbf{LBL_{PRJ,OTHER,i,t} = A_{PRJ,i} \bullet LB_{PRJ,i,t} \bullet f_{PRJ,HARVEST,i,t} \bullet f_{PRJ,DAMAGE,i,t}} \qquad \textbf{(37)}$$

where:

$A_{PRJ,i}$ = area (ha) of forest land in polygon, *i*;

$LB_{PRJ,i,t}$ = average live tree biomass (t d.m. ha^{-1}) in polygon, *i,* for year, *t*

[24] Note, for Equation 35, 36, and 37: $\mathbf{(f_{PRJ,NATURAL,i,t} + f_{PRJ,HARVEST,i,t} + f_{PRJ,DAMAGE,i,t}) \leq 1.0}$

$f_{PRJ,HARVEST,i,t}$ = the proportion of biomass removed by harvesting from polygon, *i,* in year, *t* (unitless; $0 \leq f_{PRJ,HARVEST,i,t} \leq 1$).

$f_{PRJ,DAMAGE,i,t}$ = the proportion of additional biomass removed for road and landing construction in polygon, *i,* year, *t* (unitless; $0 \leq f_{PRJ,DAMAGE,i,t} \leq 1$)[25]. Data for this variable should be based on regional and local comparative studies and experiential information derived from the local forest industry[26].

8.2.8 Dead Organic Matter Dynamics ($\Delta C_{PRJ,DOM}$)

Dead organic matter (DOM) included in this methodology comprises three components: standing dead wood (minimum ≥ 5 cm DBH and 1.3 m height; termed snags), lying dead wood (minimum ≥ 5 cm DBH; LDW), and belowground dead wood (i.e., dead roots). Standing dead wood is < 45º of vertical, while lying dead wood is ≥ 45º of vertical.

The annual change in carbon stocks in DOM ($\Delta C_{PRJ,DOM}$; t C yr^{-1}) is calculated as:

$$\Delta C_{PRJ,DOM,t} = \Delta C_{PRJ,LDW,t} + \Delta C_{PRJ,SNAG,t} + \Delta C_{PRJ,DBG,t} \quad (38)$$

where:

$\Delta C_{PRJ,LDW,t}$ = change in lying dead wood (LDW) carbon stocks in year, *t*; t C yr^{-1}

$\Delta C_{PRJ,SNAG,t}$ = change in snag carbon stock in year, *t*; t C yr^{-1}

$\Delta C_{BSL,DBG,t}$ = change in belowground carbon stock in year, *t*; t C yr^{-1}.

$$\Delta C_{PRJ,LDW,t} = \Sigma(LDW_{PRJ,IN,i,t} - LDW_{PRJ,OUT,i,t}) \bullet CF \quad (39a)$$

$$LDW_{PRJ,i,t+1} = LDW_{PRJ,i,t} + (LDW_{PRJ,IN,i,t} - LDW_{PRJ,OUT,i,t}) \quad (39b)$$

where:

$LDW_{PRJ,i,t}$= The total mass of lying dead wood accumulated in polygon *i* at time t (t d.m.).

$LDW_{PRJ,IN,i,t}$ = annual increase in LDW biomass for polygon *i*, year, *t* (t d.m ha^{-1} yr^{-1}). LDW increases occur as a result of natural mortality (typically, blowdown), and as a direct or indirect result of harvesting.

$LDW_{PRJ,OUT,i,t}$ = annual loss in LDW biomass through decay, for polygon *i*, year, *t*, (t d.m ha^{-1} yr^{-1})

$LDW_{PRJ,IN,i,t}$ and $LDW_{PRJ,OUT,i,t}$ are summed across polygons.

CF = carbon fraction of dry matter (IPCC default value = 0.5).

$$LDW_{PRJ,IN,i,t} = (LBL_{PRJ,NATURALi,t} - LBL_{PRJ,NATURALi,t} \bullet R_i) \bullet f_{PRJ,BLOWDOWN,i,t} +$$
$$((LBL_{PRJ,FELLINGS,i,t} - LBL_{PRJ,FELLINGS,i,t} \bullet R_i) +$$
$$(LBL_{PRJ,OTHER,i,t} - LBL_{PRJ,OTHER,i,t} \bullet R_i)) \bullet f_{PRJ,BRANCH,i,t} +$$

[25] Projecting ex ante road and landing removals beyond a few years is difficult and complex. As described, $f_{PRJ,DAMAGE,i,t}$ functions as a proxy for estimating biomass impacts of all new roads and landings associated with annual harvesting in polygon, *i*. Project proponents can simulate $LBL_{PRJ,OTHER,i,t}$ directly, if appropriate models are available.

[26] $f_{PRJ,DAMAGE,i,t}$ may be zero or de minimis in cases where a polygon is already roaded.

$$\mathbf{((LBL_{PRJ,FELLINGS,i,t} - LBL_{PRJ,FELLINGS,i,t} \bullet R_i) +}$$

$$\mathbf{(LBL_{PRJ,OTHER,i,t} - LBL_{PRJ,OTHER,i,t} \bullet R_i)) \bullet}$$

$$\mathbf{(1 - f_{PRJ,BRANCH,i,t}) \bullet f_{PRJ,BUCKINGLOSS,i,t} + SNAG_{PRJ,,i,t} \bullet f_{PRJ,SNAGFALLDOWN,i,t} \quad (40)}$$

where:

$LBL_{PRJ,NATURALi,t}$, $LBL_{PRJ,FELLINGS,i,t,}$ and $LBL_{PRJ,OTHER,i,t}$ are as calculated in equations 35, 36, and 37, respectively.

R_i is the root:shoot ratio in polygon, *i* (see equation 33b).

$f_{PRJ,BLOWDOWN,i,t}$ = the annual proportion of live aboveground tree biomass subject to blowdown in polygon, *i,* year*, t* (unitless; $0 \leq f_{PRJ,BLOWDOWN,i,t} \leq 1$). Ex ante estimates must be derived from regional reports in similar forest types.

$f_{PRJ,BRANCH,i,t}$ = the annual proportion of aboveground tree biomass comprised of branches $\geq$ 5 cm diameter in polygon, *i* (unitless; $0 \leq f_{PRJ,BRANCH,i,t} \leq 1$). Ex ante data are available from allometric equations and models (for example, (Kurz & Apps, 2006) for Canada; (Smith, Miles, Vissage, & Pugh, 2004) for the U.S.). In the event slash burning is undertaken, this parameter should be reduced accordingly to reflect the proportion of biomass remaining. Estimates should be obtained from expert opinion; as a default, assume 100% consumption.

$f_{PRJ,BUCKINGLOSS,i,t}$ = the annual proportion of the log bole biomass left on site after assessing and/or merchandizing the log bole for quality, in polygon, *i* (unitless; $0 \leq f_{PRJ,BUCKINGLOSS,i,t} \leq 1$). Preferably, data for this variable must be based on regional and local comparative studies and experiential information derived from the local forest industry. Otherwise, an average default value of 21% can be used, based on US national summary statistics (Smith, Miles, Vissage, & Pugh, 2004).

$SNAG_{PRJ,i,t}$ = the total mass of the snag pool in polygon, *i*, year, *t* (see equation 42b).

$f_{PRJ,SNAGFALLDOWN,i,t}$ = the annual proportion of snag biomass in polygon, *i*, year, *t*, that falls over and thus is transferred to the LDW pool (unitless; $0 \leq f_{PRJ,SNAGFALLDOWN,i,t} \leq 1$). Ex ante estimates for this parameter can be derived from peer reviewed literature (for example, (Parish, Antos, Ott, & Di Lucca, 2010) and forest carbon accounting models that track the rates of input and losses from dead organic matter pools (for example, (Kurz & et al, 2009).

$$\mathbf{LDW_{PRJ,OUT,i,t} = LDW_{PRJ,i,t} \bullet f_{PRJ,lwDECAY,i,t} \quad (41)}$$

where:

$LDW_{PRJ,i,t}$ = the total amount of lying deadwood mass in polygon *i,* year*, t (see equation 39b)*. $f_{PRJ,lwDECAY,i,t}$ = the annual proportional loss of lying dead biomass due to decay, in polygon *i,* year*, t* (unitless; ; $0 \leq f_{PRJ,lwDECAY,i,t} \leq 1$). A common approach to ex ante estimation of $f_{PRJ,lwDECAY,i,t}$ is to assume mass loss occurs in proportion to the amount of mass remaining in accordance with an a single exponential model, of the general form:

$Y_t = Y_o e^{-kt}$

where Y_o is the initial quantity of material, Y_t the amount left at time *t*, and k is a decay constant (Harmon, et al., 1986). Other types of exponential models are available (reviewed in (Harmon, et al., 1986)) and may be more appropriate to particular forest types (to be described and justified by the project proponent, if used). Ex ante estimates for the decay parameter appropriate for the project should be derived from peer-reviewed literature (for example, (Harmon, et al., 1986); (Laiho & and Prescott, 2004); (Harmon et al, 2008)).

The change in standing dead wood (snag) carbon stock in year, *t* (t C yr^{-1}) is calculated as:

$$\Delta C_{PRJ,SNAG,t} = \Sigma(SNAG_{PRJ,IN,i,t} - SNAG_{PRJ,OUT,i,t}) \bullet CF \quad \textbf{(42a)}$$

$$SNAG_{PRJ,i,t+1} = SNAG_{PRJ,i,t} + (SNAG_{PRJ,IN,i,t} - SNAG_{PRJ,OUT,i,t}) \quad \textbf{(42b)}$$

where:

$SNAG_{PRJ,i,t}$ = The total mass of snags accumulated in polygon *i* at time *t* (t d.m.)

$SNAG_{PRJ,IN,i,t}$ = annual gain in snag biomass for polygon *i*, year, *t* (t d.m ha^{-1} yr^{-1}). Snag biomass develops as a result of natural mortality. In cases where snags are created through management activities, these should be accounted for here.

$SNAG_{PRJ,OUT,i,t}$ = annual loss in snag biomass through decay, or falldown (i.e, transfer to the LDW pool)(t d.m ha^{-1} yr^{-1})

CF = carbon fraction of dry matter (IPCC default value = 0.5).

Note that $SNAG_{PRJ,IN,i,t}$ and $SNAG_{PRJ,OUT,i,t}$ are summed across polygons.

$$SNAG_{PRJ,IN,i,t} = (LBL_{PRJ,NATURALi,t} - LBL_{PRJ,NATURALi,t} \bullet R_i) \bullet (1 - f_{PRJ,BLOWDOWN,i,t}) \quad \textbf{(43)}$$

where:

$LBL_{PRJ,NATURALi,t}$ is as calculated in equation 35, and

$1 - f_{PRJ,BLOWDOWN,i,t}$ is the proportion of live tree aboveground biomass that dies in polygon, *i*, year, *t*, but remains as standing dead organic matter (i.e. snags) (unitless; $0 \leq f_{PRJ,BLOWDOWN,i,t} \leq 1$). Ex ante default estimates for this calculation can be derived from literature values (for example (Harmon, et al., 1986); (Runkle, 2000); (Harmon et al, 2008)) and should be matched to the ecosystems that most closely characterize the project area.

$$SNAG_{PRJ,OUT,i,t} = SNAG_{PRJ,i,t} \bullet f_{PRJ,SWDECAY,i,t} + SNAG_{PRJ,i,t} \bullet f_{PRJ,SNAGFALLDOWN,i,t} \quad \textbf{(44)}$$

where:

$SNAG_{PRJ,i,t}$ = the total amount of snag mass in polygon *i,* year*, t (see equation 42b).* $f_{PRJ,SWDECAY,i,t}$ = the annual proportional loss of snag biomass due to decay, in polygon, *i*, year, *t* (unitless; $0 \leq f_{PRJ,SWDECAY,i,t} \leq 1$). As with lying dead wood, a common approach to estimating $f_{PRJ,SWDECAY,i,t}$ is to assume mass loss occurs in proportion to the amount of mass remaining in accordance with an a single exponential model (see equation 41). Ex ante estimates for this parameter can be derived from peer reviewed literature appropriate for the project site (for example, Vanderwel et al. 2006a) and forest carbon accounting models that track the rates of input and losses from dead organic matter pools for each forest type, productivity, and age-class (see, for example, Vanderwel et al., 2006b; (Kurz & et al, 2009)).

$f_{PRJ,SNAGFALLDOWN,i,t}$ = the annual proportion of snag biomass in polygon, *i*, that falls over and thus is transferred to the LDW pool (unitless; $0 \leq f_{PRJ,SNAGFALLDOWN,i,t} \leq 1$). See equation 40 for parameter estimates.

The annual change in DOM derived from dead belowground biomass ($\Delta C_{PRJ,DBG,\ ,t}$; t C yr^{-1}) is calculated for each polygon as per equation 45a. Calculation of $\Delta C_{PRJ,DBG,t}$ is specific to a given polygon; each polygon must therefore be summed in order to calculate total annual loss across the project activity area.

$$\Delta C_{PRJ,DBG,t} = \Sigma(DBG_{PRJ,IN,i,t} - DBG_{PRJ,OUT,i,t}) \bullet CF \quad (45a)$$

$$DBG_{PRJ,i,t+1} = DBG_{PRJ,i,t} + (DBG_{PRJ,IN,i,t} - DBG_{PRJ,OUT,i,t}) \quad (45b)$$

where:

$DGB_{PRJ,i,t}$ = The total quantity of dead belowground biomass accumulated in polygon *i* at time *t* (t d.m.).

$DBG_{PRJ,IN,i,t}$ = annual gain in dead belowground biomass for polygon *i*, year, *t* (t d.m ha^{-1} yr^{-1}). Dead belowground biomass develops as a result of mortality through natural causes or through harvesting activities.

$DBG_{PRJ,OUT,i,t}$ = annual loss in dead belowground biomass through decay, (t d.m ha^{-1} yr^{-1})

CF = carbon fraction of dry matter (IPCC default value = 0.5).

$$DBG_{PRJ,IN,i,t} = [(A_{PRJ,i} \bullet LB_{PRJ,i,t} \bullet R_i) \bullet (f_{PRJ,NATURAL,i,t} + f_{PRJ,HARVEST,i,t} + f_{PRJ,DAMAGE,i,t})] \quad (45c)$$

where:

$A_{PRJ,i}$ = area (ha) of forest land in polygon, *i*;

$LB_{PRJ,i,t}$ = average live tree biomass (t d.m. ha^{-1}) in polygon, *i,* for year, *t.* $LB_{PRJ,i,t}$ is calculated for year, *t*, beginning with biomass estimates in year *t*=1 (the project start year) and with annual biomass increments ($G_{PRJ,i,t}$) added as per calculations in equation 33 a, b. This value is then multiplied by $A_{PRJ,i,}$ the area (ha) of forest land in polygon, *i*.

R_i is the root:shoot ratio in polygon, *i* (see equation 33b).

$f_{PRJ,NATURAL,i,t}$ = the annual proportion of biomass that dies from natural mortality in polygon, *i* (unitless; $0 \leq f_{NATURALi} \leq 1$), year, *t* (see equation 35),

$f_{PRJ,HARVEST,i,t}$ = the proportion of biomass removed by harvesting from polygon, *i,* (unitless; $0 \leq f_{PRJ,HARVESTIi} \leq 1$), year, *t* (see equation 36),

$f_{PRJ,DAMAGE,i,t}$ = the proportion of additional biomass removed by for road and landing construction in polygon, *i* (unitless; $0 \leq f_{PRJ,DAMAGE,i,t} \leq 1$), year, *t* (see equation 37),

$$DBG_{PRJ,OUT,i,t} = DBG_{PRJ,i,t} \bullet f_{PRJ,dgbDECAY,i,t} \quad (45d)$$

where:

$DBG_{PRJ,i,t}$ = the total quantity of dead belowground in polygon *i,* year*, t (equation 17b)*. $f_{PRJ,dgbDECAY,i,t}$ = the annual proportional loss of dead belowground biomass due to decay, in polygon *i,* year*, t* (unitless; $0 \leq f_{PRJ,lwDECAY,i,t} \leq 1$). The ex ante estimation of the decay of dead belowground biomass should be done using a similar single exponent decay function as that described above for lying deadwood biomass. Estimates for the decay parameter appropriate for specific project should be derived from peer-reviewed literature (see for example: (Moore, Trofymow, Siltanen, Prescott, & CIDET, 2005); (Melin, Petersson, & Nordfjell, 2009).

8.2.9 Harvested Wood Products

See Section 8.1.6 for various discussion and background on HWP calculations.

The annual change in emissions associated with the production of harvested wood products (HWP), $\Delta C_{BSl,HWP,t}$, is calculated as:

$$\Delta C_{PRJ,HWP,t} = \Delta C_{PRJ,STORHWP,t} - \Delta C_{PRJ,EMITFOSSIL,t,} \quad (46)$$

$\Delta C_{PRJ,STORHWP,t}$ = the annual change in harvested carbon that remains in storage after conversion to wood products (t C yr^{-1})

$\Delta C_{PRJ,EMITFOSSIL,t}$ = the annual change in fossil fuel emissions from harvesting (logging and log transport) and processing of the various wood products.

8.2.10 Carbon storage harvested wood products ($\Delta C_{PRJ,STORHWP,t}$)

If harvesting is occurring in the project case, see Section 8.1.7 for a discussion of key issues.

The annual change in carbon storage in harvested wood products in year *t* ($\Delta C_{PRJ,STORHWP,t}$; t C yr^{-1}) is determined based upon the following equation:

$$\Delta C_{PRJ,STORHWP,t} = (C_{PRJ,STORHWP,t2} - C_{PRJ,STORHWP,t1}) / T \quad (47)$$

where:

$C_{PRJ,STORHWP,t2}$ = carbon storage in harvested wood products at t=2; t C

$C_{PRJ,STORHWP,t1}$ = carbon storage in harvested wood products at t=1; t C

T = number of years between monitoring t1 and t2

t : 1,2,3…t years elapsed since the project start date

Storage in the harvested wood products pool at a given time t ($C_{PRJ,STORHWP,t}$; t C) is calculated according to the following steps for each harvest period *h*:

Step 1 (Carbon contained in harvested timber): Determine the carbon contained within harvested timber removed from the project landbase. This can be calculated from measures of total merchantable volume generated during the harvest period *h* using species-specific wood densities and standard carbon conversions or estimated from live biomass removals after accounting for removal of belowground components, branches, and bucking losses (equation 48). In accordance with the 1605(b) approach, the harvested wood carbon ($C_{PRJ,TIMBER,h}$) must be divided into the following product type (*k*) categories: 1) softwood saw log, 2) softwood pulpwood, 3) hardwood saw log, 4) hardwood pulpwood. This can be done using local data if available or estimated based upon region and forest type according to Table 1.4 in the 1605(b) document. Table 3 provides recommendations for analogs for areas within North America but outside of the conterminous US; however the project proponent must justify the appropriateness of the selected analog. In the case of global project locations outside of North America, the project proponent must identify and justify the use of alternative data from peer-reviewed sources

$$C_{PRJ,TIMBER,h} = \Sigma[(LBL_{PRJ,FELLINGS,i,h} - LBL_{PRJ,FELLINGS,i,h} \bullet R_i + LBL_{PRJ,OTHER,i,h} - LBL_{PRJ,OTHER,i,h} \bullet R_i) \bullet (1 - f_{PRJ,BRANCH,i,h}) \bullet (1 - f_{PRJ,BUCKINGLOSS,i,h})] \bullet \bullet CF \quad (48)$$

where:

$C_{PRJ,TIMBER,h}$= carbon contained in timber harvested in period *h* (summed for all harvested polygons, *i*); t C

$LBL_{PRJ,FELLINGS,i,h}$ = annual removal of live tree biomass due to commercial felling in polygon, *i*; t d.m. (equation 36)

$LBL_{PRJ,OTHER,i,h}$ = annual removal of live tree biomass from incidental sources in polygon, *i*; t d.m. (equation 37)

R_i is the root:shoot ratio in polygon, *i* (see equation 33b).

1 - $f_{PRJ,BRANCH,i,h}$ the proportion of live tree biomass remaining after netting out branch biomass, in polygon *i* (unitless; $0 \leq f_{BRANCH,i,t} \leq 1$)(see equation 12)

1 - $f_{PRJ,BUCKINGLOSS,i,h}$ = the proportion of the log bole remaining after in-woods log processing/bucking for quality, length, etc., in polygon, *i* (unitless; $0 \leq f_{BUCKINGLOSS,i,t} \leq 1$) (equation 40)

h = harvest period ; yr

Step 2: (Carbon contained in harvested timber after milling): Determine the total carbon in harvested timber that will enter the wood products pool by product type accounting for mill efficiencies and estimated product disposition percentages ($C_{PRJ,MILL,h}$; t C). The gross quantity of carbon contained in harvested timber for each of the four product types described in Step 1 must be decremented to account for losses during processing (equation 49). These losses including bark and other milling wastes and may be determined using local data or estimated based upon region and product type according to Table 1.5 in the 1605(b) document. Table 3 provides recommendations for analogs for areas within North America but outside of the conterminous US; however, the project proponent must justify the appropriateness of the selected analog.. The 1605(b) document also provides specific examples demonstrating the use of values from Tables 1.4 and 1.5 to determine net carbon storage in wood product types after milling (See examples 1.4 and 1.5 on pages 25-27). In the case of global project locations outside of North America, the project proponent must identify and justify the use of alternative data from peer-reviewed sources

$$\mathbf{C_{PRJ,MILL,h,k} = (C_{PRJ,TIMBER,h,k} \bullet f_{RND,k} \bullet r_{RND,k})} \quad \mathbf{(49)}$$

where:

$C_{PRJ,MILL,h,k}$ = carbon contained in harvested timber after milling in period h, for product type *k*; t C

$C_{PRJ,TIMBER,h,k}$ = carbon contained in timber harvested in period h, for product type *k*; t C

k = wood product type – (softwood saw log, softwood pulpwood, hardwood saw log, or hardwood pulpwood; proportions determined from Table 1.4 of 1605(b) document)

$f_{RND,k}$ = fraction of growing stock volume removed as roundwood for product type *k* (default values by region in Table 1.5 of the 1605(b) document); dimensionless

$r_{RND,k}$ = ratio of industrial roundwood to growing stock volume removed as roundwood for product type *k* (default values by region in Table 1.5 of the 1605(b) document); dimensionless

Step 3: (Carbon storage in medium-term and long-term wood products): Calculate the total carbon lost in short-lived products and stored in medium-term and long-term products. For each harvest period *h*, carbon stored in harvested wood products of a defined type (k) after accounting for milling losses ($\mathbf{C_{PRJ,MILL,h,k}}$) must be apportioned into one of the following categories:

d) Short lived wood products: harvested wood products and wood waste that will decay within 3 years.
e) Medium lived wood products: harvested wood products and wood waste that will be retired between 3 and 100 years from the date of harvest.
f) Long lived wood products: harvested wood products and wood waste that may be considered permanent (stored for 100 years or more).

To determine the proportion of harvested wood products (by type) that fall into each category, refer to the "In Use" column for the selected forest region in Table 1.6 in the 1605(b) document. Table 3 provides recommendations for analogs for areas within North America but outside of the conterminous US; the project proponent must justify the appropriateness of the selected analog .Three values are then calculated from these data selected from Table 1.6 in the 1605(b) document, for each product type, *k* : the short-lived fraction ($P_{PRJ,SLF,k}$), medium-lived fraction ($P_{PRJ,MLF,k}$), and long-lived fraction ($P_{PRJ,LLF,k}$):

$$\mathbf{P_{PRJ,SLF,k} = 1-P_{3\text{-}year}} \qquad \textbf{(50a)}$$

$$\mathbf{P_{PRJ,LLF,k} = P_{100\text{-}year}} \qquad \textbf{(50b)}$$

$$\mathbf{P_{PRJ,MLF,k} = P_{3\text{-}year} - P_{100\text{-}year}}\ , \qquad \textbf{(50c)}$$

Each category of wood products (*k*) stores carbon according to the following rules:

iv. Short-lived wood products – immediate emission of all carbon upon harvest
v. Medium-lived wood products – no emission of carbon upon harvest, but carbon stored will decrease by 1/20th for the next 20 years after harvest, such that after 20 years the term becomes zero
vi. Long-lived wood products – no loss of carbon.

Thus, carbon storage in harvested wood products at time *t* may be calculated using a cohort approach in which medium-term and long-term wood products from each harvest period *h* are tracked independently and then summed over the project time period as indicated in equation 51.

$$\mathbf{C_{PRJ,STORHWP,t,}} = \Sigma\ \Sigma\ \mathbf{((\ C_{PRJ,MILL,h,k} \bullet P_{LLF,k}) + [(C_{PRJ,MILL,h,k} \bullet P_{MLF,k}) \bullet ((20\text{-}h) / 20)])} \qquad \textbf{(51)}$$

where:

$C_{PRJ,STORHWP,t,}$ = carbon stored in harvested wood products in year *t* summed for all product types *k* and then over all harvest periods *h*; t C

k = wood product type – (softwood saw log, softwood pulpwood, hardwood saw log, or hardwood pulpwood; proportions determined from Table 1.4 of 1605(b) document)

h = year of harvest (the term (20-h) should not be allowed to drop below 0)

8.2.11 mustFossil fuel emissions associated with logging, transport, and manufacture

The annual change in fossil fuel emissions from harvesting and processing of the various wood products ($\Delta C_{PRJ,EMITFOSSIL,t}$) are calculated as:

$$\Delta C_{PRJ,EMITFOSSIL,t} = C_{PRJ,EMITHARVEST,t} + C_{PRJ,EMITMANUFACTURE,t} + C_{PRJ,EMITTRANSPORT,t} \quad (52)$$

Where

$C_{PRJ,EMITHARVEST,t}$ = the annual fossil fuel emissions associated with harvesting of raw material (t C yr^{-1})

$C_{PRJ,EMITMANUFACTURE,t}$ = the annual fossil fuel emissions associated with the manufacturing of raw material (t C yr^{-1})

$C_{PRJ,EMITTRANSPORT,t}$ = the annual fossil fuel emissions associated with the transport of raw material (t C yr^{-1})

The simplest approach to calculating $C_{PRJ,EMITFOSSIL,t}$ is to use published or derived carbon emission intensity factors. In the case of harvesting, $_{PRJ,}C_{EMITHARVEST,t}$; t C yr^{-1}), can be calculated as:

$$C_{PRJ,EMITHARVEST,t} = \Sigma[(LBL_{PRJ,FELLINGS,i,t} - LBL_{PRJ,FELLINGS,i,t} \bullet R_i + LBL_{PRJ,OTHER,i,t} - LBL_{PRJ,OTHER,i,t} \bullet R_i) \bullet (1 - f_{PRJ,BRANCH,i,t}) \bullet (1 - f_{PRJ,BUCKINGLOSS,i,t})] \bullet CF \bullet c_{HARVEST} \quad (53)$$

where:

$c_{HARVEST}$ = carbon emission intensity factor (t C emitted/t C raw material) associated with harvesting (see Table 4 for default values); all other terms are as defined in equation 19.

$C_{PRJ,EMITTRANSPORT,t}$ must be calculated after consideration of the transport distance from harvest to processing facility, and the means of transportation. This term can be calculated as follows (after (Heath, et al., 2010)):

$$C_{PRJ,EMITTRANSPORT,t} = \Sigma[(LBL_{PRJ,FELLINGS,i,t} - LBL_{PRJ,FELLINGS,i,t} \bullet R_i + LBL_{PRJ,OTHER,i,t} - LBL_{PRJ,OTHER,i,t} \bullet R_i) \bullet (1 - f_{PRJ,BRANCH,i,t}) \bullet (1 - f_{PRJ,BUCKINGLOSS,i,t})] \bullet CF \bullet \Sigma(f_{PRJ,TRANSPORTk} \bullet d_{TRANSPORTk} \bullet c_{TRANSPORTk}) \quad (54)$$

where:

$f_{PRJ,TRANSPORTk}$ = the fraction of raw material transported by transportation type, *k*. (unitless; $0 \leq f_{PRJ,TRANSPORTk} < 1$).

$d_{TRANSPORTk}$ = the distance transported by transportation type, *k*. (km);

$c_{TRANSPORTk}$ = the carbon emission intensity factor (kg C emitted/t C raw material) associated with transportation type, *k* (see Table 4 for default values); all other terms are as defined in equation 48.

$$C_{PRJ,EMITMANUFACTURE,t} = \Sigma[(LBL_{PRJ,FELLINGS,i,t} - LBL_{PRJ,FELLINGS,i,t} \bullet R_i + LBL_{PRJ,OTHER,i,t} - LBL_{PRJ,OTHER,i,t} \bullet R_i) \bullet (1 - f_{PRJ,BRANCH,i,t}) \bullet (1 - f_{PRJ,BUCKINGLOSS,i,t})] \bullet \Sigma(f_{PRJ,PRODUCTk} \bullet c_{MANUFACTUREk}) \bullet CF \quad (55)$$

$c_{MANUFACTUREk}$ = the carbon emission intensity factor (t C emitted/t C raw material) associated with manufacture of product type, k; all other terms are as defined in equation 48.

Default values for $c_{MANUFACTUREk}$ are provided in Table 4. Data are from a comprehensive analysis conducted in Finland (Pingoud, Perälä, Soimakallio, & Pussinen, 2003). Higher comparative values from North America are provided for harvesting and sawnwood manufacturing to illustrate inherent variability. Project proponents may use the default values in Table 4, or substitute regional data, if available.

8.3 Leakage

Leakage is defined as any increase in GHG emissions that occurs outside the project boundary (but within the same country), and is measurable and attributable to the project activities. All leakage must be assessed and accounted for in GHG calculations. Positive leakage effects must be discounted.

8.3.1 Activity Shifting Leakage:

Activity shifting leakage occurs when the actual agent of harvesting moves to an area outside of the project boundary and initiates compensatory harvesting activities elsewhere. Activity shifting leakage in IFM projects can result from current activities shifting within the project proponent's operations due to the implementation of the carbon project. This effectively offsets a portion of the benefits of the carbon project emissions reductions. The project proponent will demonstrate that, as per VCS requirements for IFM projects and the applicability conditions of this methodology, there is no leakage due to activity shifting within the project proponents' lands upon the start up of the project[27], using the following steps:

STEP 1 - The project proponent must annually provide to the validator and/or verifier the locations and descriptions of all forestlands within the project country over which the project proponent has ownership, management, or legally sanctioned rights of use.

STEP 2 - Project proponents must demonstrate annually that there is no activity shifting leakage to areas that are outside the project area but within the project proponents operating areas, and that the management plans and/or land-use designations of all other lands operated by the project proponent have not materially changed as a result of the project activity (e.g., harvest rates have not been increased). Demonstration methods must include:

1. Historical records showing trends in harvest volumes paired with records from the project time period showing no deviation from historical trends, or
2. Forest management plans prepared ≥ 24 months prior to the start of the project showing harvest plans on all owned/managed lands paired with records from the project time period showing no deviation from management plans; and/or
3. Other evidence and justification to demonstrate activity shifting related to the project is not occurring[28].

8.3.2 Market Leakage:

Market leakage risk occurs when a project significantly reduces the production of a commodity causing a change in the supply and market demand equilibrium that results in a shift of production elsewhere to make up for the lost supply. VCS provides project proponents with two options for quantifying market leakage, which are further defined for this methodology:

[27] See footnote 4 (and applicability criterion 7) for further requirements in the event activity shifting is found to be occurring in later years of the project duration.

[28] The onus is on the project proponent to demonstrate and justify that the source of data and the geographic scale and scope used to assess activity shifting are appropriate for the project to meet the requirements of VCS and the methodology.

1. Apply the most current VCS market leakage tool to determine a discount factor to the net change in carbon stock associated with the activity that reduces timber harvest (see Section 8.3.3); or,

2. Develop a project-specific market leakage factor that accounts for country level leakage within similar forest types[29]. This methodology allows two variations on this option:
   a. Utilize the CAR Forest Protocol 3.2 market leakage equation, if the project is located within countries where CAR applies, or can demonstrate equivalent market conditions (currently CAR applies only in the US but is developing protocol assumptions for Mexico and Canada) (see Section 8.3.4); or
   b. Utilize a detailed leakage risk assessment form provided in this methodology and provide related additional supporting evidence for the assessments made therein (see Section 8.3.5).

8.3.3 Market Leakage Option 1 – VCS Default Market Leakage Discount Factors

In exercising this option, project proponents must utilize the most current approved VCS leakage discount method as outlined in the most recent VCS AFOLU requirements document[30]. Projects will determine the appropriate discount factor in accordance with the most recent requirements for market leakage. Project proponents must provide justification and evidence of how the leakage discount factor is determined.

For project proponents using Market Leakage Option 1:

The outcome of the VCS Leakage Discount Factor determination = the value for MLF_y (56a)

To calculate the project market leakage (LE_Y, t CO2e yr^{-1}):

$$LE_Y = MLF_y \cdot ER_{y,GROSS} \quad \textbf{(56b)}$$

Where,

MLF_y = Market leakage factor, as calculated above.

$ER_{y,GROSS}$ = the gross difference in the overall annual carbon change between the baseline and project scenarios in year 'y' (in tonnes CO_2e yr^{-1}). This term is calculated in equation 57.

8.3.4 Market Leakage Option 2 – CAR Market Leakage Formula

Based on the fact that the CAR forest protocol is widely accepted in North America, thoroughly reviewed, generally mutually recognized by VCS, and developed for a single country leakage condition; it is considered a valid approach to leakage discount factors when applied to projects located in CAR-eligible jurisdictions (currently the United States). Further, project proponents may justify the application of the CAR leakage formula for log market conditions fundamentally similar to the United States and which are currently under development as CAR jurisdictions (i.e. Canada and Mexico pending).

The CAR leakage formula is calculated as per the latest approved CAR Forest Protocol. The currently approved calculation is provided Figure 1, which is to be replaced by the most up to date approved CAR method as required:

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[29] Specifically: "…market leakage shall be accounted for at the country-scale applied to the same general forest type as the project (i.e., forests containing the same commercial species as the forest in the project area)...." (Voluntary Carbon Standard, 2008b).

[30] Note the VCS May 24th AFOLU Program Update, which specifies using the ratio of merchantable biomass to total biomass in the project versus leakage area.

Figure 1 - CAR Forestry Protocol v.3.2 Market Leakage Process[31][32]

Forest Project Protocol *Version 3.2, August 2010*

6.2.6 Quantifying Secondary Effects

For Improved Forest Management Projects, significant Secondary Effects can occur if a project reduces harvesting in the Project Area, resulting in an increase in harvesting on other properties. Changes in energy-related emissions, which could result from a Forest Project causing consumers of forest products to increase or decrease their use of alternative materials, are not accounted for because it is assumed that energy sector emissions will be capped in the relatively near future under a regulatory cap-and-trade system.

Equation 6.10 must be used to estimate Secondary Effects for Improved Forest Management Projects.

Equation 6.10. Secondary Effects Emissions

$$If \sum_{n=1}^{y-1}(AC_{hv,n} - BC_{hv,n}) > 0, then\ SE_y = 0$$

$$If \sum_{n=1}^{y-1}(AC_{hv,n} - BC_{hv,n}) < 0, then\ SE_y = (AC_{hv,y} - BC_{hv,y}) \times 20\%$$

Where,

SE_y	=	Estimated annual Secondary Effects (used in Equation 6.1)
$AC_{hv,n}$	=	Actual amount of onsite carbon harvested in reporting period n (prior to delivery to a mill), expressed in CO_2-equivalent tonnes
$BC_{hv,n}$	=	Estimated average baseline amount of onsite carbon harvested in reporting period n (prior to delivery to a mill), expressed in CO_2-equivalent tonnes, as determined in Step 1 of Section 6.2.3
y	=	The current year or reporting period

For project proponents using Leakage Option 2:

Utilize the CAR formulas (Equation 6.10 – shown in Figure 1), with variables calculated as follows:

Note: for consistency, y = n = t.

$$BC_{hv,n} = \Sigma[(LBL_{BSL,FELLINGS,i,t} - LBL_{BSL,FELLINGS,i,t} \bullet R_i + LBL_{BSL,OTHER,i,t} - LBL_{BSL,Other,i,t} \bullet R_i) \bullet (1 - f_{BSL,BRANCH,i,t}) \bullet (1 - f_{BSL,BUCKINGLOSS,i,t})] \bullet CF \bullet 44/12 \quad (56c.1)$$

As calculated using the *baseline scenario data*, and where:

$LBL_{BSL,FELLINGS,i,t}$ = annual removal of live tree biomass due to commercial felling in polygon, *i*; t d.m. yr^{-1} (equation 6)

[31] "Secondary Effects" = Market Leakage

[32] Figure 1 is to be replaced with the latest approved CAR Forest Protocol Secondary Effects calculations at the time of PD validation.

$LBL_{BSL,OTHER,i,t}$ = annual removal of live tree biomass from incidental sources in polygon, *i*; t d.m. yr^{-1} (equation 6)

1 - $f_{BSL,BRANCH,i,t}$ = the proportion of aboveground live tree biomass remaining after netting out branch biomass, in polygon *i* (unitless; $0 \leq f_{BRANCH,i,t} \leq 1$)(see equation 12)

1 - $f_{BSL,BUCKINGLOSS,i,t}$ = the proportion of the log bole remaining after processing for quality, in polygon, *i* (unitless; $0 \leq f_{BUCKINGLOSS,i,t} \leq 1$) (equation 12)

R_i = the root:shoot ratio in polygon, *i*

CF = carbon fraction of dry matter (IPCC default value = 0.5).

$$\mathbf{AC_{hv,\,n} = \Sigma[(LBL_{PRJ,FELLINGS,i,t} - LBL_{PRJ,FELLINGS,i,t} \bullet R_i + LBL_{PRJ,OTHER,i,t} - LBL_{PRJ,Other,i,t} \bullet R_i) \bullet (1 - f_{PRJ,BRANCH,i,t}) \bullet (1 - f_{PRJ,BUCKINGLOSS,i,t})] \bullet CF \bullet 44/12} \qquad \mathbf{(56c.2)}$$

As calculated using the *project scenario data*, and where:

$LBL_{PRJ,FELLINGS,i,t}$ = annual removal of live tree biomass due to restoration felling in polygon, *i*; t d.m. yr^{-1} (equation 6)

$LBL_{PRJ,OTHER,i,t}$ = annual removal of live tree biomass from incidental sources in polygon, *i*; t d.m. yr^{-1} (equation 6)

1 - $f_{PRJ,BRANCH,i,t}$ = the proportion of aboveground live tree biomass remaining after netting out branch biomass, in polygon *i* (unitless; $0 \leq f_{BRANCH,i,t} \leq 1$)(see equation 12)

1 - $f_{PRJ,BUCKINGLOSS,i,t}$ = the proportion of the log bole remaining after processing for quality, in polygon, *i* (unitless; $0 \leq f_{BUCKINGLOSS,i,t} \leq 1$) (equation 12)

CF = carbon fraction of dry matter (IPCC default value = 0.5).

$$\mathbf{SE_y = LE_y} \qquad \mathbf{(56c.3)}$$

where:

SE_y = Secondary Effects in year 'y' (tCO_2e) calculated using equations in Figure 1 and equations 56c.1, 56c.2 and 56c.3.

LE_Y = Leakage in year y (in tonnes CO_2e yr^{-1}) – used in equation 58.

8.3.5 Market Leakage Option 3 – Leakage Assessment Tool

Currently, the VCS method for assessing leakage used in Option 1 does not provide a mechanism for weighting leakage into different biomass areas, and also does not provide a mechanism to separate domestic versus international leakage proportions. This methodology therefore provides a third option to project proponents who wish to undertake an assessment of market leakage conditions more detailed and specific to their project location and condition.

This tool sets out a procedure to weight the VCS leakage categories according to publically available forest products market data for where the leakage risk is most likely to be leaked to (or replaced from).

Following Table 5, the project proponent must conduct the risk analysis as follows:

1. Determine the proportion of leakage expected to be replaced by international sources (i.e. proportion of international leakage) versus domestic sources, and;
2. For the domestic proportion, determine the proportion of leakage to other national biomass forests, based on the VCS default values and categories, and the ratio of merchantable biomass to total biomass on the project site versus the leakage sites.

Where a project is unable to provide any relevant published justification or supporting evidence for a risk factor selection in Table 5, then the project is not eligible to use this tool and must use one of the other provided options to assess market leakage risk.

Table 5 - Market Leakage Option 3 Assessment Table

1.	**International Leakage Proportion**			
	In order to determine the proportion of potential leakage which will occur within domestic markets versus international markets, the project proponent must calculate the proportion of the project leakage which is expected to be *replaced from* domestic (in-project country) sources versus the proportion that will likely be *replaced from* international source (and hence, be international leakage, which is given a leakage risk of zero in VCS). It is assumed that the forest products market is efficient, and any leakage will be replaced proportionally across the project countries current national forest products market conditions. The following calculation provides a method to estimate the proportion of leakage which is domestic versus international. International Leakage Factor = $(FP_{TO\_DOMESTIC}) * (DOM.DEMAND_{FROM\_INTL}) + (FP_{TO\_EXPORT}) * (EXP.DEMAND_{FROM\_INTL})$ Where, $FP_{TO\_DOMESTIC}$ = Total project country forest products delivered to domestic markets (%) FP_{TO_EXPORT} = Total project country forest products delivered to export (international) markets (%) $DOM.DEMAND_{FROM\_INTL}$ = Proportion of total project country Forest Products to International Markets (%) $EXP.DEMAND_{FROM\_INTL}$ = Weighted sum of the proportions of key markets which are supplied from non-project country sources (%) Definitions: "Domestic" = project country "International" = sum of all non-project countries which individually represent >10% of the total project country's forest products production, and which collectively represent >80% of the total project country's forest products export production. "Forest Products" = the market data utilized must be demonstrated to be representative of >80% of the project harvested wood products product mix. Proponents may use forest products volume or value as long			

as the units are consistent and comparable across markets and used consistently within this entire tool.

"Key market(s)" = collectively must represent >80% of the project country's domestic, import, and export supply, either on a log basis or lumber basis. Individual market countries representing <10% of the total domestic or export market may be excluded.

Example:

Example of *Canadian-based* projects under this tool (Stats Can Data & FAO data) (only the US market meets the key market definition for Canadian forest products production):

$FP_{TO\_DOMESTIC}$ = 20%

FP_{TO_EXPORT} = 80% (>90% to US = single 'Key Market')

$DOM.DEMAND_{FROM\_INTL}$ = 10% (i.e. 10% of the domestic market is supplied by non-Canadian supply)

$EXP.DEMAND_{FROM\_INTL}$ = 65% (i.e. 65% of the US market is supplied by non-Canadian supply)

$LF_{INTL} = (FP_{TO\_DOMESTIC}) * (DOM.DEMAND_{FROM\_INTL}) + (FP_{TO\_EXPORT}) * (EXP.DEMAND_{FROM\_INTL})$

$LF_{INTL} = (0.20 * 0.10) + (0.80 * 0.65) = 54\%$

Therefore, 54% of the market leakage is expected to be replaced by international sources, which is assigned a leakage factor of "0". The remaining domestic/national leakage, 46%, is then further considered in the biomass ratio calculations below.

	International Leakage Factor (LF_{INTL}*)*	$LF_{INTL} = (FP_{TO\_DOMESTIC}) * (DOM.DEMAND_{FROM\_INTL}) + (FP_{TO\_EXPORT}) * (EXP.DEMAND_{FROM\_INTL})$

2.	**Proportional Leakage by Biomass Ratio:**			
	VCS Default Biomass Ratio Categories (see: VCS 2008 May 24, 2010 Program Update) Calculated as: ((Project Biomass Ratio – Leakage Biomass Ratio) / (Project Biomass Ratio)) * 100	> 15%[33] Lower merchantable biomass to total biomass (t/ha)	+/- 15% merchantable biomass to total biomass (t/ha)	>15% Higher merchantable biomass to total biomass (t/ha)
	Starting VCS Default Leakage Factors[34]:	20%	40%	70%

[33] VCS does not specify a quantitative range for determining "higher", "lower" or "similar" biomass ratios, and hence a 15% factor has been selected to represent a reasonable range of biomass ratios. This factor is consistent with other approved VCS and ACR IFM methodology approaches.

[34] These factors are from the 2008 VCS leakage calculation method, and should be retained for use in this leakage tool Option 3 regardless of new VCS market leakage tool calculations.

<table>
<tr><td>1a.</td><td colspan="4">2a Calculating Weighted Average Leakage Biomass Ratio:

This is a typical weighted average calculation, with the objective of creating an average difference in biomass ratio between the project and the national leakage areas, weighted by the proportion of timber supply coming from each leakage forest type:

- Identify national forest type (or ecotype) data where merchantable log volume biomass and total forest biomass estimates are available (i.e. from published national inventory data sources, etc.)
- Determine the biomass ratio in each national forest type (ratio of merchantable volume in biomass (t/ha) to total biomass (t/ha);
- Determine the proportion of the domestic national market that is supplied by each of the national forest types (%);
- Determine the difference between the forest type containing the project and each leakage area biomass ratio (Biomass Ratio Difference (%) = ((Project Biomass Ratio – Leakage Area Biomass Ratio) / Project Biomass Ratio) * 100);
- Select the VCS default leakage factor for each national forest type, based on the difference between the project biomass ratio and each national forest type biomass ratio (see biomass ratio categories above);
- Multiple the proportion (%) of market supplied by each leakage forest type by the VCS Default Leakage Factor from each forest type to determine the weighted average VCS Leakage Factor for biomass ratios.

Example (simplified, using 4 national forest types):

Project is located in national forest type 1 (biomass ratio = 0.65):
Forest Type 1: Biomass Ratio = 0.65; 25% of national timber inventory
Forest Type 2: Biomass Ratio = 0.75; 30% of national timber inventory
Forest Type 3: Biomass Ratio = 0.55; 25% of national timber inventory
Forest Type 4: Biomass Ratio = 0.75; 20% of national timber inventory

Biomass Ratio difference between leakage area and project area:
Forest Type 1 = (0.65 – 0.65)/0.65 = 0 = 40% VCS Leakage Factor
Forest Type 2 = (0.65 – 0.75)/0.65 = -15.4% = 20% VCS Leakage Factor
Forest Type 3 = (0.65 – 0.55)/0.65 = 15.4% = 70% VCS Leakage Factor
Forest Type 4 = (0.65 – 0.75)/0.65 = -15.4% = 20% VCS Leakage Factor

Weighted Average = (25% * 40%) + (30% * 20%) + (25% * 70%) + (20% * 20%) = 37.4%
Example Weighted Biomass Discount Factor = 37.4%</td></tr>
<tr><td></td><td>VCS Default Leakage Discount Factor, by forest type (selected by +-15% criteria)</td><td>20%</td><td>40%</td><td>70%</td></tr>
<tr><td></td><td>Proportional of Market Supplied by National Forest Type in each Leakage Discount Category (note: X + Y + Z = 100%):</td><td>= X</td><td>= Y</td><td>= Z</td></tr>
<tr><td></td><td>Proportional Biomass Leakage Discount Factor ($LF_{BIOMASS}$):</td><td colspan="3">$LF_{BIOMASS} = (20\% * X) + (40\% * Y) + (70\% * Z)$</td></tr>
<tr><td>3.</td><td>MARKET LEAKAGE FACTOR (MLF_y):</td><td colspan="3">$=(1 - LF_{INTL})$[35] $* LF_{BIOMASS}$</td></tr>
</table>

[35] The inverse of the international leakage factor is the portion of the market leakage related to national leakage. International leakage is given a leakage factor discount of "0" in VCS.

For project proponents utilizing Leakage Option 3, project market leakage (LE_Y; t CO_2e yr^{-1}) is calculated as:

$$LE_Y = MLF_y \cdot ER_{y,GROSS} \quad (56d)$$

Where,

MLF_y = the market leakage factor in year, *y* (as calculate per section 8.3.5)

$ER_{y,GROSS}$ = the gross difference in the overall carbon balance between the baseline and project scenarios in year, *y* (t CO_2e yr^{-1}). See equation 57 for its calculation.

8.4 Summary of GHG Emission Reduction and/or Removals

The net GHG emissions and removals are calculated for each scenario following the methods outlined in Section 8.1 and 8.2.

8.5 Summary Gross Emissions Reductions and/or Removals Equation

Gross carbon emissions reductions (ER_y,gross; t CO_2e yr^{-1}) created by the carbon project are calculated annually as the difference between the baseline and project scenario net emission reductions/emissions:

$$ER_{y,GROSS} = (\Delta C_{BSL,t} - \Delta C_{PRJ,t}) \bullet 44/12 \quad (57)$$

Where,

$\Delta C_{BSL,t}$ = total net baseline scenario emissions calculated from equation 1 (t C yr^{-1}).

$\Delta C_{PRJ,t}$ = total net project scenario emissions calculated from equation 29 (t C yr^{-1}).

44/12 = factor to convert C to CO_2e

8.5.1 Summary Net Emissions Reductions and/or Removals Equation

The annual *net* carbon emissions reductions is the actual net GHG removals by sinks from the project scenario minus the net GHG removals by sinks from the baseline scenario, were then calculated by applying the leakage and uncertainty discount factors (but not the VCS permanence buffer), on an annualized basis:

$$ER_y = ER_{y,GROSS} - LE_y \quad (58)$$

where:

ER_y = the net GHG emissions reductions and/or removals in year *y* (the overall annual carbon change between the baseline and project scenarios, net all discount factors except the permanence buffer) (t CO_2e yr^{-1}).

$ER_{y,GROSS}$ = the difference in the overall annual carbon change between the baseline and project scenarios (t CO_2e yr^{-1}).

LE_y = Leakage in year y (t CO_2e yr^{-1}), as calculated in equation 56b.

8.5.2 Calculating Verified Carbon Units (VCU's) for the Project

The number of VCU's the project available for issuance and sale in year, *y* (VCU_y; t CO_2e yr^{-1}), is calculated as:

$$\mathbf{VCU_y = ER_y \cdot (1 - ER_{y,ERR}) - BR_y} \quad \textbf{(59)}$$

where:

ER_y = the net GHG emissions reductions and/or removals in year (t $CO_2e\ yr^{-1}$), as calculated in equation 58.

$ER_{y,ERR}$ = the uncertainty factor for year, y, (calculated in Section 8.5.3), expressed as a proportion.

BR_y = estimated VCU-equivalent tCO_2e issued to the VCS Buffer Pool in year, *y*, calculated using the latest version of the VCS AFOLU Non-Permanence Risk Tool. BRy is calculated by multiplying the most current verified permanence risk Buffer Withholding Percentage for the project by the change in carbon stocks (difference between baseline and project scenario) for the project area as per the latest approved VCS AFOLU Requirements (Voluntary Carbon Standard, 2008a).

8.5.3 Calculation of an Uncertainty Factor

Estimated carbon emissions and removals arising from AFOLU activities have uncertainties associated with forest inventory, carbon stocks, biomass growth rates, modeling error, and their various expansion factors, equations and coefficients. Use of conservative estimates, peer-reviewed scientific data and analysis, and high quality inventory sampling procedures, will mitigate uncertainty, and improve accuracy as new and reliable data are acquired over time.

To be conservative, this methodology employs an over-riding project confidence deduction as a proxy for collective project uncertainty by assessing statistical uncertainty in the forest carbon inventory *and* associated modeling. The approach is based partly on CAR's "Confidence Deduction" module (Climate Action Reserve, 2010). Project proponents are required to apply this uncertainty factor to the net emission reductions claimed by the project each year based on the results of the latest ex-post inventory field data collection and modeling output.

Note that physical field plot measurement error is calculated and compared directly against a set of minimum accuracy threshold requirements, as described in Section 9.

Refer to Section 8.1 for guidance on the process of stratification and how *polygons* and *analysis units* are defined.

The methodology monitoring section specifies that all analysis units or polygons[36] will have representation by one or more field plots. However, due to the difficulty of determining the independence of plot data within individual homogeneous polygons (i.e. a specifically similar forest type, site, and age), it will be necessary to only calculate a single carbon density *observation* for each individual polygon sampled; either through the use of a single plot within that polygon, or calculation of the mean of multiple plots within that polygon. *Throughout these calculations a plot observation, subscript i, is defined to represent the mean of all plots within a given polygon.*

The project-level uncertainty factor is calculated as follows:

Step 1 – Calculate the average percent model error (E_M) for the project based on the average area-weighted difference between measured values in monitored plot observations and model-predicted values using Equations 60a,b. In the case where analysis units have been used for stratification, the difference between the plot observation and model-predicted value (both expressed on a per hectare basis) for a given analysis unit ($y_{d,h,i}$) is weighted by the area of its associated analysis unit ($A_{PRJ,h}$) (Eq. 60a). The use of an area-weighting factor places more emphasis on analysis units that represent a relatively larger proportion of the total project area. In the case

[36] If polygons are the primary stratification unit being used by the project, then each polygon shall have field plot representation. If polygons are grouped into analysis units for the project, then each analysis unit shall have field plot representation (noting that not all polygons will have plot representation within a given analysis unit).

where only polygons are used in the stratification, the area weighting term (see equations 60a-c) would change to the area of the polygon ($A_{PRJ,i}$), and the subscript, *h*, is dropped from the $\mathbf{y_{d,h,i}}$ term in equations 60a-e.

$$E_M = 100 \cdot (\sum y_{d,h,i} / \sum(A_{PRJ,h} \cdot y_{m,h,i})) \quad \textbf{(60a)}$$

where:

The summation is across all plot observations, *i*, and across all analysis units , *h*;

$$y_{d,h,i} = A_{PRJ,h} \cdot (y_{m,h,i} - y_{p,h,i}) \quad \textbf{(60b)}$$

E_M = Mean model error for the project (%)

$y_{d,h,i}$ = the area-weighted difference between measured and predicted carbon storage in analysis unit, *h*, plot observation, *i* (t C)

$y_{m,h,i}$ = carbon storage measured in analysis unit, *h*, plot observation, *i* (t C ha^{-1})

$y_{p,h,i}$ = carbon storage predicted by model for analysis unit , *h*, plot observation, *i* (t C ha^{-1})

$A_{PRJ,h}$ = area of project analysis unit, *h* (ha)

Step 2 – Calculate the inventory error (E_I) at a 90% confidence interval expressed as a percentage of the mean area-weighted inventory estimate from the measured plots.

This methodology was designed to accommodate complex landscapes consisting of hundreds to thousands of polygons, which can be further grouped into analysis units. Inventory error is estimated based upon the difference between modeled and measured values for monitoring plots established in polygons or in polygons grouped within analysis units.

Inventory error, E_I, is estimated by first calculating the standard error of the area-weighted differences between the plot observation measurement and the associated model-predicted carbon storage (both on a per hectare basis) for analysis units or polygons. The standard error is then multiplied by the *t*-value for the 90% confidence interval. Finally E_I is expressed in relative terms (in Equation 60c) by dividing the 90% confidence interval of the area-weighted differences between predicted and measured values in all plots by the area-weighted average of the measured values in all monitoring plots.

$$E_I = 100 \cdot [SE * 1.654 / ((1/N) \cdot \sum(A_{PRJ,h} \cdot y_{m,h,i}))] \quad \textbf{(60c)}$$

Where,

E_I = Inventory error for the project (%)

SE = the project level standard error of the area weighted differences between measured plot observation and predicted values of carbon storage.

N = total number of plot observations in all analysis units or polygons[37]

1.654 = the 90% confidence interval *t*-value

[37] For clarity, the plot observation sample size (N) is equivalent to the number of polygons sampled (for projects using either a polygon or analysis unit stratification method). As noted, a single *plot observation* is created for each polygon using the mean when there are multiple plots within a polygon. Thus, in some situations the number of actual installed plots may be higher than the number of plot observations (N).

All other terms as defined in equation 60a.

$SE = S/\sqrt{N}$ **(60d)**

Where,

N = total number of plot observations in all analysis units or polygons (see Footnote 37)

S = the standard deviation of the area weighted differences between measured and predicted values of carbon storage across all analysis unit or polygons.

$S = \sqrt{[(1/N-1) \cdot \sum(y_{d,h,i} - \bar{y}bar_d)^2]}$ **(60e)**

Where,

$\bar{y}bar_d$ = the project-level mean of the area weighted differences between measured plot observation and predicted values of carbon storage. See equation 60b for the calculation of $\mathbf{y_{d,h,i}}$

All other terms as defined in equation 60b and 60c.

Step 3 - The total error for the project (E_P; %) is calculated by adding the model and inventory error terms, as calculated in Steps 1 and 2.

$E_P = E_M + E_I$ **(60f)**

Step 4 – Compare the result of Step 3 against Table 6 to determine the uncertainty factor:

Table 6 - Uncertainty Factor Calculation

Estimated Project Error, E_P (%)	Uncertainty Factor (=$ER_{Y,ERR}$)
0 – 10%	= 1.5%[38]
>10%	= 1.5% + E_P – 10%

The uncertainty factor is calculated at each verification and applied annually until the next verification.

9 MONITORING

9.1 Data and Parameters Available at Validation

Selection of parameter values and assumptions requires a balance between accuracy and conservativeness. Accuracy should always prevail except when alternative values are of equivalent accuracy, in which case the more conservative value is used, the more conservative being the value that provides the least over-estimation of net anthropogenic GHG removals by sinks.

[38] To be conservative, the minimum uncertainty factor is set to 1.5% to account for possible uncertainty within other unmeasured assumptions used in calculations and modeling.

Data/parameter	$\mathbf{A_{BSL,i}}$
Data unit	Ha
Description:	Area of baseline polygon, *i*
Used in	Various equations from Equation #4-17.
Source of data	GPS coordinates and/or remote sensing and/or inventory records
Measurement procedures	n/a
Comments:	

Data/parameter	$\Delta \mathbf{C_{,t}}$
Data unit	t C yr^{-1}
Description:	The annual carbon balance in the baseline or project scenario for year, *t*
Used in	Equation 57, labeled by baseline (BSL) and project (PRJ).
Source of data	Calculated in equation 1 (Section 8.1); equation 29 (Section 8.2). Labeled with subscript BSL and PRJ, respectively.
Measurement procedures	n/a
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\Delta \mathbf{C_{P,t}}$
Data unit	t C yr^{-1}
Description:	The annual change in carbon stocks in all pools in the baseline or project scenario across the project activity area for year, *t*
Used in	Calculation of $\Delta \mathbf{C_{,t}}$
Source of data	Calculated in equation 2 (Section 8.1); equation 30 (Section 8.2)
Measurement procedures	n/a
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\Delta \mathbf{C_{LB,t}}$
Data unit	t C yr^{-1}
Description:	The annual change in carbon stocks in living tree biomass (above- and belowground) for year, *t*
Used in	Calculation of $\Delta \mathbf{C_{P,t}}$
Source of data	Calculated in equation 3 (Section 8.1); equation 31 (Section 8.2)
Measurement procedures	n/a
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\Delta \mathbf{C}_{\mathbf{DOM,t}}$
Data unit	t C yr^{-1}
Description:	The annual change in carbon stocks in dead organic matter for year, *t*
Used in	Calculation of $\Delta \mathbf{C}_{\mathbf{P,t}}$
Source of data	Calculated in equation 10 (Section 8.1); equation 38 (Section 8.2)
Measurement procedures	n/a
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\Delta \mathbf{C}_{\mathbf{HWP,t}}$
Data unit	t C yr^{-1}
Description:	The annual change in carbon stocks in harvested wood products for year, *t*
Used in	Calculation of $\Delta \mathbf{C}_{\mathbf{P,t}}$
Source of data	Calculated in equation 18 (Section 8.1); equation 46 (Section 8.2)
Measurement procedures	n/a
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\Delta \mathbf{C}_{\mathbf{G,t}}$
Data unit	t C yr^{-1}
Description:	The annual change in carbon stocks due to live biomass gain for year, *t*
Used in	Calculation of $\Delta \mathbf{C}_{\mathbf{LB,t}}$
Source of data	Calculated in equation 4 (Section 8.1); equation 32 (Section 8.2)
Measurement procedures	n/a
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\Delta \mathbf{C}_{\mathbf{L,t}}$
Data unit	t C yr^{-1}
Description:	The annual change in carbon stocks due to live biomass loss for year, *t*
Used in	Calculation of $\Delta \mathbf{C}_{\mathbf{LB,t}}$
Source of data	Calculated in equation 6 (Section 8.1); equation 34 (Section 8.2)
Measurement procedures	n/a
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\Delta \mathbf{C}_{\mathbf{LDW,t}}$
Data unit	t C yr^{-1}
Description:	The annual change in lying dead wood carbon stocks for year, *t*
Used in	Calculation of $\Delta \mathbf{C}_{\mathbf{DOM,t}}$
Source of data	Calculated in equations 11a, 12, 13 (Section 8.1); equations 39a, 40, 41 (Section 8.2)
Measurement procedures	n/a
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\Delta \mathbf{C}_{\mathbf{SNAG,t}}$
Data unit	t C yr^{-1}
Description:	The annual change in standing dead wood carbon stocks for year, *t*
Used in	Calculation of $\Delta \mathbf{C}_{\mathbf{DOM,t}}$
Source of data	Calculated in equations 14a, 15, 16 (Section 8.1); equations 42a, 43, 44 (Section 8.2)
Measurement procedures	n/a
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\Delta \mathbf{C}_{\mathbf{DBG,t}}$
Data unit	t C yr^{-1}
Description:	The annual change in dead belowground carbon stocks for year, *t*
Used in	Calculation of $\Delta \mathbf{C}_{\mathbf{DOM,t}}$
Source of data	Calculated in equations 17a, 17c, 17d (Section 8.1); equations 45a, 45c, 45d (Section 8.2)
Measurement procedures	n/a
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	**CF**
Data unit	t C t^{-1} d.m.
Description:	Carbon fraction of dry matter
Source of data	IPCC default value = 0.5, if more relevant values are not available
Measurement procedures	n/a
Comments:	

Data/parameter	**R_i**
Data unit	unitless
Description:	Root:shoot ratio in polygon , *i*
Source of data	If project-specific values have not been measured, use Cairns 1997).
Measurement procedures	n/a
Comments:	Root allocation can be vary by site productivity; relatively more biomass may be allocated to roots in poor than richer soils

Data/parameter	**BEF**
Data unit	unitless
Description:	Biomass expansion factors for conversion of productivity metrics to biomass
Source of data	The source of data must be chosen with priority from higher to lower preference as follows: (a) Existing local and forest type-specific; (b) National and forest type-specific or eco-region-specific (e.g. from national GHG inventory); (c) Forest type-specific or eco-region-specific from neighboring countries with similar conditions. Sometimes (c) might be preferable to (b); (d) Globally forest type or eco-region-specific (e.g. IPCC literature: Table 3A.1.10 of GPG-LULUCF)
Measurement procedures	n/a
Comments:	BEFs are age dependent, and use of average data may result in significant errors for both young and old stands – as BEFs are usually large for young stands and quite small for old stands.

Data/parameter	**$f_{BRANCH,i,t}$**
Data unit	unitless
Description:	The annual proportion of aboveground tree biomass comprised of branches $\geq$ 5 cm diameter in polygon, i
Source of data	The source of data must be chosen with priority from higher to lower preference as follows: (a) Research publications relevant to the project area; (b) National and species-specific or group of species-specific (e.g. from National GHG inventory); (c) Species-specific or group of species-specific from neighboring countries with similar conditions. Sometimes (b) may be preferable to (a); (d) Globally species-specific or group of species-specific (e.g. IPCC GPG-LULUCF).
Measurement procedures	n/a

Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, same value

Data/parameter	$f_{BUCKINGLOSS,i,t}$
Data unit	unitless
Description:	Annual proportion of the log bole biomass left on site after assessing and/or merchandizing the log bole for quality, in polygon, *i*
Source of data	Preferably, data for this variable must be based on regional and local comparative studies and experiential information derived from the local forest industry. Otherwise, an average default value of 21% can be used, based on US national summary statistics (Smith, Miles, Vissage, & Pugh, 2004).
Measurement procedures	n/a
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	**$P_{3\text{-}year}$ and $P_{100\text{-}year}$**
Data unit	unitless
Description:	The proportion of total carbon stored in wood products after 3 years ($P_{3\text{-}year}$); and the proportion of harvested wood stored for 100 years ($P_{100\text{-}year}$), for product type, *k*.
Source of data	Calculated for the baseline and project case
Measurement procedures	n/a
Comments:	

Data/parameter	$P_{BSL,SLF}$, $P_{BSL,MLF}$, $P_{BSL,LLF}$
Data unit	unitless
Description:	The short-lived fraction (P_{SLF}), medium-lived fraction (P_{MLF}), and long-lived fraction (P_{LLF}), respectively, for product type, *k*
Source of data	Calculated as per equations 22a-c (baseline) and equations 50ac (project)
Measurement procedures	n/a
Comments:	

Data/parameter	$f_{TRANSPORTk}$
Data unit	(unitless; $0 \leq f_{BSL,TRANSPORTk} < 1$).
Description:	The fraction of raw material transported by transportation type, *k*.

Source of data	Estimated based on Heath et al. 2006 Supplementary
Measurement procedures	n/a
Comments:	Variables used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$c_{HARVEST}$
Data unit	t C emitted/t C raw material
Description:	The carbon emission intensity factor associated with harvesting
Source of data	See Table 4
Measurement procedures	n/a
Comments:	

Data/parameter	$c_{MANUFACTUREk}$
Data unit	t C emitted/t C raw material
Description:	The carbon emission intensity factor associated with manufacture of product, k
Source of data	See Table 4
Measurement procedures	n/a
Comments:	

Data/parameter	$c_{TRANSPORTk}$
Data unit	t C emitted/t C raw material ● km
Description:	The carbon emission intensity factor associated with the transport of raw material by transportation type of product, k
Source of data	See Table 4
Measurement procedures	n/a
Comments:	

Data/parameter	$d_{TRANSPORTk}$
Data unit	km
Description:	The distance transported by transportation type, *k*.
Source of data	Estimated based on Heath et al. 2006 Supplementary
Measurement procedures	n/a
Comments:	

Data/parameter	**$C_{EMITTRANSPORT,t}$**
Data unit	t C yr^{-1}
Description:	The annual fossil fuel emissions associated with the transport of raw material
Source of data	Heath et al. 2006 Supplementary
Measurement procedures	n/a
Comments:	Variables used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	**$G_{AG,i,t}$**
Data unit	t d.m. ha^{-1} yr^{-1}
Description:	Annual increment rate in aboveground biomass (t d.m. ha^{-1} yr^{-1}), in polygon, *i*,
Source of data	Modeled (See Section 8.1 & Section 8.2)
Measurement procedures	n/a
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	**$G_{BG,i,t}$**
Data unit	t d.m. ha^{-1} yr^{-1}
Description:	Annual increment rate in belowground biomass (t d.m. ha^{-1} yr^{-1}), in polygon, *i*,
Source of data	Calculated from G_{AG} and R_i
Measurement procedures	n/a
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	**$LBL_{NATURALi,t}$**
Data unit	t d.m. yr^{-1}
Description:	Annual loss of live tree biomass due to natural mortality in polygon, i; t d.m. yr^{-1}
Source of data	Modeled (See Section 8.1 & Section 8.2)
Measurement procedures	n/a
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	**$LBL_{FELLINGSi,t}$**
Data unit	t d.m. yr^{-1}
Description:	Annual loss of live tree biomass due to commercial felling in polygon, i; t d.m. yr^{-1}

Source of data	Modeled (See Section 8.1 & Section 8.2)
Measurement procedures	n/a
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\mathbf{LBL_{OTHERi,t}}$
Data unit	t d.m. yr^{-1}
Description:	Annual loss of live tree biomass from incidental sources in polygon, i; t d.m. yr^{-1}
Source of data	Modeled (See Section 8.1 & Section 8.2)
Measurement procedures	n/a
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\mathbf{LB_{i,t}}$
Data unit	t d.m. yr^{-1}
Description:	Average live tree biomass in polygon, *i*, for year, *t*
Source of data	Calculated from $G_{i,t}$
Measurement procedures	n/a
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\mathbf{f_{BSL,NATURAL,i,t}}$
Data unit	unitless; $0 \leq f_{NATURAL,i,t} \leq 1$
Used in:	Equation 7, Section 8
Description:	The annual proportion of biomass that dies from natural mortality in forest type analysis unit or polygon, *i*, year, *t*.
Source of data	Literature reports, and/or inventory data.
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{f_{BSL,HARVEST,i,t}}$
Data unit	unitless; $0 \leq f_{BSL,HARVESTIi} \leq 1$
Used in:	Equation 8, Section 8.1
Description:	The proportion of biomass removed by harvesting from polygon, *i*, in year, *t*.
Source of data	Literature reports, and/or inventory data.
Measurement procedures	

Comments:	

Data/parameter	$\mathbf{f_{BSL,DAMAGE,i,t}}$
Data unit	unitless; $0 \leq f_{BSL,DAMAGE,i,t} \leq 1$
Used in:	Equation 9, Section 8
Description:	The proportion of additional biomass removed for road and landing construction in polygon, *i,* year, *t*
Source of data	Literature reports, and/or inventory data.
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{f_{BSL,BLOWDOWN,i,t}}$
Data unit	unitless; $0 \leq f_{BSL,BLOWDOWN,i,t} \leq 1$
Used in:	Equation 12, Section 8.1
Description:	The annual proportion of live aboveground tree biomass subject to blowdown in polygon, *i*, year, t.
Source of data	Literature reports, and/or inventory data.
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{f_{BSL,SNAGFALLDOWN,i,t}}$
Data unit	unitless; $0 \leq f_{BSL,SNAGFALLDOWN,i,t} \leq 1$
Used in:	Equations 12 & 16, Section 8.1
Description:	The annual proportion of snag biomass in polygon, *i*, year, *t*, that falls over and thus is transferred to the LDW pool.
Source of data	Literature reports, and/or inventory data.
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{f_{BSL,lwDECAY,i,t}}$
Data unit	unitless; ; $0 \leq f_{BSL,lwDECAY,i,t} \leq 1$
Used in:	Equation 13, Section 8.1
Description:	The annual proportional loss of lying dead biomass due to decay, in polygon *i,* year*, t*,
Source of data	Literature reports, and/or inventory data.
Measurement procedures	

Comments:	

Data/parameter	$\mathbf{f_{BSL,SWDECAY,i,t}}$
Data unit	unitless; $0 \leq f_{BSL,SWDECAY,i,t} \leq 1$
Used in:	Equation 16, Section 8.1
Description:	The annual proportional loss of snag biomass due to decay, in polygon, *i*, year, *t*.
Source of data	Literature reports, and/or inventory data.
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{SNAG_{BSL,i,t}}$
Data unit	t d.m. yr^{-1}
Description:	The total amount of snag mass in polygon *i,* year*, t*
Source of data	Calculated in equations 14b, 15,16
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{DBG_{,i,t}}$
Data unit	t d.m. yr^{-1}
Description:	The total quantity of dead belowground biomass accumulated in polygon *i* since the project start; t biomass.
Source of data	Calculated in equations 17b, 17c,17d (Section 8.1); Calculated in equations 45b, 45c,45d (Section 8.2)
Measurement procedures	Modeled.
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\mathbf{\Delta C_{STORHWP1,t}}$
Data unit	t C yr^{-1}
Used in:	The calculation of the annual change in emissions associated with the production of harvested wood products (HWP), $\Delta C_{BSl,HWP,t}$,
Description:	Annual harvested carbon that remains in permanent storage after conversion to wood products during primary processing
Source of data	Calculated in equation 19 (Section 8.1) and equation 47 (Section 8.2)
Measurement procedures	
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may

	be different

Data/parameter	$\mathbf{C_{MILL,h,k}}$
Data unit	t C
Used in:	The calculation of the annual change in the carbon stored in harvested wood products (HWP), $\Delta C_{BSL,HWP,t}$,
Description:	The carbon contained in harvested timber after milling in period h, for product type *k*
Source of data	Calculated in equation 21 (Section 8.1) and equation 49 (Section 8.2)
Measurement procedures	
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\mathbf{C_{TIMBER,h}}$
Data unit	t C
Used in:	The calculation of the annual change in the carbon stored in harvested wood products (HWP), $\Delta C_{BSL,HWP,t}$,
Description:	The carbon contained in timber harvested in period *h*
Source of data	Calculated in equation 20 (Section 8.1) and equation 48 (Section 8.2)
Measurement procedures	
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\mathbf{C_{STORHWP,h,t}}$
Data unit	t C
Used in:	The calculation of the annual change in the carbon stored in harvested wood products (HWP), $\Delta C_{BSL,HWP,t}$,
Description:	The carbon stored in harvested wood products in year *t* summed for all product types *k* and then over all harvest periods *h*; t C
Source of data	Calculated in equation 23 (Section 8.1) and equation 51 (Section 8.2)
Measurement procedures	
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\mathbf{f_{RND,k}}$
Data unit	dimensionless

Used in:	The calculation of carbon contained in harvested timber after milling in period h, for product type *k* ($C_{MILL,h,k}$).
Description:	The fraction of growing stock volume removed as roundwood for product type *k*
Source of data	(default values by region in Table 1.5 of the 1605(b) document)
Measurement procedures	
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario

Data/parameter	$\mathbf{r_{RND,k}}$
Data unit	dimensionless
Used in:	The calculation of carbon contained in harvested timber after milling in period h, for product type *k* ($C_{MILL,h,k}$).
Description:	The ratio of industrial roundwood to growing stock volume removed as roundwood for product type *k.*
Source of data	(default values by region in Table 1.5 of the 1605(b) document)
Measurement procedures	
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario

Data/parameter	$\mathbf{\Delta C_{EMITFOSSIL,t}}$
Data unit	t C yr^{-1}
Used in:	The calculation of the annual change in the carbon stored in harvested wood products (HWP), $\Delta C_{HWP,t}$,
Description:	Fossil fuel emissions from harvesting (logging and log transport) and processing of the various wood products.
Source of data	Calculated in equation 24 (Section 8.1) and equation 52 (Section 8.2)
Measurement procedures	
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\mathbf{C_{EMITHARVEST,t}}$
Data unit	t C yr^{-1}
Used in:	The calculation of $\mathbf{\Delta C_{EMITFOSSIL,t}}$
Description:	Annual fossil fuel emissions associated with harvesting of raw material.
Source of data	Calculated in equation 25 (Section 8.1) and equation 53 (Section 8.2)

Measurement procedures	
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\mathbf{C_{EMITMANUFACTURE,t}}$
Data unit	t C yr^{-1}
Used in:	The calculation of $\Delta\mathbf{C_{EMITFOSSIL,t}}$
Description:	Annual fossil fuel emissions associated with the manufacturing of raw material.
Source of data	Calculated in equation 27 (Section 8.1) and equation 55 (Section 8.2)
Measurement procedures	
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\mathbf{C_{EMITTRANSPORT,t}}$
Data unit	t C yr^{-1}
Used in:	The calculation of $\Delta\mathbf{C_{EMITFOSSIL,t}}$
Description:	Annual fossil fuel emissions associated with the transport of raw material.
Source of data	Must be calculated after consideration of the transport distance from harvest to processing facility, and the means of transportation (after Heath et al. 2006 Supplementary). An example of calculation steps is provided in Section 8.1.
Measurement procedures	
Comments:	Variable used in both baseline (BSL) and project (PRJ) scenario, values may be different

Data/parameter	$\mathbf{LE_y}$
Data unit	t CO2e yr^{-1}
Used in:	The calculation of Market Leakage (Option 1)
Description:	the project market leakage in year, *y*
Source of data	Calculated in Section 8.3.2, Option 1
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{SE_y}$
Data unit	t CO2e yr^{-1}
Used in:	The calculation of Market Leakage (Option 2)
Description:	The project market leakage in year, *y*

Source of data	Calculated in Section 8.3.2, Option 2
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{MLF_y}$
Data unit	Unitless
Used in:	Calculation of $\mathbf{LE_y}$ in year, *y*
Description:	The project market leakage
Source of data	Calculated in Section 8.3.2
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{BC_{hv,\ n}}$
Data unit	t CO2e yr^{-1}
Used in:	Calculation of $\mathbf{SE_y}$
Description:	The estimated average baseline amount of onsite carbon harvested in reporting period, *n* (prior to delivery to a mill).
Source of data	Calculated in Section 8.3.2
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{AC_{hv,\ n}}$
Data unit	t CO2e yr^{-1}
Used in:	Calculation of $\mathbf{SE_y}$
Description:	The actual onsite carbon harvested in reporting period, *n* (prior to delivery to a mill).
Source of data	Calculated in Section 8.3.2
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{ER_{y,GROSS}}$
Data unit	t CO2e yr^{-1}
Used in:	Calculation of $\mathbf{LE_y}$
Description:	The gross difference in the overall annual carbon change between the baseline and project scenarios in year, *y*
Source of data	Calculated in equation 57

Measurement procedures	
Comments:	

Data/parameter	$\mathbf{ER_{y,}}$
Data unit	t CO2e yr^{-1}
Used in:	Calculation of $\mathbf{VCU_y}$
Description:	The net GHG emissions reductions and/or removals in year y (the overall annual carbon change between the baseline and project scenarios, net all discount factors except the permanence buffer)
Source of data	Calculated in equation 58
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{VCU_{y,}}$
Data unit	t CO2e yr^{-1}
Description:	Amount of Verified Carbon Units the project estimates are available for issuance and sale in year 'y'
Source of data	Calculated in equation 59
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{E_M}$
Data unit	%
Used in:	The calculation of uncertainty factor (Section 8.5.3)
Description:	An estimate of model error based on the relative area-weighted difference between of model-predicted values of carbon storage and those values measured in field plots
Source of data	Model output and field data
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{E_I}$
Data unit	%
Used in:	The calculation of uncertainty factor (Section 8.5.3)
Description:	An estimate of Inventory sampling error calculated as the 90% confidence limit of the area-weighted differences between the model-predicted values of carbon storage and those values measured in field plots

Source of data	Model output and field data
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{E_P}$
Data unit	%
Used in:	The calculation of uncertainty factor (Section 8.5.3)
Description:	An estimate of total project error based sum of the model and inventory error terms
Source of data	Model output and field data
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{ER_{y,ERR,}}$
Data unit	Unitless
Used in:	Calculation of $\mathbf{VCU_y}$
Description:	The uncertainty factor calculated for year 'y' in Section 8.5.3
Source of data	Calculated in Section 8.5.3
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{BR_{y,}}$
Data unit	t CO2e yr^{-1}
Used in:	Calculation of $\mathbf{VCU_y}$
Description:	Estimated VCU-equivalent tCO_2e issued to the VCS Buffer Pool in year, *y*.
Source of data	Calculated using the latest version of the VCS AFOLU Non-Permanence Risk Tool
Measurement procedures	
Comments:	

9.2 Data and Parameters Monitored

The following parameters must be monitored during the project activity. When applying all relevant equations provided in this methodology for the ex-ante calculation of net anthropogenic GHG removals by sinks, project proponents must provide transparent estimates for the parameters that are monitored during the crediting period. These estimates must be based on measured or existing published data where possible and project proponents must retain a conservative approach: if different values for a parameter are equally plausible, a value that provides the least over-estimation of net anthropogenic GHG removals by sinks must be selected.

Data/parameter	$\mathbf{A_{PRJ,i,}}$
Data unit	Ha
Used in	Various equations in equation #32-60
Description:	Area of forest land in polygon, *i*
Source of data	Monitoring of polygons and stand boundaries must be done preferably using a Geographic Information System (GIS), which allows for integrating data from different sources (including GPS coordinates and Remote Sensing data).
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{A_{p,i,t}}$
Data unit	m^2
Used in:	Calculation of mean aboveground biomass B_{AG} and DOM_{SNAG} in Section 9.3.2 and 8.2.3.
Description:	Area of sample plot in polygon, *i*, at time, *t*
Source of data	Recording and archiving of size of sample plots
Measurement procedures	
Comments:	

Data/parameter	$\mathbf{DBH_{,t}}$
Data unit	cm
Used in:	Calculation of mean aboveground biomass B_{AG} in Section 9.3.2 and 8.2.3.
Description:	Diameter at breast height measured for each tree in the sample plots at time, *t*
Source of data	Field measurements in sample plots
Measurement procedures	Typically measured at 1.3m height above ground. Measure all trees above minimum DBH (5 cm) in the sample plots that result from the IFM project activity.
Comments:	

Data/parameter	$\mathbf{Height_{,t}}$
Data unit	m
Used in:	Calculation of mean aboveground biomass B_{AG} in Section 9.3.2 and 8.2.3.
Description:	Tree height measured for each tree in the sample plots at time, *t*
Source of data	Field measurements in sample plots

Comments:	

Data/parameter	$L_{,t}$
Data unit	m
Used in:	Calculation of mean mass of DOM_{LDW} in Section 9.3.2 and 8.2.3.
Description:	Length of the transects to used determine volume of lying dead wood in the sample plots at time, *t* (default 100m)
Source of data	Field measurements
Measurement procedures	
Comments:	

Data/parameter	$d_{n,t}$
Data unit	cm
Used in:	Calculation of mean mass of DOM_{LDW} in Section 9.3.2 and 8.2.3.
Description:	Diameter of each piece *n* of dead wood along the transects in the sample plots at time, *t*
Source of data	Field measurements
Measurement procedures	Measured using the line-intersect method (Section 9).
Comments:	

Data/parameter	$D_{LDW,c,i,t}$
Data unit	(t d.m. m^{-3})
Used in:	Calculation of mean mass of DOM_{LDW} in Section 9.3.2 and 8.2.3.
Description:	Density of dead wood in density class, *c* along the transect in polygon, *i*, at time, *t*
Source of data	Field measurements
Measurement procedures	Measured using the line intersect method (Section 9).
Comments:	

Data/parameter	$N_{,t}$
Data unit	unitless
Used in:	Calculation of mean mass of DOM_{LDW} in Section 9.3.2 and 8.2.3.
Description:	Total number of wood pieces intersecting transects in the sample plots at time, *t*
Source of data	Field measurements
Measurement procedures	Measured using the line-intersect method (Section 9).

Comments:	

Data/parameter	$\mathbf{B_{AGi,t}}$
Data unit	t d.m. ha^{-1} (d.m. = dry matter)
Used in:	Calculation of carbon stocks in above- and belowground living tree biomass in equations 28b & 28c, Section 8.2.3.
Description:	Average total aboveground biomass in polygon, *i,* for year, *t*
Source of data	Calculated from $Height_{i,t}$, $DBH_{i,t}$, and $A_{p,i,t}$
Measurement procedures	
Comments:	Calculated

Data/parameter	$\mathbf{B_{BGi,t}}$
Data unit	t d.m. ha^{-1} (d.m. = dry matter)
Used in:	Calculation of carbon stocks in above- and belowground living tree biomass in equations 28b & 28c, Section 8.2.3.
Description:	Average total belowground biomass in polygon, *i,* for year, *t*
Source of data	Estimated from $B_{AGi,t}$
Measurement procedures	
Comments:	Estimated

Data/parameter	$\mathbf{B_{TOTAL,i,t}}$
Data unit	t d.m. ha^{-1} (d.m. = dry matter)
Used in:	Calculation of carbon stocks in above- and belowground living tree biomass in equation 28c, Section 8.2.3.
Description:	Average total live biomass in polygon, *i,* for year, *t*
Source of data	Calculated from $B_{AGi,t}$ and $B_{BGi,t}$
Measurement procedures	
Comments:	Calculated

Data/parameter	$\mathbf{DOM_{LDW,i,t}}$
Data unit	t d.m. ha^{-1} (d.m. = dry matter)
Used in:	Calculation of carbon stocks in dead organic matter (equation 28e, Section 8.2.3)
Description:	Average mass of dead organic matter contained in lying dead wood in polygon, *i,* year, *t*
Source of data	Calculated from $L_{,i,t}$, $d_{n,i,t}$, $D_{LDW,c,i,t}$, and $N_{i,t}$
Measurement procedures	

Comments:	Calculated

Data/parameter	**$DOM_{SNAG,i,t}$**
Data unit	t d.m. ha^{-1} (d.m. = dry matter)
Used in:	Calculation of carbon stocks in dead organic matter (equation 28e, Section 8.2.3)
Description:	Average mass of dead organic matter contained in standing dead wood in polygon, *i,* year, *t*
Source of data	Calculated from $Height_{i,t}$, $DBH_{i,t}$, and $A_{p,i,t}$ of dead trees measured in sample plots described in Section 9
Measurement procedures	
Comments:	Calculated

Data/parameter	**$f_{PRJ,NATURAL,i,t}$**
Data unit	unitless; $0 \leq f_{NATURAL,i,t} \leq 1$
Used in:	Equation 35, Section 8.2
Description:	The annual proportion of biomass that dies from natural mortality in polygon, *i*, year, *t*.
Source of data	Permanent sample plots in similar stand types, literature reports, and inventory data
Measurement procedures	
Comments:	

Data/parameter	**$f_{PRJ,HARVEST,i,t}$**
Data unit	unitless; $0 \leq f_{PRJ,HARVESTIi} \leq 1$
Used in:	Equation 36, Section 8.2
Description:	The proportion of biomass removed by harvesting from polygon, *i*, in year, *t*.
Source of data	Permanent sample plots in similar stand types, literature reports, and inventory data
Measurement procedures	
Comments:	

Data/parameter	**$f_{PRJ,DAMAGE,i,t}$**
Data unit	unitless; $0 \leq f_{PRJ,DAMAGE,i,t} \leq 1$
Used in:	Equation 37, Section 8.2
Description:	The proportion of additional biomass removed for road and landing construction in polygon, *i,* year, *t*

Source of data	Permanent sample plots in similar stand types, literature reports, and inventory data
Measurement procedures	
Comments:	

Data/parameter	$f_{PRJ,BLOWDOWN,i,t}$
Data unit	unitless; $0 \leq f_{PRJ,BLOWDOWN,i,t} \leq 1$
Used in:	Equation 40, Section 8.2
Description:	The annual proportion of live aboveground tree biomass subject to blowdown in polygon, *i*, year, t.
Source of data	Permanent sample plots in similar stand types, literature reports, and inventory data
Measurement procedures	
Comments:	

Data/parameter	$f_{PRJ,SNAGFALLDOWN,i,t}$
Data unit	unitless; $0 \leq f_{PRJ,SNAGFALLDOWN,i,t} \leq 1$
Used in:	Equation 40 & 44, Section 8.2
Description:	The annual proportion of snag biomass in polygon, *i*, year, *t*, that falls over and thus is transferred to the LDW pool.
Source of data	Permanent sample plots in similar stand types, literature reports, and inventory data
Measurement procedures	
Comments:	

Data/parameter	$f_{PRJ,lwDECAY,i,t}$
Data unit	unitless; ; $0 \leq f_{PRJ,lwDECAY,i,t} \leq 1$
Used in:	Equation 41, Section 8.2
Description:	The annual proportional loss of lying dead biomass due to decay, in polygon *i,* year*, t*,
Source of data	Permanent sample plots in similar stand types, literature reports, and/or inventory data
Measurement procedures	
Comments:	

Data/parameter	$f_{PRJ,SWDECAY,i,t}$

Data unit	unitless; $0 \leq f_{PRJ,SWDECAY,i,t} \leq 1$
Used in:	Equation 44, Section 8.2
Description:	The annual proportional loss of snag biomass due to decay, in polygon, *i*, year, *t*.
Source of data	Permanent sample plots in similar stand types, literature reports, and/or inventory data
Measurement procedures	
Comments:	

9.3 Description of the Monitoring Plan

The objective of the project monitoring program is to reliably monitor changes in carbon stocks related to the calculation of VCU's prior to each verification. In particular, the program will monitoring changes in spatial forest inventory conditions and collect field data on carbon stocks to compare against modeled carbon stocks and to calculate an uncertainty factor.

9.3.1 Project Monitoring Requirements

The project must develop and maintain an up to date monitoring plan which includes:

1. Spatial inventory change monitoring procedures
2. Carbon stock field plot sampling monitoring procedures
3. Standard Operating Procedures (SOPs) for monitoring activities
4. Quality Control/Quality Assurance and Data Archiving procedures

These elements must meet the requirements described in the sections below.

The results of implementing the monitoring plan must be produced in a project monitoring report for each monitoring period; prior to each verification.

9.3.2 Monitoring Annual Spatial Inventory Changes

Project proponents will undertake and document annual monitoring to identify and update spatial changes in the forest inventory data (i.e. changes in forest polygons due to planned or unplanned project activities and natural disturbances which change the classification of spatial areas within the project boundary).

Projects will undertake remote and ground-based monitoring (for example: satellite and aerial photography, aerial observation, ground observation, aerial and ground-based GPS mapping, etc.) to identify and update inventory data for:

a. Natural disturbance events > 4ha (i.e. fires, pest & disease outbreaks, slides and other disturbances;
b. Planned project activities (i.e. harvests, road construction, reforestation, etc.); and
c. Unplanned man-made disturbances (for example, non-*de minimis* illegal or unplanned harvests).

Annual spatial monitoring activities will be documented and dated, and inventory data updates identified by date or other notations.

9.3.3 Carbon Stock Monitoring Field Plot Sampling Design and Stratification

9.3.4 Stratification for Field Plot Sampling:

When an area is not homogeneous, stratification generally reduces monitoring costs by grouping areas with low variation in carbon stocks (Pearson et al. 2007).

Stratification for monitoring sample design should be consistent with that employed for the calculation of carbon stocks in the baseline (Section 8.1) and project (Section 8.2) scenarios.

The project proponent has the option to further stratify modeled polygons or analysis units to facilitate efficient field carbon stock monitoring. In particular, projects may need to further stratify modeled polygons or analysis units to gain sampling representation within analysis unit age classes. For example, an analysis unit might include similar forest type polygons that range from 40-200 years. For monitoring plot sampling, the analysis unit would likely need to be stratified into age classes with similar stand carbon content.

Any stratification undertaken for monitoring purposes must be documented and justified, including documenting any variation from stratification made for modeling in Section 8.1 and 8.2. Monitoring stratification may be updated based on monitoring results (see Section 9.3.10).

9.3.5 Field Plot Sampling Framework

The objective of the field plot network is to determine the statistical accuracy of the modeled carbon stocks by polygon or analysis unit. The field-measured values of the tree biomass and dead organic matter pools described below will be compared against the associated modeled values described in Section 8.2 to determine error in the modeled value for a particular polygon or analysis unit (see Section 8.2.2). Some deviation of the field-measured values from the modeled values can be expected, which is then accounted for in the uncertainty factor calculation (Section 8.5.3).

The "Sourcebook for Land Use, Land-Use Change and Forestry Projects" (Pearson, Walker, & Brown, 2005) provides methods and procedures to generate accurate and precise estimates of changes in carbon stocks. (Pearson, Brown, & Birdsey, 2007). Project proponents can substitute other comparable published and peer-reviewed forest carbon sampling and measurement manuals and techniques if they are demonstrated to be applicable and consistent with the data collection requirements of this methodology.

Type and Number of Sampling Plots

Plot Type

For forestry activities, both permanent and temporary sampling plots have been used to estimate changes in carbon pools (Pearson, Brown, & Birdsey, 2007). Permanent sample plots are regarded as statistically more efficient for estimating changes in forest-carbon stocks over time than temporary plots because there is high covariance between observations in successive sampling events (Pearson, Brown, & Birdsey, 2007). Moreover, the use of permanent plots allow for efficient verification. Hence, the majority of plots used in the monitoring program should be geo-referenced, permanently re-measurable plots with all trees marked. Geo-referenced temporary plots may also be used for efficient supplemental data collection.

Number of Plots, Precision, and Sample Size

The proponent will develop a plot network with representation in every polygon or analysis unit[39] (based on the primary stratification method identified in Section 8.1 and used throughout the project calculations) and a design

[39] See Section 8.5.3 for additional clarification on plot requirements. If using a polygon stratification, representation of each polygon is required; if using an analysis unit stratification, representation of each analysis unit is required (and not each polygon within the analysis unit).

target of establishing enough plots such that the estimate of carbon stocks across all polygon or analysis units will lie within 10 percent of the true value of the mean at the 90-percent confidence level[40].

Project proponents may develop initial estimates of the number of plots needed for monitoring using variance estimates from existing or comparable forest inventory data and following procedures outlined in (Pearson et al. 2007), or other peer reviewed published methods.

For practical purposes it is recognized that on large or complex project areas the plot network may need to be developed across several years (no longer than 5 years) to approach the target level of precision. Samples sizes should be evaluated for suitability following the initial monitoring period and then adjusted as appropriate to achieve the desired level of precision.

Plot Sampling Design

Plot Layout

Permanent sample plots can be located at random or systematically using a plot grid. The latter approach results in greater precision if some areas within polygons have higher carbon content than others (Pearson, Brown, & Birdsey, 2007).

Size and Shape of Sample Plots

Plot shape and size can be determined by the project proponent based on local common practice and the most suitable methods for the project conditions, so long as the procedures are fully documented in project SOP's and the results provide verifiable statistical sampling as required by this methodology. Projects may consider consistent fixed area square or circular plots, or consider a variable nested plot area design which may be better suited to highly variable stand diameter conditions ((see (Pearson, Brown, & Birdsey, 2007)).

Measurement and Data Analysis Techniques

Trees

Although the tree carbon stock is estimated most accurately and precisely by direct methods (whereby all the trees in a sample plot above a minimum diameter are harvested, dried and weighed), it is expected this approach will be impractical for most projects. Therefore, tree biomass should be estimated from allometric biomass equations that predict aboveground biomass from mathematical relationships between DBH and/or height and species. Allometric biomass equations have been published for many species and regions. The project proponent should select the most appropriate equations by determining which published equations are most representative of the species and conditions on the project site. Other factors that should be taken into account include the relative statistical accuracy of the equations, and the number and size range of the samples used to generate the equation parameters.

All living trees within a sample plot with DBH ≥ 5cm must be measured for height (m) and diameter (cm) at breast height (1.3m).

Tree-level measurements (kg biomass per tree) must be converted to area-based stand-level measurements (t ha^{-1}). A description of the steps and equations employed in the process are provided in Section 8.2.3.

Dead Organic Matter

An efficient method for sampling lying dead wood is the line-intersect (Pearson, Brown, & Birdsey, 2007). For example, (Harmon & Sexton, 1996) use a minimum 100m line length[41]. Placing two 50-m sections of line at right

[40] The uncertainty factor calculation in Section 8.5.3 accounts for, and penalizes the project credits for higher uncertainty error, and hence this target is provided as guidance for plot network design to achieve the lowest uncertainty factor.

angles across the plot center also is an efficient and valid approach. To allow re-measurement of the same "dead wood plot", it is important to accurately record where the line was placed. The diameters of all pieces of wood that intersect the line are measured and the density class noted. A minimum diameter for measurement is defined in this methodology as 5 cm (Harmon & Sexton, 1996).

Each piece of dead wood will be assigned to one of three density classes, sound (1), intermediate (2), and rotten (3) (details below). The volume per unit area is calculated for each density class, *c*, as:

$$V_{LDW,c} = \pi^2 * [(d_1^2 + d_2^2 \ldots d_n^2)/8L] \quad \textbf{(60a)}$$

where:

d_1, d_2, d_n = diameter (cm) of each of *n* pieces intersecting the line, and

L = the length of the line (100 m default (Harmon, et al., 1986).

The mass of LDW in density class, *c* (t ha^{-1}), is:

$$M_{LDW,c} = V_{LDW,c} * D_{LDW,c} \quad \textbf{(60b)}$$

where:

$V_{LDW,c}$ = the volume per unit area calculated for each density class, *c*, as calculated in 60a.

$D_{LDW,c}$ = the density of LDW in density class, *c* (t d.m. m^{-3})

The total mass of LDW in each plot summed over all density classes (t ha^{-1}) is:

$$DOM_{LDW} = \sum M_{LDW,c} \quad \textbf{(60c)}$$

where:

$M_{LDW,c}$ = the mass of LDW in density class, *c* (t ha^{-1}), is as calculated in 60b.

A key step in this method is classifying the dead wood into its correct density class and then sampling a sufficient number of logs in each class to derive a reasonable estimate of wood density. Ideally at least 10 logs should be sampled for each density class (Pearson, Brown, & Birdsey, 2007). For a given piece of dead wood, a field characterization of its density class can be made by striking it with a strong sharp blade. If the blade bounces off it is classed as sound, if it enters slightly it is of intermediate density, and if the wood falls apart it is rotten. Samples of dead wood in each class will then be collected to determine their density in the laboratory, after drying for 48 hours. Mass of dead wood is calculated as the product of volume per density class and the wood density for that class (as per equations 60 a-c)[42].

The total mass of lying dead wood for a given polygon should be calculated as the average of all transects measured for that polygon. This value is then used for calculations of carbon storage in dead organic matter (**$DOM_{LDW,i,t}$**), as described in Section 8.2.3.

[41] Other sample line lengths may be used if referenced from other published sources (i.e. see (Harmon et al, 2008)).

[42] Alternatively, projects may use other published decay sampling classifications and methods, and in particular may find useful additional methods outlined in Harmon et al. 2008. Woody Detritus Density and Density Reduction Factors for Tree Species in the United States: A Synthesis. USDA Forest Service GTR NRS-29.

Standing dead wood should be measured in the same plots as used for measuring live trees. Snags suitability is defined using the same criteria for live trees. However, measurement records will differ slightly from those for live trees, depending on the degree to which branches and twigs are present. If the snag possesses branches and twigs and its structure resembles a live tree (but without leaves), this should be indicated in the field data records. From the measurement of DBH, the amount of biomass can then be estimated using the appropriate allometric biomass equation and subtracting the biomass of leaves. Snags may possess only a fraction of their full complement of small and large branches, only large branches, or no branches at all. These conditions will be recorded in the field measurements. Branches will then be classified in proportion to the size of the standing dead tree so that the total biomass can be reduced accordingly to account for less of the dead tree remaining. When a tree has no branches and is only the bole, biomass can be estimated from measurements of its basal diameter and height and an estimate of top diameter.

Once the biomass of standing dead trees within a plot has been calculated, the tree-level measurements (kg biomass per tree) must be converted to area-based stand-level measurements (t ha^{-1}) by summing the total mass (aboveground + belowground) of all the standing dead trees within a sample plot (converting kg to t) and dividing the sum by the plot area in ha. All plots within a particular polygon should be averaged to get an average estimate of stand-level live biomass (t ha^{-1}). This value is an estimate of the average snag biomass variable ($\mathbf{DOM_{SNAG,i,t}}$) used in Section 8.2.3.

9.3.6 Quality Assurance/Quality Control (QA/QC) Methods

The monitoring plan or associated SOPs should include QA/QC procedures for: (1) collecting reliable field measurements; (2) verifying laboratory procedures; (3) verifying data entry; and (4) data archiving.

QA/QC for Field Measurements

A set of Standard Operating Procedures (SOP) must be developed for field carbon measurements. The SOPs will detail all phases of the field measurements so that the measurements can be repeated reliably. A document will be produced and filed with the project documents verifying that all QA/QC steps have been taken.

Field crews must be trained in all field data collection SOPs and records of training kept by the project proponent.

An audit program for field measurements and sampling must be established. A typical audit program should consist of three types of checks. During a hot check, auditors observe members of the field crew during actual data collection (this is primarily for training purposes). Cold checks occur when field crews are not present for the audit. Blind checks represent the complete re-measurement of a plot by the auditors. Hot checks allow the correction of errors in technique. Measurement variance can be calculated through blind checks.

At a minimum, 10% of the measured field plots will be check-cruised using blind checks with 100% re-measurement of all variables. Minimum thresholds in measurement error are as follows:

1. DBH (standing live and dead): +/- 10% standard error at 90% confidence interval

2. Height (standing live and dead): +/- 10% standard error at 90% confidence interval

3. Tree Count: +/- 10% standard error at 90% confidence interval

These are minimum thresholds for monitoring plot field accuracy, and will require re-measurement or re-establishment of plots as necessary to meet these requirements.

QA/QC for Laboratory Measurements

SOPs will be prepared and followed for each laboratory analyses. Typical steps in the SOP for laboratory measurements will include calibrating standards for instruments used. Where practical, 10 percent of the samples will be re-analyzed/re-weighed following the check cruise thresholds outlined above.

QA/QC for Data Entry

Projects must develop procedures to ensure proper entry of data and conversion between paper and electronic formats. Data anomalies will be resolved using the original field data, or re-measurement of data if feasible. If there are anomalies that cannot be resolved, the plot will be omitted from the analysis.

Data Archiving

The project will provide data archiving SOPs which provide procedures for securely retaining and maintaining the following records for each monitoring period for 2 years past the duration of the project:

1. Original copies of the field measurement, check plots, laboratory data, and related data summaries will be maintained in their original and electronic form
2. Copies of all monitoring data analyses, models, model input and output files, carbon calculations required for this methodology, GIS inventory dated by year, and copies of the monitoring reports.
3. Records of the version and relevant change history of software or data storage media changed between monitoring periods.

9.3.7 Leakage Monitoring

Activity shifting leakage monitoring requires reporting the ‘demonstration of activity shifting’ annually, as required by VCS, and as per the methods outlined in section 8.3.1.

Market leakage monitoring requirements depend on the selected option:

1. Market Leakage Option 1 – VCS Default Market Leakage Discount Factors:
   a. No further leakage monitoring required
2. Market Leakage Option 2 – CAR Market Leakage Factor
   a. The project proponent will annually update the leakage calculation using the most current project plan harvest levels.
3. Market Leakage Option 3 – Leakage Assessment Tool
   a. Project proponents must re-evaluate the data and calculations at each verification.

9.3.8 Frequency of monitoring

Permanent sample plots must be re-measured at intervals of ≤ 5 years.

Spatial monitoring and leakage monitoring, are to be monitored annually.

9.3.9 Use of Monitoring Data to Update Carbon Stock Calculations

Data gathered through the monitoring process must be used to:

1. Update the project inventory data and related modeling and monitoring stratification as per Section 8.2.2 and 9.3.10;
2. Update leakage calculations in Section 8.3;
3. Update the inventory error estimates used in the calculation of the uncertainty factor described in Section 8.5.3; and,

4. Update and improve calculations of carbon stocks in Section 8.2 and possibly Section 8.1 as described in Section 8.2.2.

9.3.10 Updating of Monitoring Polygons

The ex-post stratification and polygon assignment to specific analysis units (see Section 9.3.2) must be updated on an annual basis and, at minimum prior to each verification, for any of the following reasons:

1. Errors in the inventory from field sampling or other monitoring. If the criteria used to allocate a polygon are not in accordance with field evidence, that polygon should be updated and re-assigned accordingly if necessary. Any non-*de minimis* updates due to errors in the inventory will require recalculation of both the annual project emissions (Section 8.2.5) and the annual baseline emissions (Section 8.1.2) prior to the next verification;
2. Changes to spatial inventory from monitoring for natural disturbance and planned/unplanned project activities. Updates will be made for any monitored event that affects the criteria used to define a given polygon or analysis unit in the project inventory. Note that disturbance or activity events may result in creation of a new polygon, or an age reclassification for the stand, and/or a re-assignment of the polygon. These updates only affect the calculation of carbon emissions from the project scenario (Section 8.2.5).
3. Established polygons may be merged if the original justification for their separate creation no longer applies. These updates only affect the calculation of carbon emissions from the project scenario (Section 8.2.5).

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DOCUMENT HISTORY

Version	Date	Comment
v1.0	19 Apr 2011	Initial version released
v1.1	4 May 2012	Updates: 1) Removed applicability condition that projects must be developed on fee simple or freehold private ownership properties.
v1.2	23 July 2013	Updates: 1) Emissions from harvesting equipment, log transport, and primary forest product manufacturing were made optional. 2) Procedures for calculating storage in harvested wood products have been updated from 100-year method to a method that accounts for decay of carbon in short-term, medium term and long-term wood products in accordance with the VCS rules. 3) Minor edits to language were made (eg, the term 'must' has been used where a procedure is required by the methodology).

Approved VCS Methodology
VM0013

Version 1.0
Sectoral Scope 3

Calculating Emission Reductions from Jet Engine Washing

Scope

This methodology provides a procedure to determine the net CO_2 emissions reductions associated with the on-wing washing of jet turbine engine washing.

Methodology Developer

The methodology was developed by Pratt & Whitney, in collaboration with United Technologies Corporation and Det Norske Veritas Certification, Ltd.

Authors

William Welch, Chris Garrity, Colin Karsten, Rick Love

Pratt & Whitney
A United Technologies Company

United Technologies

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1 SUMMARY

This methodology was developed to calculate the emission reductions generated by washing jet engines. All engines become contaminated through normal operation leading to restricted airflow, higher exhaust gas temperature, and increased fuel consumption. By eliminating engine contamination, engine washings improve propulsive efficiency measured as a decrease in thrust specific fuel consumption or TSFC, resulting in decreased emissions of carbon dioxide (CO_2).

It is anticipated that the methodology will be used by airline owners of jet engines who wish to utilize on-wing jet engine washing as a means of increasing engine thrust efficiency and reducing CO_2 emissions. Jet engine washing technology service providers might also use the methodology to assist airline customers in overall engine emissions reduction measurement.

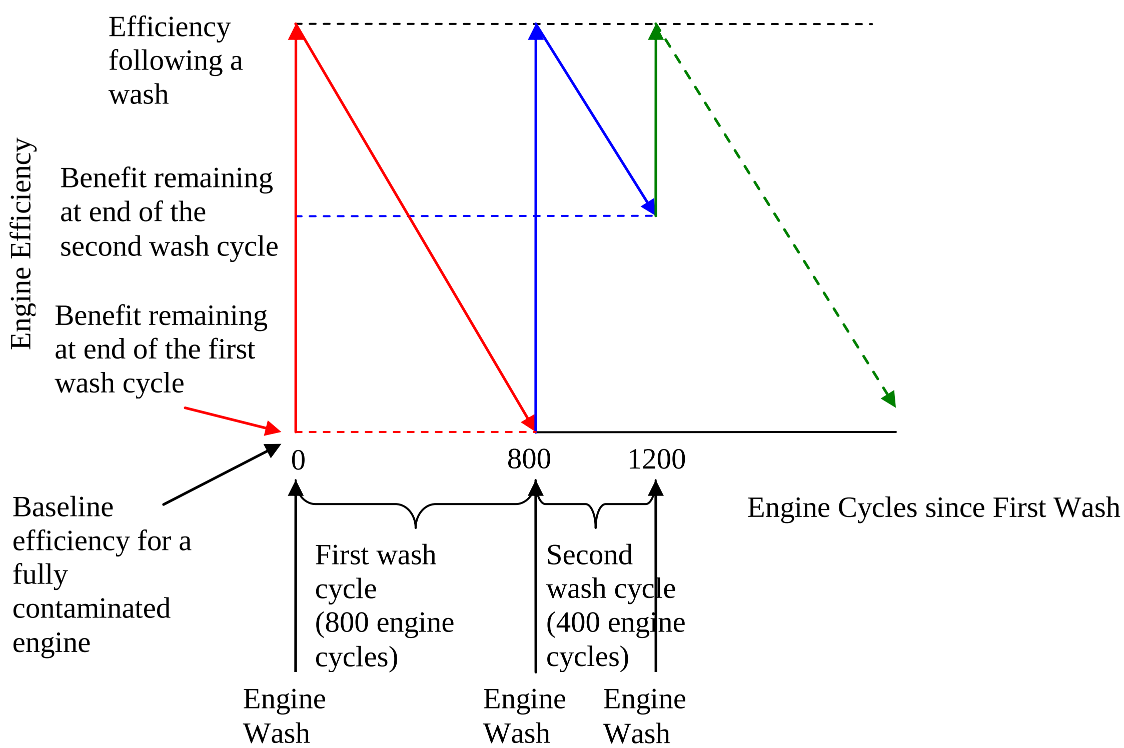
Figure 1 illustrates the general process of washing a jet engine. Once an engine is washed, it starts a wash cycle defined as the interval between two consecutive washes. As a result of the washing, engines will experience improved propulsive efficiency while in operation; the operation of an engine between one takeoff and one subsequent landing is called an engine cycle. As the number of engine cycles increase, the engine will become re-contaminated and the efficiency improvement realized by the washing will decline until the engine is washed again. The change in the efficiency improvement during the first washing cycle is tracked in red in Figure 1. This second washing terminates the first cycle and begins the subsequent cycle. The change in efficiency during the second wash cycle is tracked in blue in Figure 1. As demonstrated in Figure 1, washing cycles may not contain the same number of engine cycles for a variety of reasons, including:

Safety procedures – Some maintenance procedures prevent all engines on an aircraft from being washed at the same time. This reduces the risk that the same mistake made on one engine will be repeated on all engines of an aircraft, thus reducing the chance that all engines will fail at the same time.

Scheduling – Due to time constraints, it may not be feasible to wash all engines on an aircraft at once. Also, as engines are routinely switched between airplanes, the optimal wash interval for one engine may be different from that of the other engine on the same plane.

Since the number of engine cycles is directly correlated to the change in efficiency following a washing, the average efficiency improvement realized during the washing cycle will differ. Taking into account the average efficiency benefit realized during the wash cycle and the amount of fuel consumed by each engine cycle in a wash cycle, the fuel savings can be calculated and converted to emission reductions. As an additional environmental benefit, the methodology uses a closed-loop system for the collection, filtration and reuse of water used to wash the engine. This both saves water (of particular importance in water constrained areas of the world where engines may be washed) and eliminates the potential contamination of soil and groundwater associated with non closed-loop engine washing.

Figure 1 – Illustration of Engine Washing Process



2 SOURCE, DEFINITIONS AND APPLICABILITY

2.1 Source

- The approach for this baseline and monitoring methodology is based on elements from AMS II.J., the approved CDM (Clean Development Mechanism) small-scale baseline and monitoring methodology for demand-side activities for efficient lighting technologies. Jet engine washing technology is similar to lighting technology under AMS II.J. since both technologies provide benefits that may increase their market penetration in the baseline scenario. However, the market penetration of both technologies will increase far more rapidly under the project case. In the two methodologies, it is the additional market penetration growth achieved due to the project activities that are counted as emission reductions.

For more information regarding the methodology, please refer to http://cdm.unfccc.int/goto/MPappmeth.

2.2 Defintions

For the purpose of this methodology, the following definitions apply:

- **Engine cycle** The operation of an engine between one takeoff and one subsequent landing
- **Fleet** refers to a group of identical engines that use the same type of jet fuel and are attached to the same type of aircraft frame
- **Cruise EGT** refers to exhaust gas temperature (degrees Celsius) recorded during flight
- **Cruise Fuel Flow** refers to the rate (kg per hour or m^3 per hour) at which fuel is consumed by the engines during flight
- **Exhaust Gas Temp (EGT)** refers to temperature of the engine exhaust gases resulting from combustion of the fuel mixture, expressed in degree Celsius
- **Participant** refers to an individual airline that has agreed to wash all or a part of their fleet
- **Project Proponent** refers to the entity that is organizing airlines to wash all or part of their fleet
- **Project's engine washing technology** refers to any engine washing technology that decreases TSFC through the removal of engine contamination
- **Take off EGT** refers to engine exhaust gas temperature (degrees Celsius) recorded during takeoff
- **Thrust Specific Fuel Consumption (TSFC)** is an engineering term referring to fuel efficiency of an engine. TSFC represents the amount of fuel an engine burns to produce thrust, as measured in (Kg/hr)/Newton of thrust.
- **Wash** refers to the cleaning of an individual jet engine
- **Washing cycle** refers to the interval between consecutive washes for a particular engine

2.3 Applicability Conditions

The methodology is applicable to engine washing technology that meets the following conditions:

- The engine washing technology cleans any or all three of the compressive components of an engine: fan, low pressure compressor, and high pressure compressor.

- The engine washing was performed and completed in compliance with the wash requirements as provided in the engine's maintenance manual, or an alternative specification document as approved by a governing aviation regulatory body, such as the United States Federal Aviation Administration. Compliance with this condition will be indicated by the completion and maintenance supervisor signature on a 'released to service' form. Released to service forms are globally required for all aircraft undergoing any maintenance prior to their being put back into service.

- The only emission reductions claimed under this methodology are those related to increased propulsive efficiency due to engine washing. The project will not claim any emissions reductions as a result of other measures that result in changes in fuel consumption, e.g., changes in routes, operators' behaviour, etc, or fuel chemical property changes which increase fuel combustion efficiency.

- The engine is left on-wing during the washing and the engine washing technology is transported to the engine as opposed to removing the engine from the wing and transporting it to another location for the engine wash.

- The engine washing project will include a minimum of 100 engine washes per fleet to assure the methodology adequately compensates for single-engine model data variability.

- Applicable engines will be only those which during the period for which engine washing benefit is measured have not undergone an on-wing modification that could improve efficiency as measured by TSFC.

3 BASELINE METHODOLOGY PROCEDURE

3.1 Project Boundary

The project boundary is the physical, geographical location of each engine washed by the project technology, and the flight routes on which the emissions reductions occur. The project boundary includes emissions from generators and equipment used to transport engine wash equipment to the wash location.

The greenhouse gases included in or excluded from the project boundary are shown in Table 1.

Table 1: Emissions sources included in or excluded from the project boundary

<table>
<tr><th colspan="2">Source</th><th>Gas</th><th>Included?</th><th>Justification / Explanation</th></tr>
<tr><td rowspan="3">Baseline</td><td rowspan="3">Jet engines that are washed in the project case</td><td>CO_2</td><td>Yes</td><td>Emissions from fuel combustion represent the major emission source in the baseline</td></tr>
<tr><td>CH_4</td><td>No</td><td>Negligible</td></tr>
<tr><td>N_2O</td><td>No</td><td>Negligible</td></tr>
<tr><td rowspan="9">Project activity</td><td rowspan="3">Jet engines that are washed by the project technology</td><td>CO_2</td><td>Yes</td><td>Emissions from fuel combustion represent the major emission source in the project case</td></tr>
<tr><td>CH_4</td><td>No</td><td>Negligible</td></tr>
<tr><td>N_2O</td><td>No</td><td>Negligible</td></tr>
<tr><td rowspan="3">Energy use during engine wash</td><td>CO_2</td><td>Yes</td><td>Maybe an important emission source</td></tr>
<tr><td>CH_4</td><td>No</td><td>Negligible</td></tr>
<tr><td>N_2O</td><td>No</td><td>Negligible</td></tr>
<tr><td rowspan="3">Vehicles that transport engine wash equipment</td><td>CO_2</td><td>Yes</td><td>Maybe an important emission source</td></tr>
<tr><td>CH_4</td><td>No</td><td>Negligible</td></tr>
<tr><td>N_2O</td><td>No</td><td>Negligible</td></tr>
</table>

3.2 Identification of the baseline scenario

The project baseline activity will be demonstrated using the latest version of the *"Combined tool to identify the baseline scenario and demonstrate additionality"* that is available on the UNFCCC website.

3.3 Procedure for demonstrating additionality

Additionality shall be demonstrated using the latest version of the *"Combined tool to identify the baseline scenario and demonstrate additionality"* that is available on the UNFCCC website.

3.4 Baseline emissions

The following equations are used to estimate the baseline emissions for jet engines:

$$BE_y = \sum_{m}^{z} \left(BFC_y * EF_{CO2,ACFuel,y} \right) \quad \textbf{(1)}$$

Where:

BE_y	=	Baseline emissions in year *y* (t CO_2/yr)
M	=	An individual fleet
Z	=	Total number of fleets
BFC_y	=	Baseline fuel consumption by all engines in fleet m in year y (mass or volume unit)
$EF_{CO2,ACFuel,y}$	=	CO_2 emission factor for fuel used in fleet *m* engines (ton CO_2/mass or volume unit)

Procedure for estimating the CO_2 emission factor for fuel used in jet engines, $EF_{CO2,ACFuel,y}$

$$EF_{CO2,ACFuel,y} = EF_{C,ACFuel,y} * 44/12 * OXID_{ACFuel} * NCV_{ACFuel} \quad \textbf{(1.1)}$$

Where:

$EF_{CO2,ACFuel,y}$	=	CO_2 emission factor for fuel used in aircraft engines in fleet *m* (tonne of CO_2/mass or volume unit)
$EF_{C,ACFuel,y}$	=	Carbon content of fuel used in aircraft engines in fleet *m* (tonne/Tera Joule)
$OXID_{ACFuel}$	=	Oxidation factor of fuel used in aircraft engines in fleet *m*
NCV_{ACFuel}	=	Net caloric value of fuel used in aircraft engines in fleet *m* (Tera Joule/mass or volume units)

Procedure for estimating the baseline fuel consumption, BFC_y

$$BFC_y = \sum_{j=1}^{n} \left[\sum_{wc=1}^{x} \left[\sum_{ec=1}^{NECj,wc} MFC_r \right] \right] \quad \textbf{(1.2)}$$

Where:

BFC_y	=	Baseline fuel consumption by all engines in fleet *m* in year *y* (mass or volume units)
J	=	An individual engine in fleet *m*
N	=	Total number of engines in fleet *m* in year *y*
Wc	=	A wash cycle, or the interval between two consecutive washes
X	=	Total number of wash cycles for engine *j* in year *y*
$NEC_{j,wc}$	=	Number of engine cycles for engine *j* during wash cycle, *wc*, not to exceed $ACFC_m$

(number of cycles leading to full engine contamonation without a wash)

Ec = An engine cycle

MFC_r = Modelled fuel consumption in the baseline case, based on engine utilization (*r*) during the engine cycle (mass or volume units)

- Note: If the fuel used in an engine is changed during the project crediting period, the engine will be assigned to a different fleet corresponding to the appropriate combination of aircraft frame, engine type and fuel type for the wash cycle when the fuel switch occurs and all subsequent wash cycles where the new fuel is used.

- The methodology uses a Business Penetration (BP) factor, by which emissions reductions compared to baseline are reduced to reflect the current market penetration of jet engine washing technology. The BP factor is applied to the total modelled fuel consumption units to develop MFC_r as used above.

3.5 Project emissions

The following equation estimates the project emissions:

$$PE_y = \sum_m^z \left(PE_{EA,y} + PE_{WE,y}\right) \quad \textbf{(2)}$$

Where:

PE_y = Project emissions in year *y* (t CO_2)

m = An individual fleet

Z = Total number of fleets

$PE_{EA,y}$ = Emissions from fuel combustion by fleet *m* in year y (t CO_2)

$PE_{WE,y}$ = Emissions generated in the process of washing fleet *m* engines in year y (t CO_2)

Procedure for estimating the project emissions associated with fuel combustion by fleet *m* engines in year *y*, $PE_{EA,y}$

$$PE_{EA,y} = FC_{.y} * EF_{CO2,ACFuel,y} \quad \textbf{(2.1)}$$

Where:

$PE_{EA,y}$ = Emissions from jet engine fuel combustion in year *y* (tonne of CO_2)

FC_y = Fuel consumption by fleet *m* in year *y* (mass or volume unit)

$EF_{CO2,ACFuel,m,y}$ = Carbon dioxide emission factor of fuel used in fleet *m* engines (tonne of CO_2/ mass or volume unit)

Procedure for estimating the CO_2 emission factor for the fuel used in engines in year *y*, $EF_{CO2,ACFuel,y}$

$$EF_{CO2,ACFuel,y} = EF_{C,ACFuel,y} * 44/12 * OXID_{ACFuel} * NCV_{ACFuel} \quad \textbf{(2.1.1)}$$

Where:

$EF_{CO2,ACFuel,y}$	=	Carbon dioxide emission factor of fuel used in fleet *m* engines (tonne of CO_2/ mass or volume unit)
$EF_{C,ACFuel,y}$	=	Carbon content of fuel used in aircraft engines (tonne/Tera Joule)
$OXID_{ACFuel}$	=	Oxidation factor of fuel used in aircraft engines
NCV_{ACFuel}	=	Net caloric value of fuel used in aircraft engines (Tera Joule/mass or volume units)

Procedure for estimating the fuel consumption by fleet *m* in year *y*, *$FC_{m,y}$*

$$FC_y = \sum_{j=1}^{n}\left[\sum_{wc=1}^{x}\left[\left(\sum_{ec=1}^{NECj,wc} MFC_r\right) * \left(1 - \overline{TSFC_{j,wc}}\right)\right]\right] \quad \textbf{(2.1.2)}$$

Where:

FC_y	=	Fuel consumption by all engines in fleet *m* in year *y* (mass or volume units)
J	=	An individual engine in fleet *m*
N	=	Total number of engines in fleet *m* in year *y*
Wc	=	A wash cycle, or the interval between two consecutive washes
X	=	Total number of wash cycles for engine *j* in year *y*
$NEC_{j,wc}$	=	Number of engine cycles for engine *j* during wash cycle, *wc*, not to exceed $ACFC_m$
Ec	=	An engine cycle
MFC_r	=	Modelled fuel consumption in the baseline case, based on engine utilization (*r*) during the engine cycle (mass or volume units)
$\overline{TSFC_{j,wc}}$	=	Average TSFC improvement for engine *j* throughout the wash cycle, *wc,* due to wash *w* (%)

- As described above, the benefit of a wash will vary for each washing cycle depending on the number of engine cycles. However, airlines do not track fuel consumption at the level of detail that would be required to determine fuel consumption per wash cycle (fuel consumption is tracked at the fleet level, not by aircraft, engine or cycle). Since data limitations prevent accurate reporting of fuel consumption by wash cycle in the project case, the baseline fuel consumption for each engine cycle is determined using industry standard models (as described in section 4) and aggregated for each washing cycle. Wash cycle fuel consumption is then adjusted based on the average TSFC benefit realized during the wash cycle, to determine the wash cycle fuel consumption in the project case. This is aggregated across all wash cycles to determine annual fuel consumption for an engine, and then engine fuel consumption is aggregated across the fleet.

- Note 1: If the fuel used in an engine is changed during the project crediting period, the engine will be assigned to a different fleet (corresponding to the appropriate combination of aircraft frame, engine type and fuel type) for the wash cycle when the fuel switch occurs and all subsequent wash cycles where the new fuel is used.

- Note 2: Fuel consumption associated with engine cycles that are in excess of $ACFC_m$ during a particular wash cycle will not be included in this calculation. This is described further under equation 2.1.2.1.2

Procedure for estimating the average TSFC improvement per wash cycle, $\overline{TSFC}_{j,wc}$

$$\overline{TSFC}_{j,wc} = \left(\frac{\Delta TSFC_{j,w} + \Delta TSFC_{j,NECj,wc}}{2} \right) \quad \textbf{(2.1.2.1)}$$

Where:

$\overline{TSFC}_{j,wc}$	=	Average TSFC improvement for engine *j* throughout the washing cycle, *wc*, due to wash *w* (%)
$\Delta TSFC_{j,w}$	=	TSFC improvement for engine *j* following wash *w* (%)
$\Delta TSFC_{j,NECj,wc}$	=	TSFC improvement remaining for engine *j* after $NEC_{j,wc}$ cycles following a wash
W	=	An individual engine washing

Immediately following a wash, aircraft engines will realize the greatest increase in TSFC (represented by $\Delta TSFC_{j,w}$) and this declines in a linear fashion as the engine becomes more contaminated with each engine cycle (as shown in Figure 1 above) until the end of the wash cycle (the TSFC improvement remaining at the end of the wash cycle is represented by $\Delta TSFC_{j,NECj,wc}$). Since this decline is linear, the net effect of the wash throughout the wash cycle can be expressed as the average TSFC benefit.

Procedure for estimating the TSFC improvement for engine *j* following wash *w*, $\Delta TSFC_{j,w}$

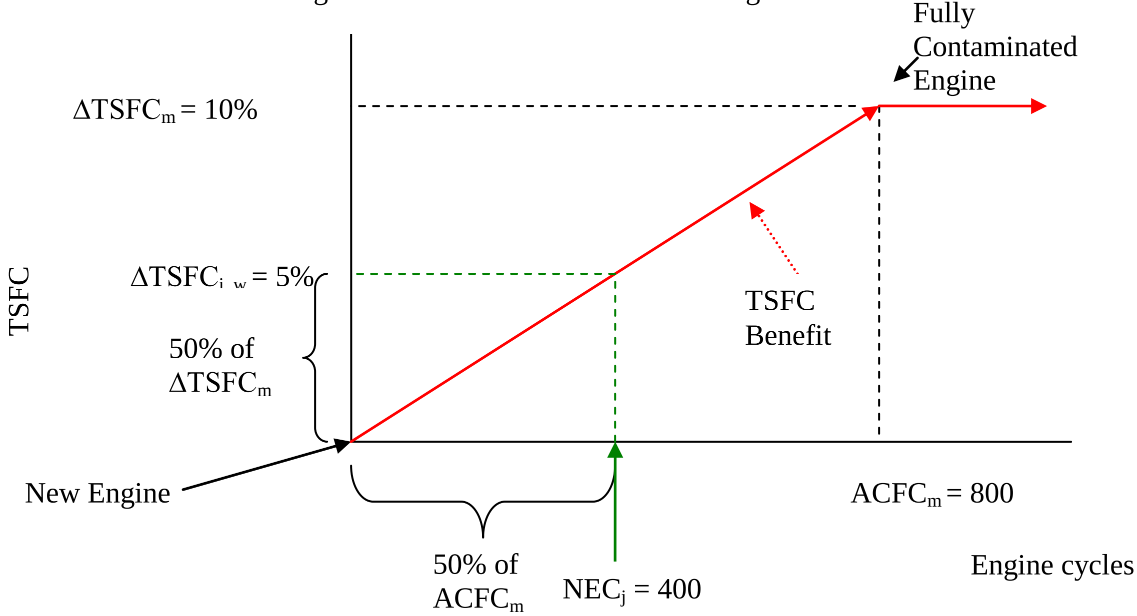
$$\Delta TSFC_{j,w} = \Delta TSFC_m * \left(\frac{NEC_j}{ACFC_m} \right) \quad \textbf{(2.1.2.1.1)}$$

Where:

$\Delta TSFC_{j,w}$	=	TSFC improvement for engine *j* following wash *w* (%)
$\Delta TSFC_m$	=	TSFC improvement for an engine in fleet *m* following a wash (%)
NEC_j	=	Number of engine cycles for engine j since it was put into service, not to exceed $ACFC_m$
$ACFC_m$	=	Number of engine cycles that, in the absence of any engine washings, will lead a clean engine in fleet *m* to become fully contaminated.

The TSFC improvement following washing in the project case ($\Delta TSFC_{j,w}$) can, in most cases, be compared to a fully contaminated engine, as defined by $\Delta TSFC_{m}$. The exception is an engine that has not yet travelled the number of cycles that causes full contamination as defined by $ACFC_m$, such as a new engine that has just been put into service. If an engine is washed before it reaches $ACFC_m$ cycles, it would be inappropriate to compare the wash benefit to the fully contaminated case. As engine contamination increases in a linear fashion relative to engine cycles until $ACFC_m$ is reached, and because engine contamination and TSFC benefit are directly correlated, the TSFC benefit for a wash that occurs before $ACFC_m$ cycles can be found by discounting the maximum TSFC benefit by the proportion of $ACFC_m$ cycles that has been reached before the wash takes place (see Figure 2).

Figure 2 – TSFC Benefit for a New Engine



Procedure for estimating the TSFC improvement remaining at the end of the wash cycle, $\Delta TSFC_{j,NECj,wc}$

$$\Delta TSFC_{j,NECj,wc} = \left(\Delta TSFC_m * \left(1 - \frac{NEC_{j,wc}}{ACFC_m} \right) \right) \qquad \textbf{(2.1.2.1.2)}$$

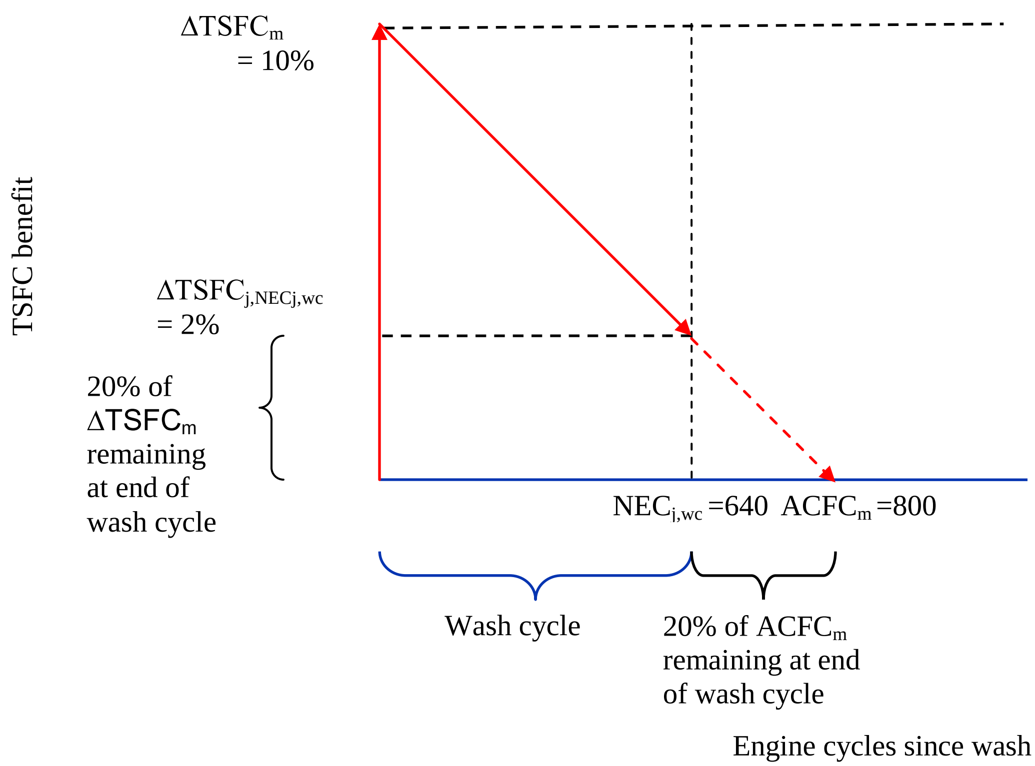
Where:

$\Delta TSFC_{j,NECj,wc}$	=	TSFC improvement for engine *j* after $NEC_{j,wc}$ cycles following a wash
$\Delta TSFC_m$	=	TSFC improvement for engine *j* following a wash (%)
$NEC_{j,wc}$	=	Number of engine cycles for engine ***j*** during wash cycle, *wc*, not to exceed $ACFC_m$
$ACFC_m$	=	Number of engine cycles that, in the absence of any engine washings, will lead a clean engine in fleet *m* to become fully contaminated.
W	=	An individual wash

If it were certain that the wash cycle would contain $ACFC_m$ engine cycles, equation 2.1.2.1 would simply take the average between $\Delta TSFC_{j,w}$ (the benefit immediately following wash *w*) and 0 (since $ACFC_m$ represents the point where the TSFC benefit is entirely lost). However, project participants may elect to shorten the wash cycle (note that cycles in excess of $ACFC_m$ are eliminated from consideration – see below), as demonstrated in figure 3. As a result, the TSFC benefit remaining at the end of this shortened wash cycle, $\Delta TSFC_{j,NECj,wc}$, is calculated in equation 2.1.2.1.2 Since the decline in TSFC is linear as the number of engine cycles increases, this equation calculates $\Delta TSFC_{j,NECj,wc}$ by multiplying the initial TSFC benefit by one minus the proportion of the maximum engine cycles realized during the wash cycle. For instance, if $ACFC_m$ is 800 and $NEC_{j,wc}$ is 640, then 1-(640/800) = 0.2. If the $\Delta TSFC_m$ is 10%, then the remaining TSFC benefit is 10% * 0.2 =2%.

As mentioned above, cycles in excess of $ACFC_m$ following a wash are eliminated from consideration. Once an engine reaches $ACFC_m$ cycles following a wash, it is by definition fully contaminated. The fuel efficiency is therefore no better than it would have been in the baseline and so the project does not provide any additional benefit.

Figure 3 – TSFC Benefit Remaining at End of Wash Cycle



Procedure for estimating the emissions generated during the engine washing process per year, $PE_{WE,y}$

$$PE_{WE,m,y} = GE_{m,y} + TE_{m,y} \qquad \textbf{(2.2)}$$

Where:

$PE_{WE,y}$	=	Emissions generated during the washing process in year *y* (t CO_2)
$GE_{m,,y}$	=	Emissions from energy usage to run generators during the washing of engines in fleet *m* in year *y* (t CO_2)
$TE_{m,y}$	=	Emissions from the transport of washing technology to the wash engines in fleet *m* in year *y* (t CO_2)

Procedure for estimating the emissions from energy usage to run the generator during the washing of engines in fleet *m*, $GE_{m,y}$

$$GE_{m,y} = \sum_{g}^{q} \left(FC_{gen,y} * EF_{CO2,GenFuel,y} \right) \quad \textbf{(2.2.1)}$$

Where:

$GE_{m,y}$	=	Emissions from energy usage to run generators during the washing of engines in fleet *m* in year *y* (t CO_2)
G	=	A particular fuel used by generators during the washing of fleet *m* engines
Q	=	Total number of different fuels used by all generators to wash engines in year *y*
$FC_{gen,y}$	=	Fuel consumption by generators used to wash the engines of fleet m in year *y* (mass or volume of fuel)
$EF_{CO2,GenFuel,y}$	=	CO_2 emission factor for the fuel consumed by generator *g* in year *y* (t CO_2/ mass or volume unit)

Procedure for estimating the fuel consumption by generators used to wash the engines of fleet *m* in year *y*, $FC_{gen,y}$

$$FC_{gen,y} = \sum_{j}^{n} \left[\sum_{w}^{x} \left(CR_{fuel} * D_{w} \right) \right] \quad \textbf{(2.2.1.1)}$$

Where:

$FC_{gen,y}$	=	Fuel consumption by generators used to wash the engines of fleet *m* in year *y* (mass or volume of fuel)
J	=	An individual engine in fleet *m*
N	=	Total number of engines in fleet *m* in year *y*
W	=	An engine wash
X	=	Total number of engine washes for engine *j* in year *y* (note that the number of wash cycles is equal to the number of washes, and so the same variable *x* is used)
CR_{fuel}	=	Fuel consumption rate of the generator in year *y* (mass or volume of fuel per hour)
D_w	=	Length of time that the generator is in use during a wash (hours)

Procedure for estimating the CO_2 emission factor for the fuel consumed by the generator in year *y*, $EF_{CO2,GenFuel,y}$

$$EF_{CO2,GenFuel,y} = EF_{C,GenFuel,y} * 44/12 * OXID_{GenFuel} * NCV_{GenFuel} \quad \textbf{(2.2.1.2)}$$

Where:

$EF_{CO2,GenFuel,y}$	=	CO_2 emission factor for the fuel consumed by the generator in year *y* (tonne of CO_2/ mass or volume unit)
$EF_{C,GenFuel,y}$	=	Carbon content of the fuel consumed by the generator (ton/Tera Joule)
$OXID_{GenFuel}$	=	Oxidation factor of the fuel consumed by the generator (%)
$NCV_{GenFuel}$	=	Net caloric value of the fuel consumed by the generator (Tera Joule/mass or volume units)

Procedure for estimating the emissions from the transport of washing technology to the wash location in year *y*, TE_y

$$TE_{m,y} = \sum_{f=1}^{l} \left(FC_{TV,fuel} * EF_{CO2,TVFuel,y} \right) \quad \textbf{(2.2.2)}$$

Where:

$TE_{m,y}$	=	Emissions from the combustion of fuel in vehicles used to transport washing equipment to the wash location in year *y* (mass or volume unit)
F	=	A particular fuel used by vehicles to transport wash equipment to wash engines in fleet *m*
L	=	Total number of different fuels that are used by vehicles to transport wash equipment (i.e., propane and electricity)
FC_{TVF}	=	Fuel consumption by vehicles during the transport of washing equipment in year *y* (volume units)
$EF_{CO2,TVFuel,y}$	=	CO2 emission factor for a fuel consumed by transport vehicles in year *y* (tonnetonneof CO_2/mass or volume unit)

Procedure for estimating the quantity of a particular fuel consumed in the transport of washing equipment, FC_{ETF}

$$FC_{TV,fuel} = \sum_{j=1}^{n}\left[\sum_{w=1}^{x}\left[\sum_{v=1}^{p}(TD/FE)\right]\right] \quad \textbf{(2.2.2.1)}$$

Where:

$FC_{TV,fuel}$	=	Fuel consumption by vehicles during the transport of engine washing equipment in year *y* (volume units)
J	=	An individual engine in fleet m
N	=	Total number of engines in fleet m in year y
W	=	A wash
X	=	Total number of washings for engine *j*
V	=	A vehicle used to transport engine washing equipment for a wash
P	=	Total number of vehicles used to transport engine washing equipment for a wash
TD	=	Total distance travelled by a vehicle to transport washing equipment for a wash (distance units)
FE	=	Fuel efficiency of a vehicle used to transport washing equipment (volume units per distance units)

Procedure for estimating the CO_2 emission factor for fuel consumed by transport vehicles in year *y*, $EF_{CO2,TVF,y}$

$$EF_{CO2,TVFuel,y} = EF_{C,TVFuel,y} * 44/12 * OXID_{TVFuel} * NCV_{TVFuel} \quad \textbf{(2.2.2.2)}$$

Where:

$EF_{CO2,TVFuel,y}$	=	CO_2 emission factor for fuel consumed by transport vehicles in year *y* (tonne of CO_2/mass or volume unit)
$EF_{C,TVFuel,y}$	=	Carbon content of the fuel consumed by transport vehicles (tonne/Tera Joule)
$OXID_{TVFuel}$	=	Oxidation factor of the fuel consumed by transport vehicles (%)
NCV_{TVFuel}	=	Net caloric value of the fuel consumed by transport vehicles (Tera Joule/mass or volume units)

3.6 Leakage

There are no identified sources of leakage for this project activity

3.7 Emission reductions

Since the impact of an engine wash will vary by fleet, the calculation of emission reductions is done for each fleet and then aggregated across all fleets. Emission reductions are calculated as follows:

$$ER_y = (BE_y - PE_y) \quad \textbf{(3)}$$

Where:

ER_y = Emission reductions in year *y* (tonne of CO_2e/yr)
BE_y = Baseline emissions in year *y* (tonne of CO_2e/yr)
PE_y = Project emissions in year *y* (tonne of CO_2/yr)

4 MONITORING METHODOLOGY

All data collected as part of monitoring will be archived electronically and will be kept at least for 2 years after the end of the last crediting period. The data to be monitored is listed in the tables below. All measurements will be conducted with calibrated measurement equipment according to relevant industry standards.

In addition, the monitoring provisions in the tools referred to in this methodology apply.

4.1 Data and parameters not monitored

In addition to the parameters listed in the tables below, the provisions on data and parameters not monitored in the tools referred to in this methodology apply.

Data / parameter:	BP
Data unit:	%
Description:	Business penetration factor
Source of data:	Fleet-specific wash penetration data.
Measurement procedures (if any):	Option 1: Project proponents must use fleet-specific wash penetration data to establish this parameter. The parameter is expressed as the percentage of engines washed in a given fleet (i.e., Number of engine washes / total potential engine washes). Option 2: Where fleet-specific data is not available, a default BP factor of 5% shall be used. The default BP factor was developed to discount total project emissions reductions by an amount comparable to the small market adoption of the project technology by potential project participants prior to commencement of the project. The factor was developed using aviation industry estimates indicating that in 2009 approximately 3,000 engines were washed on wing. The commercial aviation market eligible for the project has 40,000 jet engines and to improve performance and reduce emissions, each of these engines should be washed approximately twice per year, for a total of 80,000 potential washes. Using these figures, the project technology market penetration in 2009 was estimated at 3.75%. To provide a more conservative analysis of the market penetration data, the 3.75% has been rounded up to 5%.
Any comment:	The BP factor shall be determined at validation and at the renewal of each crediting period.

Data / parameter:	$ACFC_m$
Data unit:	Cycles
Description:	Number of engine cycles that, in the absence of any engine washings will lead a clean engine in fleet *m* to be fully contaminated.
Source of data:	Previous data analysis indicates that aircraft engines become fully contaminated between 800-1200 engine cycles, depending on the fleet and route. To assure the conservativeness of the emission reduction calculations, the default value has been set at 800 cycles. As an option, projects may use a fleet-specific $ACFC_m$ calculated as follows. The optional $ACFC_m$ value will apply for the complete duration of the crediting period and will reflect the composition of the fleet included in the project.
Measurement procedures (if any):	To calculate $\Delta TSFC_m$, data must be collected for a period of time before and after the wash such that accurate levels can be obtained for each period of time. This data is then analyzed to determine the TSFC benefit of each wash. The TSFC benefit corresponding to the wash cycle length (which corresponds to the number of engine cycles in the wash cycle or the number of cycles required for the engine to become fully contaminated) can then be determined through interpretation of the individual wash TSFC benefits plotted vs. NEC on a scatter plot. The point at which the TSFC benefit plateaus is the benefit that can be expected by a wash of a fully contaminated engine, or $\Delta TSFC_m$. The number of engine cycles that corresponds to $\Delta TSFC_m$ is $ACFC_m$.
Any comment:	Default value = 800

4.2 Data and parameters monitored

Data / parameter:	R
Data unit:	Hours
Description:	Engine utilization for each cycle or hours of operation
Source of data:	Engine operator records
Measurement procedures (if any):	Record hours per cycle, as well as date and time of cycle and the engine serial number, so that utilization can be allocated to a particular engine and wash cycle
Monitoring frequency:	Continuously
QA/QC procedures:	
Any comment:	

Data / parameter:	w
Data unit:	Wash
Description:	A wash for engine j
Source of data:	Engine operator records
Measurement procedures (if any):	Record date and time of the aircraft engine wash as well as the engine serial number, so that fuel consumption can be assigned to a particular engine and wash cycle.
Monitoring frequency:	Continuously
QA/QC procedures:	A signed 'Release to Service' form following completion of engine washing
Any comment:	

Data / parameter:	Ec / NECj,wc
Data unit:	Engine Cycle
Description:	Engine cycle for engine *j*, where an engine cycle includes one takeoff and one landing.
Source of data:	Aircraft engine operator records
Measurement procedures (if any):	Record data and time of cycle, as well as engine serial number so that engine cycle can be assigned to a wash cycle
Monitoring frequency:	Continuously, aggregated per wash cycle to determine $NEC_{j,wc}$. Cycles in excess of $ACFC_m$ during a wash cycle are eliminated from consideration, as described in equation 2.1.2.1.2
QA/QC procedures:	
Any comment:	

Data / parameter:	g
Data unit:	Fuel type
Description:	Fuel type consumed by each generator that is used to wash engines in year *y*
Source of data:	Operator records
Measurement procedures (if any):	
Monitoring frequency:	Recorded one time per year
QA/QC procedures:	
Any comment:	

Data / parameter:	CR_{fuel}
Data unit:	Mass or volume of fuel per hour
Description:	Fuel consumption rate for each generator used to wash engines in year *y*
Source of data:	Vehicle manufacturers specification sheet
Measurement procedures (if any):	
Monitoring frequency:	Recorded one time per year
QA/QC procedures:	
Any comment:	

Data / parameter:	D_w
Data unit:	Hours
Description:	Length of time that a generator is in use during a wash
Source of data:	Measurements by project proponent
Measurement procedures (if any):	In addition to duration of generator use, record date and time of wash, as well as engine serial number(s). In lieu of continuously recording wash duration, average duration of 15 washes for engines with at least $ACFC_m$ cycles may be used as default value for all washes in the fleet. Fully contaminated engines can take longer to clean, resulting in a more conservative estimation of project emissions.
Monitoring frequency:	Continuously If default value is used, record during first engine wash.
QA/QC procedures:	Data taken from written wash log data sheets
Any comment:	The use of default values is acceptable because the emissions associated with energy use during the washing process are likely to be de-minimus.

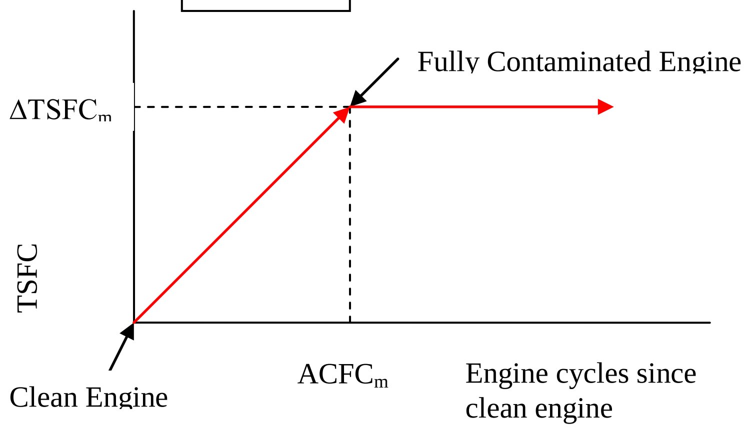
Data / parameter:	f
Data unit:	Fuel type
Description:	Fuel type consumed by a transport vehicle to transport wash equipment in year *y*
Source of data:	Vehicle operator records
Measurement procedures (if any):	
Monitoring frequency:	Continuously
QA/QC procedures:	
Any comment:	

Data / parameter:	TD_{TV}
Data unit:	Distance units
Description:	Total distance travelled by vehicles transporting engine washing equipment per engine wash
Source of data:	Vehicle odometer
Measurement procedures (if any):	Vehicle operator must record the roundtrip distance travelled for each engine wash, as well as the engine serial number that was washed and the time and date that the wash occurs. Alternatively, the vehicle operator can record the greatest roundtrip distance travelled to perform an engine wash for each location (i.e., airport), and this distance can be used as a default value for all other washings.
Monitoring frequency:	Roundtrip distance recorded for every washing. Alternatively, the distance is recorded once based on the greatest possible distance.
QA/QC procedures:	
Any comment:	

Data / parameter:	FE_{TV}
Data unit:	Mass or volume units per distance units
Description:	Fuel efficiency of a vehicle used to transport engine washing equipment to the wash location
Source of data:	Vehicle manufacturers specification sheet
Measurement procedures (if any):	
Monitoring frequency:	Recorded one time per year
QA/QC procedures:	
Any comment:	

Data / parameter:	$\Delta TSFC_m$
Data unit:	%
Description:	TSFC improvement for an engine in fleet *m* following a wash (%)
Source of data:	Engine trend data obtained from aircraft operator, including Takeoff EG Margin, Cruise EGT and Cruise Fuel Flow

Measurement procedures (if any):	To calculate $\Delta TSFC_m$, data must be collected for a period of time before and after the wash such that accurate levels can be obtained for each period of time. This data is then analyzed to determine the TSFC benefit of each wash. The TSFC benefit corresponding to the wash cycle length (which corresponds to the number of engine cycles in the wash cycle or the number of cycles required for the engine to become fully contaminated) can then be determined through interpretation of the individual wash TSFC benefits plotted vs. NEC on a scatter plot. The point at which the TSFC benefit plateaus is the benefit that can be expected by a wash of a fully contaminated engine, or $\Delta TSFC_m$. The number of engine cycles that corresponds to $\Delta TSFC_m$ is $ACFC_m$. This is shown in Figure 1. Step 1 - To calculate the TSFC improvement for varying wash cycle lengths, the following procedure is used: For each of the following variables - Takeoff EGT Margin, Cruise EGT and Cruise Fuel Flow data – obtain 20 data points before the wash and 20 data points after the wash from engine trend data. These data should be available from the aircraft on board flight performance tracking system, and should be collected immediately preceding and immediately following the wash for washed engines of the fleet in question. Make sure that all data acquired is normalized to account for differences in ambient conditions and power setting. Most industry-standard engine monitoring software programs provide fully normalized data that can be evaluated directly. If this is not available, raw data can be acquired and normalized manually. Detect and correct any biases that may be present in the data. Identify any trends in the data or performance shifts occurring before or after the wash that are not related to the wash. Omit data before the wash or after the wash that show the trend or performance shift. Omit outlier data that is greater than the appropriate variation threshold (typically 2 standard deviations) from the data population average. A minimum of 10 data points before the wash and 10 data points following the wash must remain following step 2 for accurate analysis. If fewer than 10 data points are available, a new dataset must be collected. For each variable, calculate the difference between the average of the remaining points following the wash and the remaining points prior to the wash. This difference will be defined as the "delta_delta". Input the measured "delta_delta" parameters into a thermodynamic engine model or use an applicable correlation coefficient to calculate the TSFC improvement for that wash. If correlations are used, compare the TSFC calculated based on WF and EGT to ensure accurate results. If the TSFC benefits calculated based on various parameters agree within an acceptable threshold, the data are considered valid and the wash benefit for that wash ($\Delta TSFC$)

	Step 2 – Once sufficient data points have been collected under Step 1 for the fleet (approximately 30), they are analyzed to determine $\Delta TSFC_m$. This is accomplished through a linear regression of wash TSFC benefits vs. engine contamination cycles, where the regression is forced through the origin. For the purposes of this regression, all washes taking place after more than $ACFC_m$ cycles will be re-defined as taking place at $ACFC_m$ cycles. The $\Delta TSFC_m$ benefit for each fleet will then be equivalent to the $ACFC_m$ contamination cycle intercept of the TSFC benefit regression line. Figure 1 
Monitoring frequency:	Analysis is conducted when data from a minimum of 100 engine washes has been collected from each fleet. Analysis is performed once and the resulting $\Delta TSFC_m$ value is applicable for the entire crediting period.
QA/QC procedures:	
Any comment:	- Project proponents must demonstrate to the VCS project validator applicability of the models used in Steps 1 and 2. - No performance shifting activities (i.e., as instrumentation changes, software upgrades, engine maintenance or upgrades) should be conducted between the measurement of pre and post-wash data.

Data / parameter:	MFC_r
Data unit:	Mass or volume units
Description:	Modelled fuel consumption in the baseline case, based on engine utilization (*r*) during the engine cycle
Source of data:	Data is modelled based on: utilization rates (average cycles per year and hours/cycle) as reported from aircraft operators, and fleet performance specifications obtained from airplane performance documents.
Measurement procedures (if any):	Aircraft operators report total engine cycles and total hours per year for the fleet. The average cycles per year and average hours per cycle for the fleet are calculated and these averages are used as inputs to the model.
Monitoring frequency:	Annual ex-post analysis
QA/QC procedures:	
Any comment:	At validation, project proponents must demonstrate the applicability of the model used to estimate fuel consumption. Acceptable models must have been approved by an aircraft engine manufacturer, and include those used in the certification of aircraft engine performance standards. Calculation of MFC_r must include application of the Business Penetration factor to eliminate potential non-additional emissions reductions associated with engines washed prior to methodology approval. When applied in calculation of project modelled fuel consumption, MFCr, the Business Penetration factor is expressed as 1 – BP.

Data / parameter:	NCV_{ACFuel}
Data unit:	Mega Joule / mass or volume units
Description:	Net caloric value of fuel used in aircraft engines
Source of data:	Actual measured or local data are to be used. If not available, regional data should be used, and in its absence, IPCC defaults can be used from the most recent version of the IPCC Guidelines for National Greenhouse Gas Inventories
Measurement procedures (if any):	Measurements taken according to best international practices
Monitoring frequency:	Yearly
QA/QC procedures:	
Any comment:	If the measurement results differ significantly from previous measurements or other relevant data sources, conduct additional measurements. Values must be compared to IPCC defaults if data are local or regional

Data / parameter:	$EF_{C,ACFuel,y}$
Data unit:	tonnes of carbon / mass or volume units
Description:	Carbon content of the fuel combusted in aircraft engines
Source of data:	Actual measured or local data should be used. If not available, regional data should be used, and in its absence, IPCC defaults can be used from the most recent version of the IPCC Guidelines for National Greenhouse Gas Inventories
Measurement procedures (if any):	Measurements taken according to best international practices
Monitoring frequency:	Yearly
QA/QC procedures:	
Any comment:	If the measurement results differ significantly from previous measurements or other relevant data sources, conduct additional measurements. Values must be compared to IPCC defaults if data are local or regional

Data / parameter:	$OXID_{ACFuel}$
Data unit:	Fraction
Description:	Oxidation factor for the fuel used in aircraft engines
Source of data:	Actual measured or local data should be used. If not available, regional data should be used, and in its absence, IPCC defaults can be used from the most recent version of the IPCC Guidelines for National Greenhouse Gas Inventories
Measurement procedures (if any):	Measurements taken according to best international practices
Monitoring frequency:	Yearly
QA/QC procedures:	
Any comment:	If the measurement results differ significantly from previous measurements or other relevant data sources, conduct additional measurements. Values must be compared to IPCC defaults if data is local or regional

Data / parameter:	$OXID_{GenFuel}$
Data unit:	Fraction
Description:	Oxidation factor for the fuel consumed by the generator
Source of data:	Actual measured or local data should be used. If not available, regional data should be used, and in its absence, IPCC defaults can be used from the most recent version of the IPCC Guidelines for National Greenhouse Gas Inventories
Measurement procedures (if any):	Measurements taken according to best international practices
Monitoring frequency:	Yearly
QA/QC procedures:	
Any comment:	If the measurement results differ significantly from previous measurements or other relevant data sources, conduct additional measurements. Values must be compared to IPCC defaults if data are local or regional

Data / parameter:	$NCV_{GenFuel}$
Data unit:	Mega Joule / mass or volume units
Description:	Net caloric value of the fuel consumed by the generator
Source of data:	Actual measured or local data are to be used. If not available, regional data should be used, and in its absence, IPCC defaults can be used from the most recent version of the IPCC Guidelines for National Greenhouse Gas Inventories
Measurement procedures (if any):	Measurements taken according to best international practices
Monitoring frequency:	Yearly
QA/QC procedures:	
Any comment:	If the measurement results differ significantly from previous measurements or other relevant data sources, conduct additional measurements. Values must be compared to IPCC defaults if data are local or regional

Data / parameter:	$EF_{C,GenFuel, y}$
Data unit:	tonnes of carbon / mass or volume units
Description:	Carbon content of the fuel consumed by the generator
Source of data:	Actual measured or local data should be used. If not available, regional data should be used, and in its absence, IPCC defaults can be used from the most recent version of the IPCC Guidelines for National Greenhouse Gas Inventories
Measurement procedures (if any):	Measurements taken according to best international practices
Monitoring frequency:	Yearly
QA/QC procedures:	
Any comment:	If the measurement results differ significantly from previous measurements or other relevant data sources, conduct additional measurements. Values must be compared to IPCC defaults if data are local or regional

Data / parameter:	$OXID_{TVFuel}$
Data unit:	Fraction
Description:	Oxidation factor for the fuel consumed by transport vehicles
Source of data:	Actual measured or local data should be used. If not available, regional data should be used, and in its absence, IPCC defaults can be used from the most recent version of the IPCC Guidelines for National Greenhouse Gas Inventories
Measurement procedures (if any):	Measurements taken according to best international practices
Monitoring frequency:	Yearly
QA/QC procedures:	
Any comment:	If the measurement results differ significantly from previous measurements or other relevant data sources, conduct additional measurements. Values must be compared to IPCC defaults if data are local or regional

Data / parameter:	NCV_{TVFuel}
Data unit:	Mega Joule / mass or volume units
Description:	Net caloric value of the fuel consumed by transport vehicles
Source of data:	Actual measured or local data should be used. If not available, regional data should be used, and in its absence, IPCC defaults can be used from the most recent version of the IPCC Guidelines for National Greenhouse Gas Inventories
Measurement procedures (if any):	Measurements taken according to best international practices
Monitoring frequency:	Yearly
QA/QC procedures:	
Any comment:	If the measurement results differ significantly from previous measurements or other relevant data sources, conduct additional measurements. Values must be compared to IPCC defaults if data are local or regional

Data / parameter:	$EF_{C,TVFuel, y}$
Data unit:	tonne of carbon / mass or volume units
Description:	Carbon content of the fuel consumed by transport vehicles
Source of data:	Actual measured or local data should be used. If not available, regional data should be used, and in its absence, IPCC defaults can be used from the most recent version of the IPCC Guidelines for National Greenhouse Gas Inventories
Measurement procedures (if any):	Measurements taken according to best international practices
Monitoring frequency:	Yearly
QA/QC procedures:	
Any comment:	If the measurement results differ significantly from previous measurements or other relevant data sources, conduct additional measurements. Values must be compared to IPCC defaults if data are local or regional

Data / parameter:	Δ Takeoff EGT Margin
Data unit:	°C
Description:	Change in Takeoff Exhaust Gas Temperature Margin resulting from the engine wash
Source of data:	Aircraft on-board flight performance tracking system
Measurement procedures (if any):	
Any comment:	Comparison to other measured parameters should be made to ensure validity. Values are to be used in conjunction with engineering judgment by a professional with experience in engine performance analysis.

Data / parameter:	Δ Cruise EGT
Data unit:	°C
Description:	Change in Cruise Exhaust Gas Temperature resulting from the engine wash
Source of data:	Aircraft on-board flight performance tracking system
Measurement procedures (if any):	
Any comment:	Comparison to other measured parameters should be made to ensure validity. Values are to be used in conjunction with engineering judgment by a professional with experience in engine performance analysis.

Data / parameter:	Δ Cruise fuel flow
Data unit:	%
Description:	Change in Cruise fuel flow resulting from the engine wash
Source of data:	Aircraft on-board flight performance tracking system
Measurement procedures (if any):	
Any comment:	Comparison to other measured parameters should be made to ensure validity. Values are to be used in conjunction with engineering judgment by a professional with experience in engine performance analysis.

Approved VCS Methodology
VM0014

Version 1.0
Sectoral Scopes 1, 10

Interception and Destruction of Fugitive Methane from Coal Bed Methane (CBM) Seeps

Scope
This methodology applies to projects that capture and destroy fugitive methane emissions occurring at coal bed outcroppings near active coal bed methane production operations.

Methodology Developers
The methodology element was developed by the Southern Ute Indian Tribe - Growth Fund and WSP Environment & Energy. Det Norske Veritas and Bureau Veritas provided methodology validation support through the VCS Double Approval Process.

Authors
Mike Huisenga (WSP) and Kyle Siesser (SUIT)

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I. SOURCE, DEFINITIONS AND APPLICABILITY

Sources

This baseline and monitoring methodology is based on the following approved baseline and monitoring methodologies:

ACM0008 V7*"Consolidated methodology for coal bed methane, coal mine methane and ventilation air methane capture and use for power (electrical or motive) and heat and/or destruction through flaring or flameless oxidation"*

- This consolidated methodology applies to active coal mines where methane mitigation projects are implemented to reduce emissions of methane during pre-mine drainage, post mine drainage and from ventilation air methane. Captured methane can be flared, used to generate heat and / or power and delivered to gas grids for heat and / or power use or in vehicles. ACM0008 has been approved as a baseline and monitoring methodology by the CDM Executive Board for use in registered Clean Development Mechanism (CDM) projects and which is recognized by the VCS.

- This baseline and monitoring methodology is similar to AMC0008 in that the sources of project emissions are nearly identical, because the potential uses for recovered methane are the same. However, the baseline emissions of methane from a CBM gas seep result from different physical causes than CMM emissions. ACM0008 applies to projects located at coal mines where the emissions are a result of mining operations while this methodology applies to projects located at CBM gas extraction operations where coal mining is not occurring. Furthermore, ACM0008 defines CBM as gas drainage which precedes the mining of a coal seam. This can be done to sell gas, but is mainly done to degasify the seam and make it safe for mining. The type of CBM production covered in this methodology strictly pertains to gas extraction from coal seams which aren't being mined. Fugitive methane emissions mitigated by projects covered by this methodology are a result of disturbing the equilibrium in the seam during gas extraction.

AM0009 V4*"Recovery and utilization of gas from oil wells that would otherwise be flared or vented"*

- This methodology applies to the capture and destruction of associated gas recovered during oil production. This gas is typically vented rather than put to beneficial use. Under the methodology proponents can generate power, compress and transport gas to processing facilities for upgrading.

- AM0009 is similar to this methodology in that it applies to the capture and destruction of methane which is produced as an undesirable by-product of the primary production of oil (or gas). A key difference between these methodologies and project types is that oil production operations utilizing AM0009 typically have the opportunity to recover methane at the well head; where methane recovered from CBM seeps require the use of additional capital equipment to intercept and aggregate methane from coal seam outcroppings.

This methodology also refers to the latest versions of the following CDM Executive Board approved tools:

- "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion";
- "Tool to calculate project emissions from electricity consumption";
- "Combined tool to identify the baseline scenario and demonstrate additionality";
- "Tool to determine project emissions from flaring gases containing methane";
- "Tool to determine the emission factor for an electricity system".

Definitions

For the purpose of this methodology, the following definitions apply:

- **Coal Bed Methane (CBM).** Coal bed methane is the methane gas that resides inside underground coal seams, under pressure, and thus adsorbed to the coal.
- **Coal Bed Methane Production (CBM Production).** Coal bed methane production refers to the extraction of methane from underground coal seams, the subsequent treatment and injection of the gas into natural gas grids for utilization by end users. CBM extraction involves the removal of water or gas from the coal seam decreasing the hydrostatic pressure in order to cause methane to desorb from coal allowing for its removal. For the purposes of this methodology, the act of removing water from coal seams to produce methane constitutes a coal bed methane project.
- **"Up-dip".** The up-dip areas of the coal seam refer to the ground level elevations where coal outcroppings and methane gas seeps exist. Coal bed methane flows from down-dip to up-dip within the coal seam until it reaches the outcropping where it is released to the atmosphere as fugitive emissions.
- **"Down-dip".** The down-dip areas of the coal seam refer to the location where coal bed methane extraction typically takes place. Down-dip can be considered to be in the coal seam at 1000 to 4000 feet below the surface where high pressures readily allow for the removal of methane.
- **Produced water.** Water which is pumped and removed from a coal seam in order to liberate methane from the coal.
- **Coal bed methane seep**. Ground level fugitive methane emissions from coal seam outcroppings which originate from coal beds deep underground.
- **Gas interception system**. A system consisting of vertical or horizontal gas wells or gas collection membranes, vacuum compressors and gas transmission pipelines designed to intercept and recover gas in coal seams or at the ground surface prior to its release at coal outcroppings.
- **Fugitive methane**. Methane which is emitted to the atmosphere from underground coal seams and results partly from down dip coal bed methane production operations.

- **Monitoring Wells**. Wells which have been drilled into a coal seam to monitor water levels or other environmental conditions in the context of coal, oil or gas resource assessments. These wells may be repurposed and used as gas interception wells

Applicability conditions

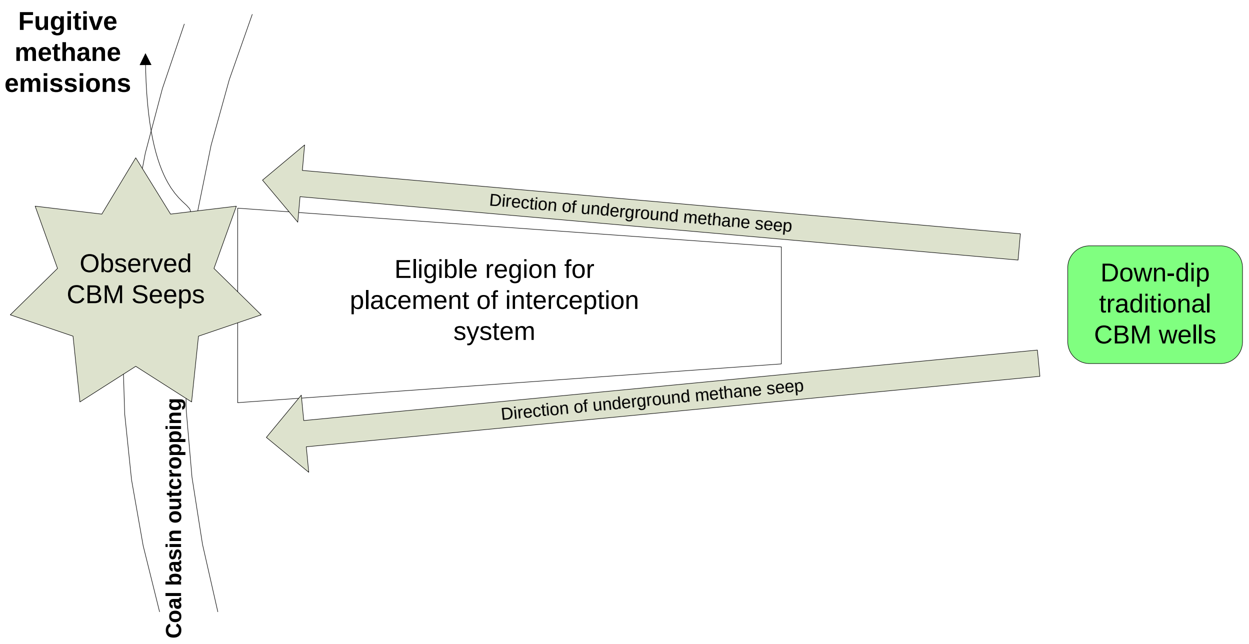
This methodology applies to project activities that capture and destroy methane which would otherwise be released to the atmosphere from coal bed outcroppings. Projects using this methodology will be implemented on coal seams or where exposed coal bed outcroppings exist having documented coal bed methane seeps. The methodology does not apply to methane captured at CBM extraction operations, but will apply to mitigation projects located between coal seam outcroppings and CBM operations.

The methodology applies to project activities that involve the use of any of the following extraction techniques:

- The use of gas drainage wells and monitoring wells, serving as gas interception wells, drilled near locations where methane gas seeps are present. Gas interception wells must be located between documented methane gas seeps at coal seam outcroppings and down dip traditional CBM wells. In other words, traditional CBM wells themselves cannot qualify as interception wells.

- The use of a gas membranes, surface covers or underground horizontal well fields to capture fugitive methane emissions at or just below the ground surface level.

Figure 1: Illustration showing that eligible interception system must be placed between CBM operations and or at locations of observed CBM gas seeps.



This methodology applies to fugitive methane capture project activities at or near known locations of methane gas seeps as well as the on-site or off-site utilization and destruction of captured methane. The baseline is the partial or total atmospheric release of the methane and the project activities include the following gas destruction scenarios:

- Captured methane is destroyed through flaring; and/or
- Captured methane is destroyed through utilization on-site to produce electricity, and/or thermal energy; and/or
- Captured methane is destroyed off-site through utilization by end users following injection into natural gas distribution grids.

This methodology **does not apply** to the following project activities:

- Methane captured at active traditional CBM extraction wells;
- Methane captured at active or abandoned coal mines;
- Degasification of methane from coal seams prior to coal mining activities.
- Injection of any fluid/gas "down-dip" of the location of methane interception in order to enhance methane capture;
- Removal of water from coal seams where gas interception systems are constructed in order to enhance gas recovery. If suitable and eligible wells which lie on the path from down-dip traditional CBM wells to up-dip exposed outcroppings and having documented methane gas seeps are flooded, they may be dewatered in order to be operated as interception wells.

II. BASELINE METHODOLOGY PROCEDURE

Project boundary

For the purpose of determining **project activity emissions**, project participants shall include:

- CO2 emissions from the combustion of methane in a flare, engine, power plant, or heat generation plant;
- CO2 emissions from the combustion of non-methane hydrocarbons (NMHCs), if they represent more than 1% by volume of the extracted coal mine gas:
- CO2 emissions from on-site fuel consumption due to the project activity, including transport of the fuel
- Fugitive methane emissions from on-site gas processing equipment
- Fugitive emissions from unburned methane and from gas treatment equipment

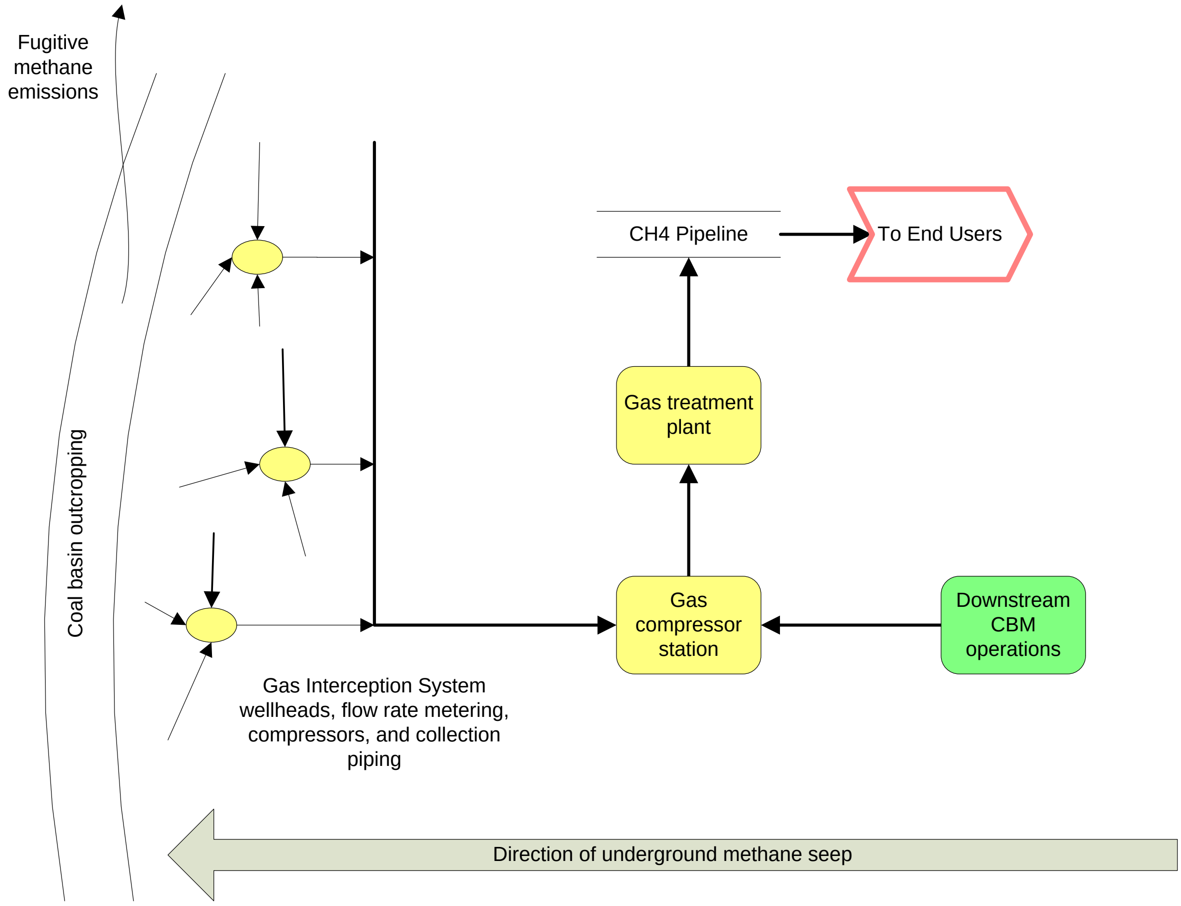
For the purpose of determining **baseline emissions**, project participants shall include the following emission sources:

- Fugitive CH_4 emissions from coal bed methane seeps;
- CO_2 emissions from the destruction of methane in the baseline scenario;
- CO_2 emissions from the production of heat and power (motive and electrical) that is replaced by the project activity.

The **spatial extent** of the project boundary encompasses:

- All equipment installed and used as part of the project activity for the extraction, compression, storage, and treatment of intercepted fugitive methane at the project site, and transport to an off-site user, including transport through natural gas distribution grids. Certain project equipment may be common between methane emissions mitigation projects and co-located CBM operations such as gas compression and treatment systems and in which case fugitive emission should be allocated appropriately
- Flaring, captive power and/or heat generation facilities installed and used as part of the project activity.
- Power plants connected to the electricity grid, where the project activity exports power to the grid, as per the definition of the project electricity system and connected electricity system given in "Tool to calculate the emission factor for an electricity system."
- Combustion of methane by end users connected to natural gas grids into which gas has been injected.

Figure 2: Hypothetical project schematic showing a gas interception system consisting of 9 vertical wellheads connected to three compression and metering systems to deliver raw gas to a common pipeline booster compressor station and gas treatment plant shared by an existing CBM operation



The greenhouse gases included in or excluded from the project boundary are shown in

Table 1.

Table 1: Emissions sources included in or excluded from the project boundary

Source		Gas	Included?	Justification / Explanation
Baseline	Emissions of methane from surface gas seeps at coal outcroppings	CO_2	No	Excluded for simplification. This is conservative.
		CH_4	Yes	This is the main source of emissions. The amount included in the baseline is the volume of methane captured by gas interception systems. This is not a total inventory of all methane seepage in the project's spatial boundary.
		N_2O	No	Excluded for simplification. This is conservative.

Source		Gas	Included?	Justification / Explanation
	Grid electricity generation (electricity provided to the grid)	CO_2	Yes	Only CO_2 emissions associated with the quantity of electricity exported to the grid which replaces marginal sources of electricity generation in the baseline will be counted; use of combined margin method as described in “Tool to calculate the emission factor for an electricity system” should be made.
		CH_4	No	Excluded for simplification. This is conservative.
		N_2O	No	Excluded for simplification. This is conservative.
	Captive power and/or heat and injection into gas grids	CO_2	Yes	Only when the baseline scenario involves such usage.
		CH_4	No	Excluded for simplification. This is conservative.
		N_2O	No	Excluded for simplification. This is conservative.
Project	On-site fuel and electricity consumption due to the project activity required to transport, compress, clean and upgrade the gas	CO_2	Yes	Energy consumption from equipment required for compressing, cleaning, upgrading and transporting gas will be accounted for. Energy use allocations will be made in cases where production facilities are shared between multiple operations.
		CH_4	No	Excluded for simplification. This emission source is assumed to be very small.
		N_2O	No	Excluded for simplification. This emission source is assumed to be very small.
	Emissions from methane destruction	CO_2	Yes	From the combustion of methane in a flare, flameless oxidation, or heat/power generation.
	Emissions from NMHC destruction	CO_2	Yes	From the combustion of NMHC in a flare of flameless oxidizer or heat/power generation, if NMHC accounts for more than 1% by volume of extracted gas.
	Fugitive emissions of un-combusted methane	CH_4	Yes	Small amounts of methane will remain unburned in flares.
	Fugitive methane emissions from on-site gas processing equipment	CH_4	Yes	If gas sales are metered upstream of a processing facility, then fugitive emissions are to be accounted for. If gas sales are metered downstream of a processing facility, then this source is not included.
	Fugitive methane emissions from gas supply pipeline	CH_4	No	Excluded for simplification. This emission source is assumed to be very small.
	Accidental methane release	CH_4	No	Excluded for simplification. This emission source is assumed to be very small.

Identification of the baseline scenario

Project participants should refer to the latest version of the "Combined tool to identify the baseline scenario and demonstrate additionality", and follow the specific guidance outlined below for step 1.

Step 1: Identify technically feasible options for capturing and/or utilizing fugitive CBM

Step 1: Options for gathering fugitive CBM

The baseline scenario alternatives should include all possible options that are technically feasible to collect CBM gas that would be emitted as fugitive methane and which comply with safety regulations. These options should include:

A. The use of vertical gas wells and collection systems drilled into the coal seam down dip of the location of known CBM gas seeps;

B. The use of surface membranes or covers or subsurface horizontal gas wells and collection systems;

C. Possible combinations of options A and B with relative shares of gas specified.

These options should include the VCS project activity not implemented as a VCS project.

Step 1b: Options for captured CBM gas treatment

A. Venting

B. Flaring of CBM

C. Use for grid power generation

D. Use for captive power generation

E. Use for heat generation

F. Feed into gas pipeline to be used as fuel for vehicles or heat/power generation

G. Possible combinations of options A to F with the relative shares of gas treated under each option specified

Step 1c: Options for energy production

The baseline scenario alternatives should include all possible options to generate electricity (grid, captive power generation using CBM or other fuels) and/or heat (using CBM or other fuels) and/or to fuel vehicles.

These options should include the proposed project activity that has however not been implemented as a VCS project activity.

Refer to "Combined tool to identify the baseline scenario and demonstrate additionality" v2.2 and complete step 2 to step 5.

Additionality

The additionality of the project activity shall be demonstrated and assessed using the latest version of the Clean Development Mechanism tool called “Combined tool to identify the baseline scenario and demonstrate additionality”.

Baseline emissions

Baseline emissions included in this methodology are:

- CO2 emissions resulting from the destruction of methane by flares and combustion in heat and / or power generation equipment
- CH_4 from free flowing gas seeps at locations where exposed coal outcroppings exist
- CO2 emissions from the generation of heat and / or power replaced by the project activity using recovered methane

Baseline emissions are calculated as follows:

$$\mathbf{BE_y = BE_{MD,y} + BE_{MR,y} + BE_{USE,y}} \quad \textbf{(1)}$$

Where:

BE_y	=	Baseline emissions in year *y* (t CO_2e/yr)
$BE_{MD,y}$	=	Baseline emissions from destruction of methane in the baseline scenario in year *y* (t CO_2e/yr)
$BE_{MR,y}$	=	Baseline emissions from release of methane into the atmosphere in year *y* that is avoided by the project activity (t CO_2e/yr)
$BE_{USE,y}$	=	Baseline emissions from the production of power, heat or supply to the gas grid replaced by the project activity in year *y* (t CO2e/yr)

Methane destruction in the baseline

Depending on the project type, methane destruction may already be occurring in the baseline in flares, flameless oxidation units or for the production or heat and/or power.

$$BE_{MD} = (CEF_{CH4} + r \times CEF_{NMHC}) \times \sum_i CM_{BL,i} \quad \textbf{(2)}$$

With:

$$r = PC_{NMHC}/PC_{CH4} \quad \textbf{(3)}$$

Where:

$BE_{MD,y}$	=	Baseline emissions from destruction of methane in the baseline scenario in year *y* (t CO_2e/yr)
CEF_{CH4}	=	Carbon emission factor for combusted methane (2.75 t CO_2/ t CH_4)
CEF_{NMHC}	=	Carbon emission factor for combusted non-methane hydrocarbons. This parameter should be obtained through periodical analysis of captured methane (t CO_2/ t NMHC)
$CM_{BL,i}$	=	Captured methane that is destroyed by use *i* in the baseline (t CH_4)
r	=	Relative proportion of NMHC compared to methane

PC_{CH4} = Concentration (in mass) of methane in extracted gas (%), measured on wet basis
PC_{NMHC} = NMHC concentration (in mass) in extracted gas (%) measured on wet basis

Methane released into the atmosphere

Fugitive methane emissions generated at down-dip traditional coal bed methane operations are freely flowing gases which migrate up-dip and are emitted at coal seam outcroppings at the ground surface. Intercepted fugitive coal bed methane is not gas that is stored in an underground reservoir or adsorbed in the coal seam below the wells. Because the gas captured by these interception systems is freely flowing up the coal seam, the effect of applying vacuum pressure to the wellhead will increase the volume of free flowing gas that can be evacuated by each well, thus increasing the methane interception rate and decreasing fugitive emissions at the outcropping. Since vacuum pumps do not act to liberate adsorbed methane or drain underground gas reservoirs, but rather act to increase the area of drainage for each interception well, all of the methane captured during a given monitoring period can be said to have been emitted at the outcropping in the absence of the project activity during the same monitoring period. Furthermore, it is true that because these wellheads do not desorb methane from coal or drain gas from reservoirs, they are only capturing up-dip migrating methane that would very soon be released to the atmosphere. In the absence of a methane interception system, this gas would be emitted to the atmosphere at coal seam outcroppings at the ground surface level.

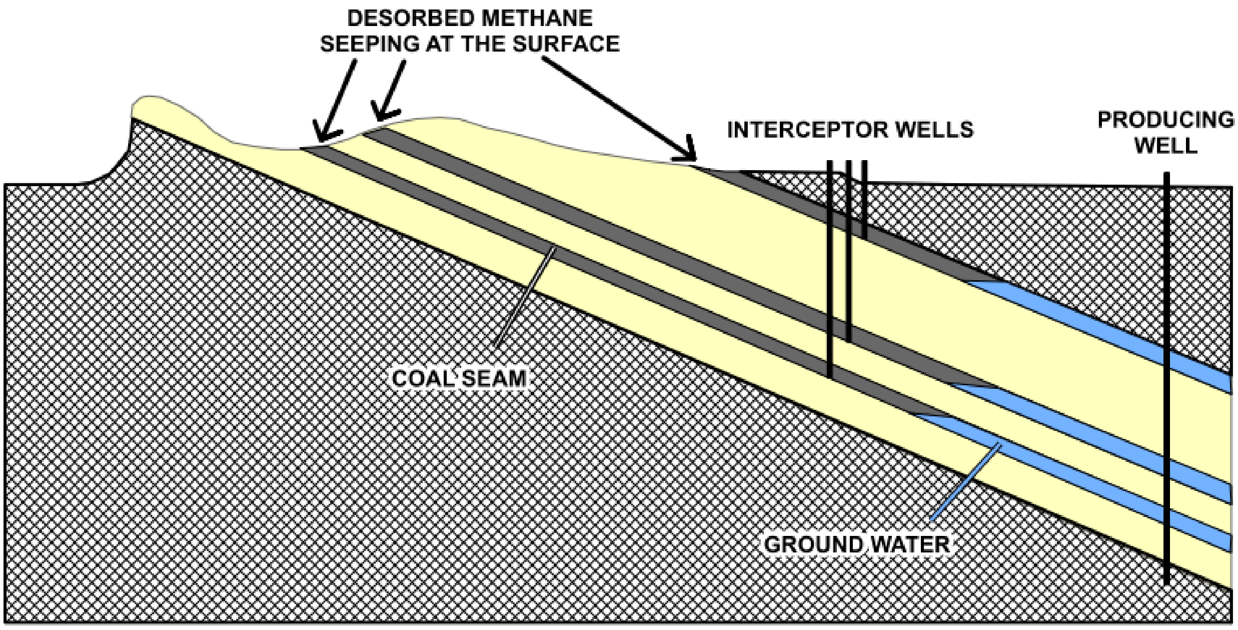
For the reasons discussed above, baseline emissions of methane for each monitoring period are determined using the volume of captured methane from the interception well system. Project proponents are required to submit documented evidence that coal bed methane gas seeps are present up-dip of where gas interception systems are placed.

This evidence may take either of the following forms:

- Arial LIDAR mappings showing the coal outcropping, the location of the proposed gas interception system and ground level methane concentration at the outcropping

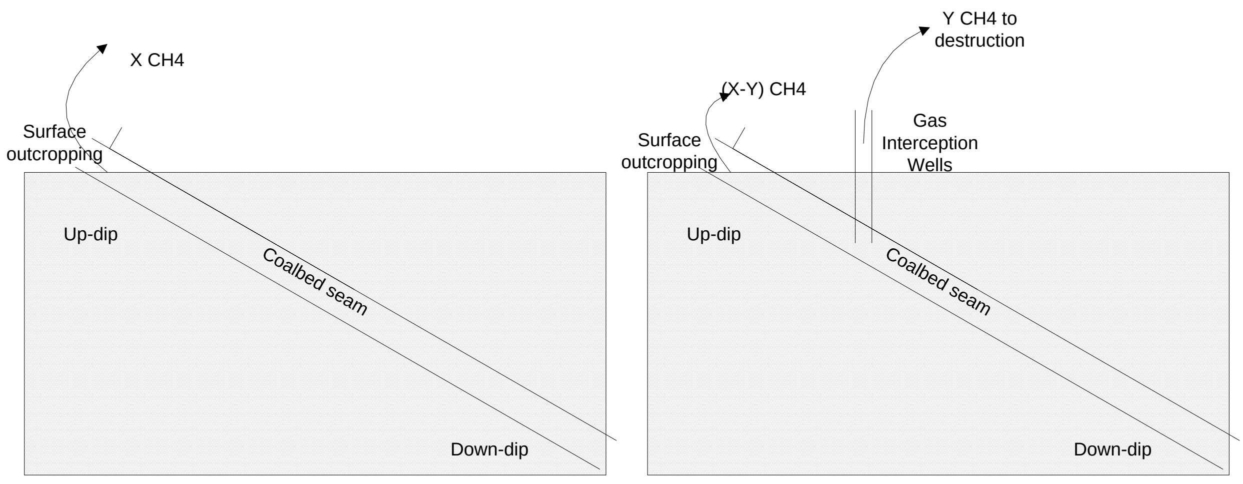
- Field surveys of the coal seam outcropping located up-dip of the interception systems using a methane flux chamber to establish ground level methane flux in mol/m^2-day

Figure 3: Cross section showing how gas interception system wells can be placed between CBM operations and the coal outcroppings where fugitive emissions occur in order to capture methane before it reaches the surface. Fugitive methane emitted at the surface can originate both from within the seam above the ground water level as well as from the main part of the CBM field below the ground water level



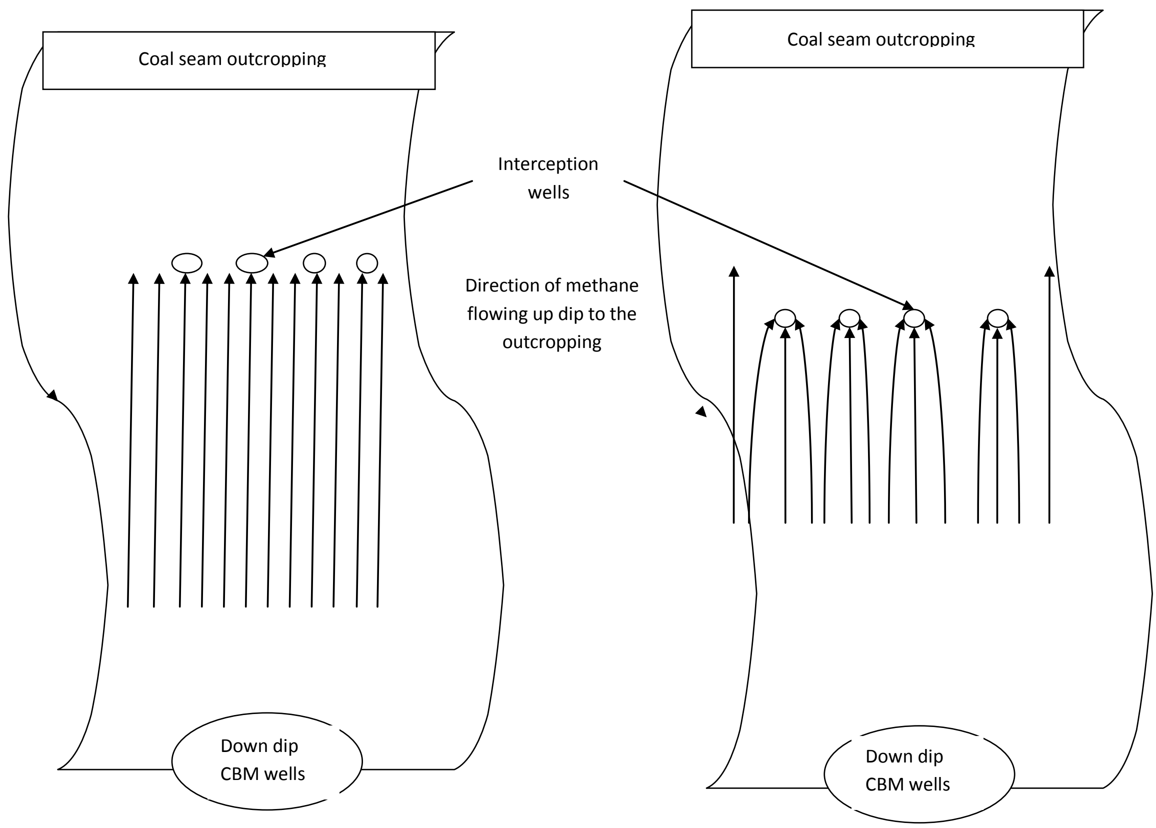
The interception system will only capture a portion of the fugitive methane emitted at the outcroppings (X CH4), as illustrated by Figure 4. The volume of gas captured by the system will be considered the baseline emissions (Y CH4) and fugitive methane eluding capture (X-Y CH4) is excluded from the project boundary, since this would be emitted in both the baseline and project cases. The figure also shows how methane flows from down-dip to up-dip before being emitted at the outcroppings. The down-dip traditional CBM extraction wells are excluded from the project boundary. Traditional CBM extraction wells and systems are ineligible as these systems act to free adsorbed methane from the coal seam and do not prevent fugitive methane emissions.

Figure 4: Schematic illustrating the change in fugitive emissions at the coal seam outcropping resulting from methane capture by the gas interception systems, in this case, vertical wells.



CBM interception wells or surface membranes will intercept and capture methane flowing up the coal seam to the outcropping or capture membrane at the outcropping in the absence of an imparted vacuum. However, the use of vacuum pumps will aid these wells by increasing their drainage area in the seam. Interception wells spaced laterally across the upward slowing coal seam will ideally capture methane flowing across the lateral line. This is illustrated in Figure 5.

Figure 5: Schematic, on the left, showing vertical gas interception wells placed in the flow of fugitive migrating CBM gas intercepting some of the gas. On the right, vacuum pressure is applied to the wells and increases each well's ability to drain gas horizontally across the seam, effectively allowing it to capture a larger share of the fugitive methane.



Baseline emissions from methane release to the atmosphere are calculated by subtracting methane which is captured and used in the baseline scenario from the methane which is captured and used by the project activity for each use.

$$BE_{MR} = GWP_{CH4} * \sum_i \left(CM_{PJ,i,y} - CM_{BL,i,y} \right) \quad \textbf{(4)}$$

Where:

BE_{MR}	=	Baseline emissions from release of methane into the atmosphere that is avoided by the project activity (t CO_2e)
$CM_{PJ,i,y}$	=	Captured methane that is destroyed by use *i* of the project activity in year *y* (tCH4)
$CM_{BL,i}$	=	Captured methane that would have been destroyed by use *i* in the baseline scenario in year *y* (t CH_4)

Emissions from power/heat generation replaced by project

$$BE_{USE} = GEN \times EF_{ELEC} + HEAT \times EF_{HEAT} + GAS \times EF_{GAS} \quad \textbf{(5)}$$

Where:

BE_{USE}	=	Baseline emissions from the production of power and / or heat or from destruction following injection into gas grids replaced by the project activity (t CO_2e/yr)
GEN	=	Electricity generated by project activity (MWh)
EF_{ELEC}	=	Emission factor of electricity (grid, captive or a combination) replaced by project (t CO_2/MWh)
HEAT	=	Heat generated by project activity (GJ)
EF_{HEAT}	=	Emission factor of heat production replaced by project activity (t CO_2/GJ)
GAS	=	Gas delivered to the gas grid (GJ)
EF_{GAS}	=	Emission factor for gas grid fuel replaced by the project activity (t CO_2/GJ)

Grid power emission factor

If the baseline scenario includes grid power supply that would be replaced by the project activity, the combined margin emission factor for replaced electricity shall be calculated using the "Tool to calculate the emission factor for an electricity system". However, projects based in the United States can choose to use emission factors corresponding to the applicable grid sub-region in the most recent version of the EPA's eGRID database.

Captive power emissions factor

If the baseline scenario includes captive power generation (either existing or new) that would be replaced by the project activity, the Emissions Factor for replaced electricity is calculated as follows:

$$EF_{captive} = \frac{EF_{CO2,i}}{Eff_{captive}} \times \frac{44}{12} \times \frac{3.6TJ}{1000MWh} \quad \textbf{(6)}$$

Where:

$EF_{captive}$	=	Emission factor for captive power generation (t CO_2e/MWh)
$EF_{CO2,i}$	=	CO2 emission factor of fuel used in captive power generation (tC/TJ)
$Eff_{captive}$	=	Efficiency of the captive power generation (%)
44/12	=	Carbon to Carbon Dioxide conversion factor
3.6/1000	=	TJ to MWh conversion factor

Combination of grid power and captive power emissions factor

If the baseline scenario selection determines that both captive and grid power would be used, then the emission factor for the baseline is the weighted average of the emissions factor for grid power and captive power.

$$EF_{ELEC} = s_{grid} \times EF_{grid} + s_{captive} \times EF_{captive} \quad \textbf{(7)}$$

Where:

EF_{ELEC}	=	CO_2 baseline emission factor for the electricity replaced due to the project activity (t CO_2/MWh)
EF_{grid}	=	CO_2 baseline emission factor for the grid electricity replaced due to the project activity (t CO_2/MWh)
$EF_{captive}$	=	CO_2 baseline emission factor for the captive electricity replaced due to the project activity (t CO_2/MWh)
s_{grid}	=	Share of facility electricity demand supplied by grid imports over the last 3 years (%)[1]
$s_{captive}$	=	Share of facility electricity demand supplied by captive power over the last 3 years (%)1

Heat generation emissions factor

If the baseline scenario includes heat generation (either existing or new) that is replaced by the project activity, the Emissions Factor for replaced heat generation is calculated as follows:

$$EF_{HEAT} = \frac{EF_{CO2,i}}{Eff_{heat}} \times \frac{44}{12} \times \frac{1TJ}{1000GJ} \quad \textbf{(8)}$$

Where:

EF_{HEAT}	=	Emission factor for heat generation (t CO_2/GJ)
$EF_{CO2,i}$	=	CO_2 emission factor of fuel used in heat generation (t C/TJ)
Eff_{heat}	=	Boiler efficiency of the heat generation (%)
44/12	=	Carbon to Carbon Dioxide conversion factor
1/1000	=	TJ to GJ conversion factor

To estimate the boiler efficiency, project propoents may choose between the following two options:

Option A:

Use the highest value among the following three values as a conservative approach:

(a) Measured efficiency prior to project implementation

(b) Measured efficiency during monitoring

(c) Manufacturer nameplate data for efficiency of the existing boilers

[1] If the facility is a new facility, then the share of grid versus import power determined to be the most likely baseline scenario should be used.

Option B:

Assume a boiler efficiency of 100% based on the net calorific values as a conservative approach.

Gas grid emission factor

The emission factor occuring in the baseline from the use of gas grid fuel replaced by the project activity is calculated as follows:

$$EF_{GAS} = EF_{CO2,i} \times \frac{1}{Eff_{processing}} \times \frac{44}{12} \times \frac{1TJ}{1000GJ} \quad \textbf{(9)}$$

Where:

EF_{GAS}	=	Emission factor for gas grid fuel replaced by the project activity (t CO_2/GJ)
$EF_{CO2,i}$	=	CO_2 emission factor for displaced gas grid fuel (t C/TJ)
$Eff_{processing}$	=	The efficiency of gas processing facilities used to treat captured methane onsite prior to injection into gas grids (%)[2]
44/12	=	Carbon to Carbon Dioxide conversion factor
1/1000	=	TJ to GJ conversion factor

Project emissions

Project emissions included in this methodology are:

- CO_2 emissions due to consumption of fossil fuels and electricity for the recovery, compression, and transportation of the raw gas stream;
- CO_2 emissions from the destruction of methane and non-methane hydrocarbons by flares, by heat and / or power generation equipment ;
- CH_4 emissions from incomplete combustion of raw gas by flares

Project emissions are calculated as follows:

$$PE_y = PE_{ME,y} + PE_{MD,y} + PE_{UM,y} \quad \textbf{(10)}$$

Where:

PE_y	=	Project emissions in year *y* (t CO_2e/yr)
$PE_{ME,y}$	=	Project emissions from energy use to capture and use methane in year *y* (t CO_2e/yr)
$PE_{MD,y}$	=	Project emissions from methane destroyed in year *y* (t CO_2e/yr)
$PE_{UM,y}$	=	Project emissions from un-combusted methane in year *y* (t CO_2e/yr)

[2] This efficiency refers to the combined efficiency of upgrading and injection into gas grids where resulting losses are fugitive emissions, gas flared and / or used for heat and power onsite. If gas delivered to gas grids is metered after the processing facility, then $Eff_{processing}$ is equal to 1. When gas sales to grid are metered before processing, $Eff_{processing}$ should reflect the fugitive emissions by the processing facility used.

Combustion emissions from additional energy required for methane capture and use

Additional energy may be used for the capture, compression, clean-up, and use or destruction of methane. Emissions from this energy use should be included as project emissions.

$$PE_{ME} = CONS_{ELEC,PJ} \times CEF_{ELEC} + CONS_{HEAT,PJ} \times CEF_{HEAT} + CONS_{FossFuelPJ} \times CEF_{FossFuel} \quad \textbf{(11)}$$

Where:

PE_{ME}	=	Project emissions from energy use to capture and use or destroy methane (t CO_2/yr)
$CONS_{ELEC,PJ}$	=	Additional electricity consumption for capture and use or destruction of methane, if any (MWh)[3]
CEF_{ELEC}	=	Carbon emissions factor of electricity used by the process equipment (t CO_2/MWh)
$CONS_{HEAT,PJ}$	=	Additional heat consumption for capture and use or destruction of methane, if any (GJ)
CEF_{HEAT}	=	Carbon emissions factor of heat used by the process equipment (t CO_2/GJ)
$CONS_{FossFuel,PJ}$	=	Additional fossil fuel consumption for capture and use or destruction of methane, if any (GJ)
$CEF_{FossFuel}$	=	Carbon emissions factor of fossil fuel used by the process equipment (t CO_2/GJ)

For electricity emissions factor, the same formulae are used as in the calculations of baseline emissions. In other words, if the source of power for the process equipment is the grid, then the formulae from "Tool to calculate the emission factor for an electricity system" for calculating the combined margin emissions factor are used. If the source of power for the process equipment is captive power generation, then the emissions factor is calculated based on the emission factor for the fuel used and efficiency of the captive power plant.

For the heat generation emission factor, the same formulae are used as in the calculations of baseline emissions. In other words, the boiler efficiency and the emission factor for the fuel used are the basis of the emissions factor.

Combustion emissions from use of captured methane

When the captured methane is burned in a flare, heat or power plant, mechanical power generation equipment, or oxidized in a flameless oxidation unit, combustion emissions are released. In addition, if NMHC account for more than 1% by volume of the extracted raw gas, combustion emissions from these gases should also be included. Captured methane delivered to heat and / or power generation is equal to the methane destroyed by these end uses since IPCC 2006 assumes complete combustion in these end uses.

$$PE_{MD} = (MD_{FL} + CM_{ELEC} + CM_{MECH} + CM_{HEAT} + CM_{GAS}) \times (CEF_{CH4} + r \times CEF_{NMHC}) \quad \textbf{(12)}$$

With:

$$r = PC_{NMHC}/PC_{CH4} \quad \textbf{(13)}$$

Where:[4]

PE_{MD}	=	Project emissions from destruction of captured methane (t CO_2/yr)
MD_{FL}	=	Methane destroyed through flaring (t CH_4)

[3] For example, electricity may be required to run pumps, motors, compressors, and gas clean-up equipment
[4] Note that throughout this baseline methodology, it is assumed that measured quantities of raw gas are converted to tones of methane using the measured concentration of the extracted raw gas and the density of methane.

CM_{ELEC} = Captured methane destroyed through electrical power generation (t CH_4)
CM_{MECH} = Captured methane destroyed through mechanical power generation (tCH4)
CM_{HEAT} = Captured methane destroyed through heat generation (t CH_4)
CM_{GAS} = Captured methane destroyed after being supplied to natural gas grid (t CH_4)
CEF_{CH4} = Carbon emissions factor for combusted methane (2.75 t CO_2/ t CH_4)
CEF_{NMHC} = Carbon emissions factor for combusted non-methane hydrocarbons (the concentration varies and, therefore, to be obtained through periodical analysis of captured methane) (t CO_2/ t NMHC)
r = Relative proportion of NMHC compared to methane
PC_{CH4} = Concentration (in mass) of methane in extracted gas (%), measured on wet basis
PC_{NMHC} = NMHC concentration (in mass) in extracted gas (%) measured on wet basis

In each end-use, the amount of gas destroyed depends on the efficiency of combustion of each end use.

$$MD_{FL} = CM_{FL} - \left(PE_{flare} / GWP_{CH4}\right) \quad \textbf{(14)}$$

Where:
MD_{FL} = Methane destroyed through flaring (t CH_4)
CM_{FL} = Captured methane delivered to flare (t CH_4)
PE_{flare} = Project emissions of non-combusted CH_4, expressed in terms of CO_2e, from flaring of the raw gas stream (t CO_2e)
GWP_{CH4} = Global warming potential of methane (21 t CO_2e/tCH_4)

The project emissions of non-combusted CH_4 expressed in terms of CO_2e from flaring of the raw gas stream (PE_{flare}) shall be calculated following the procedures described in the "Tool to determine project emissions from flaring gases containing methane". PE_{flare} can be calculated on an annual basis or for the required period of time using this tool.

Un-combusted methane from project activity

Not all of the methane sent to the flare will be combusted, so a small amount will escape to the atmosphere. These emissions are calculated using the following:

$$PE_{UM} = PE_{flare} \quad \textbf{(15)}$$

Where:
PE_{UM} = Project emissions from un-combusted methane (t CO_2e)
PE_{flare} = Project emissions of non-combusted CH4 expressed in terms of CO2e from flaring of the raw gas stream (t CO_2e)

The project emissions from flaring of the raw gas stream (PE_{flare}) shall be calculated following the procedures described in the "Tool to determine project emissions from flaring gases containing methane". PE_{flare} can be calculated on an annual basis or for the required period of time using this tool.

Leakage

There are no known sources of emissions leakage caused by the project type.

Emission Reductions

Emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y - LE_y \quad \textbf{(16)}$$

Where:

ER_y = Emission reductions in year *y* (t CO_2e/yr)
BE_y = Baseline emissions in year *y* (t CO_2e/yr)
PE_y = Project emissions in year *y* (t CO_2/yr)
LE_y = Leakage emissions in year *y* (t CO_2/yr)

III. MONITORING METHODOLOGY

All data collected as part of monitoring should be archived electronically and be kept at least for 2 years after the end of the last crediting period. 100% of the data should be monitored if not indicated otherwise in the tables below. All measurements should be conducted with calibrated measurement equipment according to relevant industry standards.

In addition, the monitoring provisions in the tools referred to in this methodology apply.

Data and parameters not monitored

In addition to the parameters listed in the tables below, the provisions on data and parameters not monitored in the tools referred to in this methodology apply.

Data / parameter:	$CM_{BL,i}$
Data unit:	tCH4
Description:	Captured methane that would have been destroyed by use *i* in the baseline
Source of data:	
Measurement procedures (if any):	
Any comment:	Flow meters will record gas volumes, pressure and temperature. Metered gas volumes are converted to mass using a density of 0.67 kg/m^3 under normal conditions of temperature and pressure.

Data / parameter:	$CM_{PJ,i}$
Data unit:	tCH4
Description:	Captured methane destroyed by use *i* in the project activity
Source of data:	
Measurement procedures (if any):	
Any comment:	Flow meters will record gas volumes, pressure and temperature. Metered gas volumes are converted to mass using a density of 0.67 kg/m^3 under normal conditions of temperature and pressure.

Data / parameter:	EF_{HEAT}
Data unit:	t CO_2/GJ
Description:	The emission factor of heat replaced by the project
Source of data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	*Ex ante*
QA/QC procedures:	
Any comment:	

Data / parameter:	EF_{GAS}
Data unit:	t CO_2/GJ
Description:	The emission factor of gas grid fuel replaced by the project
Source of data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	*Ex ante*
QA/QC procedures:	
Any comment:	

Data / parameter:	$EF_{CO2,i}$
Data unit:	t C/TJ
Description:	The emission factor of fuel used in captive power generation
Source of data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	*Ex ante*
QA/QC procedures:	
Any comment:	

Data / parameter:	CEF_{ELEC}
Data unit:	t CO_2/MWh
Description:	Carbon emission factor for electricity used by the project activity
Source of data:	Calculated using the combined margin method in the "Tool to calculate the emission factor for an electricity system". US based projects can use the EPA's eGRID database for the grid sub-region in which the project is located.
Measurement procedures (if any):	
Monitoring frequency:	*Ex ante*
QA/QC procedures:	
Any comment:	

Data / parameter:	$CEF_{FossFuel}$
Data unit:	t CO_2/GJ
Description:	Carbon emission factor for fossil fuel used by the project activity to capture and use or destroy methane
Source of Data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	*Ex ante*
QA/QC procedures:	
Any comment:	

Data / parameter:	CEF_{CH4}
Data unit:	t CO_2/ t CH_4
Description:	Carbon emission factor for combusted methane captured by the project activity
Source of Data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	*Ex ante*
QA/QC procedures:	
Any comment:	Set at 2.75 t CO_2/ t CH_4

Data / parameter:	CEF_{HEAT}
Data unit:	t CO_2/GJ
Description:	Carbon emission factor of heat used by the project activity
Source of Data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	*Ex ante*
QA/QC procedures:	
Any comment:	

Data and parameters monitored

Data / parameter:	GEN
Data unit:	MWh
Description:	Electricity generated by the project activity
Source of data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	Continuous
QA/QC procedures:	
Any comment:	

Data / parameter:	HEAT
Data unit:	GJ
Description:	Heat generated by the project activity
Source of data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	Continuous
QA/QC procedures:	
Any comment:	

Data / parameter:	GAS
Data unit:	GJ
Description:	Gas delivered to natural gas distribution grids and supplied to end users by the project activity.
Source of data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	Continuous
QA/QC procedures:	
Any comment:	Gas flow meters will measure methane injected into pipelines. The energy content of methane is determined by converting this volumetric measurement to energy. Utility sales invoices should be used where available.

Data / parameter:	EF_{ELEC}
Data unit:	t CO_2/MWh
Description:	The emission factor of electricity replaced by the project
Source of data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	Annually or *Ex ante*
QA/QC procedures:	
Any comment:	If grid electricity is replaced by the project, the combined margin emission factor should be calculated annually using “Tool to calculate the emission factor for an electricity system” For projects based in the United States, emission factors from the US EPA’s eGRID database corresponding to the gird sub-region in which the project is located can be used.

Data / parameter:	$Eff_{captive}$
Data unit:	%
Description:	The efficiency of captive power generation
Source of data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	Annually
QA/QC procedures:	
Any comment:	Annual average electrical efficiency based on the lower heating value of the fuel

Data / parameter:	Eff_{heat}
Data unit:	%
Description:	Boiler efficiency of the heat generation
Source of data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	Annually
QA/QC procedures:	
Any comment:	Annual average thermal efficiency based on the lower heating value of the fuel

Data / parameter:	$Eff_{processing}$
Data unit:	%
Description:	The efficiency of gas processing including cleanup, compression, and upgrading prior to injection into gas grids. Combined efficiency including losses for use as fuel, flaring, venting and fugitive emissions. Only to be used if gas sales metered before processing facility.
Source of data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	Continuously or Annually
QA/QC procedures:	
Any comment:	

Data / parameter:	$CONS_{ELEC,PJ}$
Data unit:	MWh
Description:	Additional electricity consumption for capture and use or destruction of methane
Source of data:	Project site
Measurement procedures (if any):	Taken from machinery data acquisition systems or utility bills
Monitoring frequency:	Continuously
QA/QC procedures:	
Any comment:	

Data / parameter:	$CONS_{HEAT,PJ}$
Data unit:	GJ
Description:	Additional heat consumption for capture and use or destruction of methane
Source of data:	Project site
Measurement procedures (if any):	Taken from machinery data acquisition systems or utility bills
Monitoring frequency:	Continuously
QA/QC procedures:	
Any comment:	

Data / parameter:	$CONS_{FossFuel,PJ}$
Data unit:	GJ
Description:	Additional fossil fuel consumption for capture and use or destruction of methane
Source of data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	Continuously
QA/QC procedures:	
Any comment:	

Data / parameter:	CEF_{NMHC}
Data unit:	t CO_2/ t NMHC
Description:	Carbon emission factor for combusted non methane hydrocarbons captured by the project activity
Source of data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	Annually
QA/QC procedures:	
Any comment:	To be obtained through annual analysis of the fractional composition of captured gas delivered to end users

Data / parameter:	CM_{FL}
Data unit:	t CH_4
Description:	Captured methane delivered to a flare and combusted
Source of data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	Continuously
QA/QC procedures:	
Any comment:	Flow meters will record gas volumes, pressure and temperature. Metered gas volumes are converted to mass using a density of 0.67 kg/m^3 under normal conditions of temperature and pressure.

Data / parameter:	CM_{ELEC}
Data unit:	t CH_4
Description:	Captured methane delivered to a power plant
Source of data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	Continuously
QA/QC procedures:	
Any comment:	Flow meters will record gas volumes, pressure and temperature. Metered gas volumes are converted to mass using a density of 0.67 kg/m^3 under normal conditions of temperature and pressure.

Data / parameter:	CM_{MECH}
Data unit:	t CH_4
Description:	Captured methane destroyed through mechanical energy generation
Source of data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	Continuously
QA/QC procedures:	
Any comment:	Flow meters will record gas volumes, pressure and temperature. Metered gas volumes are converted to mass using a density of 0.67 kg/m^3 under normal conditions of temperature and pressure.

Data / parameter:	CM_{HEAT}
Data unit:	t CH_4
Description:	Captured methane delivered to a heat plant
Source of data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	Continuously
QA/QC procedures:	
Any comment:	Flow meters will record gas volumes, pressure and temperature. Metered gas volumes are converted to mass using a density of 0.67 kg/m^3 under normal conditions of temperature and pressure.

Data / parameter:	CM_{GAS}
Data unit:	t CH_4
Description:	Captured methane delivered to a natural gas grid
Source of data:	Project site
Measurement procedures (if any):	
Monitoring frequency:	Continuously
QA/QC procedures:	
Any comment:	Flow meters will record gas volumes, pressure and temperature. Metered gas volumes are converted to mass using a density of 0.67 kg/m^3 under normal conditions of temperature and pressure.

Data / parameter:	PC_{CH4}
Data unit:	%
Description:	Concentration (in mass) of methane in captured gas (%), measured on wet basis
Source of data:	Concentration meters, optical and calorific
Measurement procedures (if any):	
Monitoring frequency:	Hourly/Daily
QA/QC procedures:	
Any comment:	To be measured on wet basis

Data / parameter:	PC_{NMHC}
Data unit:	%
Description:	Concentration (in mass) of non-methane hydrocarbons in extracted gas (%), measured on wet basis
Source of data:	Concentration meters, optical and calorific
Measurement procedures (if any):	
Monitoring frequency:	Annually
QA/QC procedures:	
Any comment:	To be measured on wet basis

VERIFIED CARBON STANDARD

A Global Benchmark for Carbon

Approved VCS Methodology
VM0015

Version 1.1, 3 December 2012

Sectoral Scope 14

Methodology for Avoided Unplanned Deforestation

This methodology is developed by:

Acknowledgements

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Methodology Developers	Amazonas Sustainable Foundation
	BioCarbon Fund
	Carbon Decisions International
	Institute for the Conservation and Sustainable Development of Amazonas

Author	Lucio Pedroni (Carbon Decisions International)

Collaborators		
Institute for the Conservation and Sustainable Development of Amazonas	**Carbon Decisions International**	**Amazonas Sustainable Foundation**
Mariano Cenamo	Álvaro Vallejo	Virgilio Viana
Mariana Pavan	Peter Schlesinger	João Tezza
Gabriel Carrero	Juan Felipe Villegas	Gabriel Ribenboim
		Thais Megid
		Victor Salviati

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TABLE OF CONTENTS

SOURCES

This methodology is based on the draft REDD project description for the "Reserva do Juma Conservation Project" in Amazonas (Brazil), whose *baseline* study, monitoring and project design documents were prepared by IDESAM, the Amazonas Sustainable Foundation (FAS) and the Government of Amazonas (SDS/SEPLAN-AM), with inputs and review from a selected group of experts and scientists in Brazil.

The methodology is an adaptation to all kinds of "*Unplanned Deforestation*" of the draft methodology for "*Mosaic Deforestation*" developed by the BioCarbon Fund for the REDD project activity "Ankeniheny - Zahamena Biological Corridor" in Madagascar, whose baseline study, monitoring and project design documents are being prepared by the Ministry of the Environment, Water, Forests and Tourism of Madagascar with assistance of Conservation International and the International Bank for Reconstruction and Development as Trustee of the BioCarbon Fund.

SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology is for estimating and monitoring greenhouse gas (GHG) emissions of project activities that avoid unplanned deforestation (AUD). It also gives the option to account for carbon stock enhancements in forests that would be deforested in the baseline case, when these are measurable and significant. Credits for reducing GHG emissions from avoided degradation are excluded in this methodology.

The methodology has no geographic restrictions and is applicable globally under the following conditions:

a) Baseline activities may include planned or unplanned logging for timber, fuel-wood collection, charcoal production, agricultural and grazing activities as long as the category is unplanned deforestation according to the most recent VCS AFOLU guidelines.

b) Project activities may include one or a combination of the eligible categories defined in the description of the scope of the methodology (see table 1 and figure 2).

c) The project area can include different types of forest, such as, but not limited to, old-growth forest, degraded forest, secondary forests, planted forests and agro-forestry systems meeting the definition of "forest".

d) At project commencement, the project area shall include only land qualifying as "forest" for a minimum of 10 years prior to the project start date.

e) The project area can include forested wetlands (such as bottomland forests, floodplain forests, mangrove forests) as long as they do not grow on peat. Peat shall be defined as organic soils with at least 65% organic matter and a minimum thickness of 50 cm. If the project area includes a forested wetlands growing on peat (e.g. peat swamp forests), this methodology is not applicable.

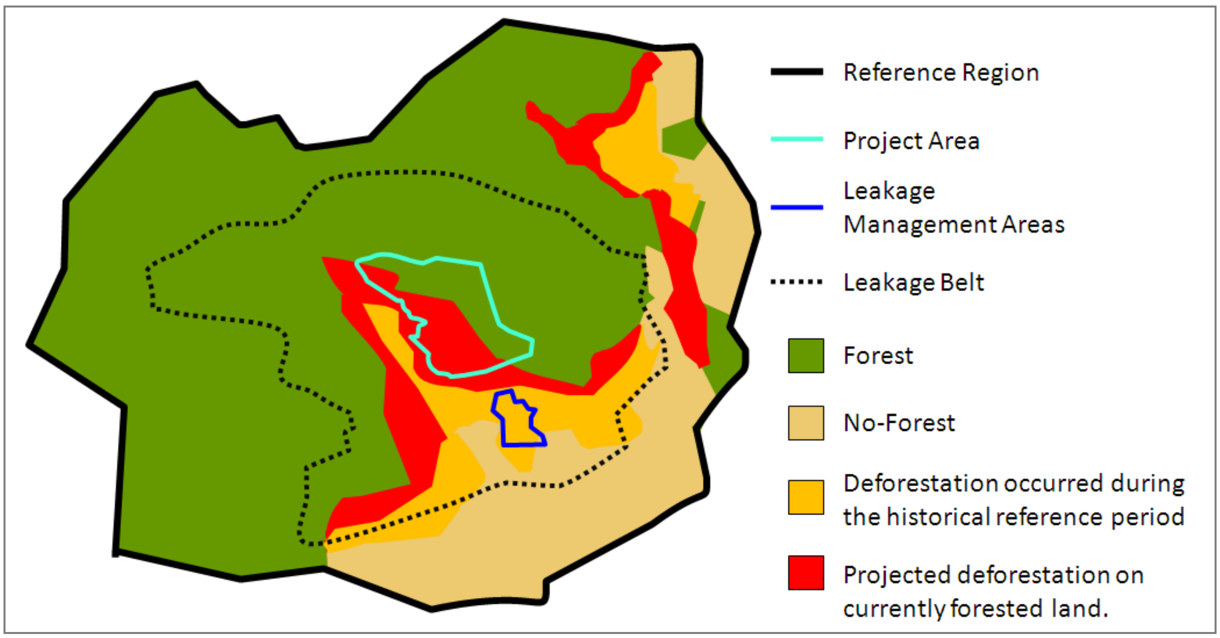
The methodology requires the use of existing deforestation baselines if these meet the applicability criteria of the methodology.

Leakage in this methodology is subject to monitoring, reporting, verification and accounting (MRV-A). However, if the project area is located within a broader sub-national or national region that is subject to MRV-A of GHG emissions from deforestation under a VCS or UNFCCC registered (and VCS endorsed) program (= "jurisdictional program"), leakage may be subject to special provisions because any change in carbon stocks or increase in GHG emissions outside the project area would be subject to MRV-A under the broader jurisdictional program. In such cases, the most recent VCS *Jurisdictional and Nested REDD+ (JNR) Requirements* shall be applied.

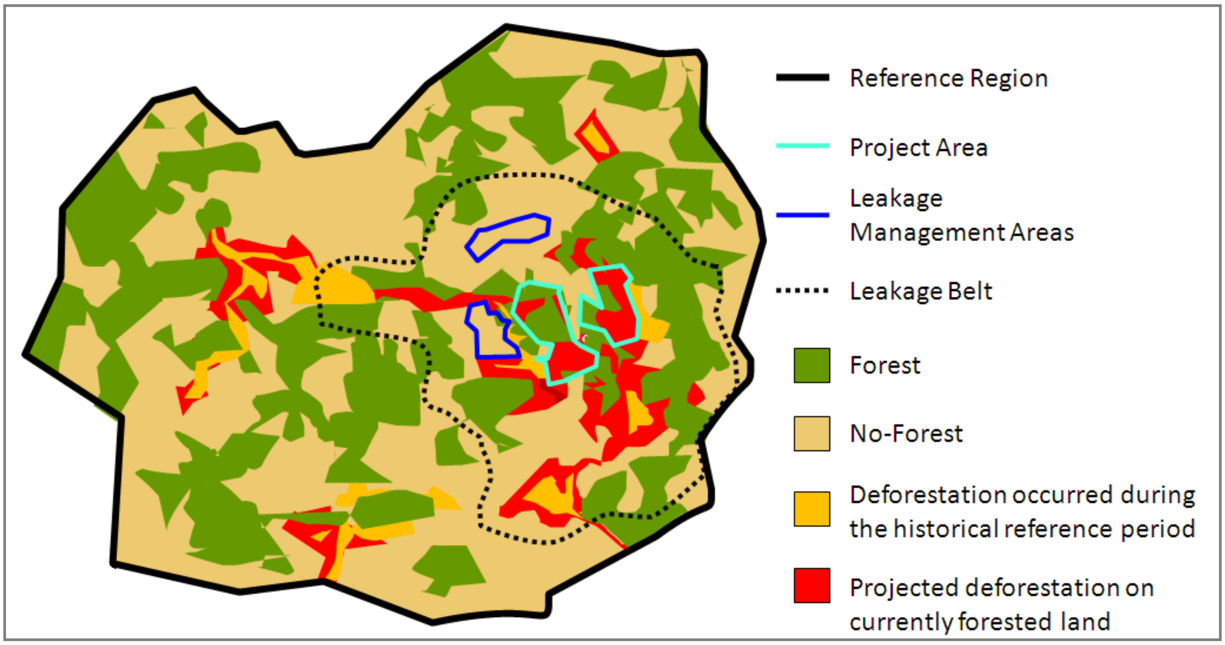
The methodology defines four spatial domains: a broad "reference region", the "project area", a "leakage belt", and a "leakage management area". The project area, leakage belt and leakage management areas are subsets of the reference region and are always spatially distinct (not overlapping) areas (see figure 1).

Figure 1. Spatial domains considered in this methodology

a) Frontier configuration



b) Mosaic configuration



- The "reference region" is the analytical domain from which information on historical deforestation is extracted and projected into the future to spatially locate the area that will be deforested in the baseline case.
- The "project area" is the area (or areas) under the control of the project participants in which the AUD project activity will be implemented and GHG emission reductions accounted.
- The "leakage belt" is the area where any deforestation above the baseline projection will be considered leakage. It must be defined only if MRV-A for leakage is required.
- The "leakage management area" is the area (or areas) specifically designed to implement activities that reduce the risk of activity displacement leakage. These are areas dedicated to enhanced crop-land and grazing land management, agro-forestry, silvo-pastoral activities and reforestation activities. At the project start date, leakage management areas shall be non-forest land.

The baseline projections must be revisited every 10 years and adjusted, as necessary, based on land-use and land-cover changes observed during the past period and changes at the level of agents, driver and underlying causes of deforestation, which are subject to monitoring. The period of time during which a validated baseline must not be reassessed is called "fixed baseline period" in this methodology. The baseline may be reassessed before the fixed 10 year baseline expires only if an applicable jurisdictional baseline becomes available.

The boundary of the leakage belt must be revisited at the end of each fixed baseline period and any time when an AFOLU project located in the project´s leakage belt area is registered under the VCS. In such case, the project area of the new AFOLU project must be excluded from the leakage belt area from the date of its registration[1]. Changes in the leakage belt boundary shall be monitored and are subject to VCS verification.

Emissions of non-CO_2 gases in the baseline are conservatively omitted, except CH_4 emissions from biomass burning, which can be counted when fire is the main technology used to deforest and when the project proponent considers that ignoring this source of emissions would substantially underestimate the baseline emissions. However, CH_4 emissions from forest fires in the project case must be accounted when they are significant.

If leakage must be estimated and accounted, then the methodology considers two potential sources of leakage:

(i) If more deforestation in the leakage belt area is observed during project implementation, this will be considered as activity displacement leakage, and the decrease in carbon stocks and increase of GHG emissions (if emissions from forest burning are included in the baseline) must be subtracted in the calculation of the project's net anthropogenic GHG emissions reductions.

(ii) If leakage prevention measures include tree planting, agricultural intensification, fertilization, fodder production and/or other measures to enhance cropland and grazing land areas in leakage management areas, then any decrease in carbon stocks and increase in GHG emissions associated with these activities is estimated and subtracted in the calculation of the project's net anthropogenic emissions reductions.

Any decrease in carbon stock or increase in GHG emissions attributed to the project activity must be accounted when it is significant, otherwise it can be neglected. Significance in this methodology is assessed using the most recent CDM-approved and VCS-endorsed version of the "Tool for testing significance of GHG emissions in A/R CDM project activities"[2].

PART 1 – SCOPE, APPLICABILITY CONDITIONS AND ADDITIONALITY

1 SCOPE OF THE METHODOLOGY

This methodology is for estimating and monitoring GHG emissions of project activities that avoid unplanned deforestation (AUD). The forest landscape configuration can be mosaic, frontier or a transition between the two. Carbon stock enhancements in forests that would be deforested in the baseline case can also be accounted under this methodology. However, credits for reducing GHG emissions from avoided degradation are excluded.

Baseline activities and project activities may include harvesting of timber, fuel-wood collection and charcoal production[3]. Project activities may include some level of planned deforestation, but planned deforestation is excluded from the baseline.

---

1 This is to avoid double counting of emissions when a new VCS AFOLU registered project and/or its leakage belt are located (partially or totally) in the leakage belt of the proposed AUD project.

2 Available at: http://cdm.unfccc.int/EB/031/eb31_repan16.pdf

3 Accounting for carbon stock decrease due to timber harvesting, fuel-wood collection and charcoal production is mandatory in both the baseline and project scenarios if the decrease is significant. The increase of carbon stocks in forests that would be deforested in absence of the project activity is optional in this methodology and can conservatively be omitted.

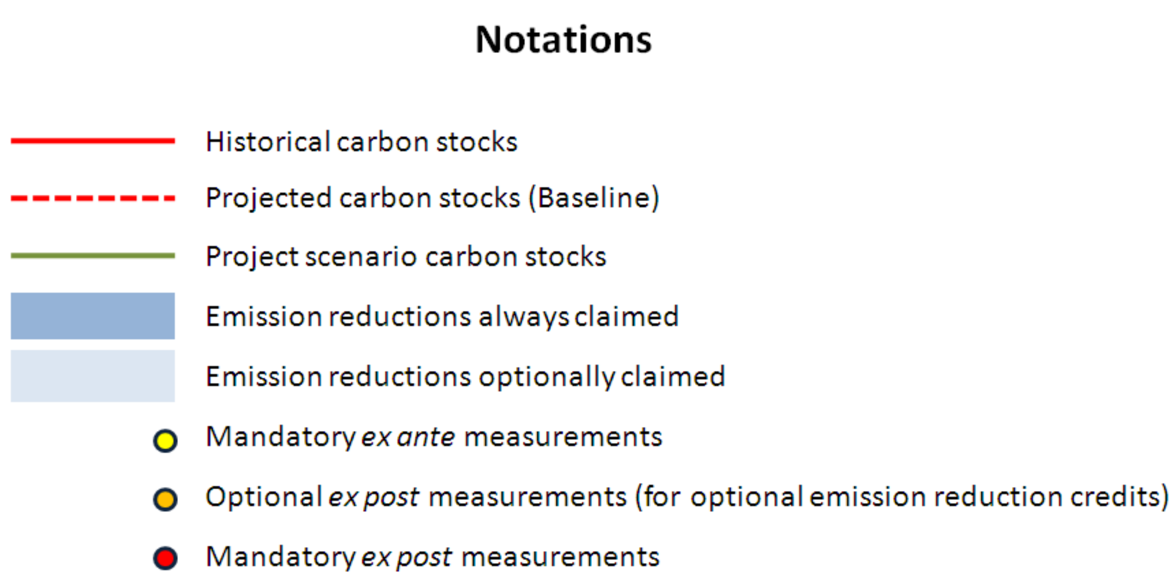
The eligible categories of project activity covered by this methodology are represented with the letters **A** to **H** in table 1 and figure 2.

Table 1. Scope of the methodology

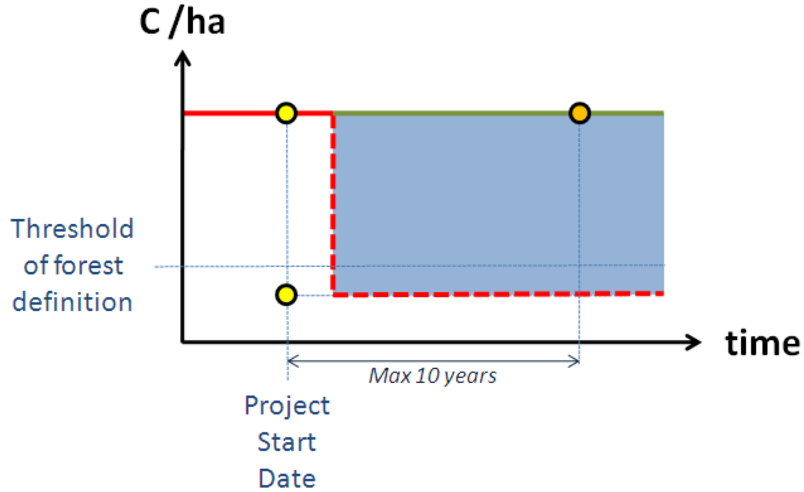
			PROJECT ACTIVITY	
			Protection without logging, fuel wood collection or charcoal production	Protection with controlled logging, fuel wood collection or charcoal production
BASELINE	Deforestation	Old-growth without logging	**A**	**B**
		Old-growth with logging	**C**[1]	**D**[1]
		Degraded and still degrading	**E**[1]	**F**[1]
		Secondary growing	**G**[1]	**H**[1]
	No-deforestation[2]	Old-growth without logging	No change	Degradation
		Old-growth with logging	IFM	IFM-RIL
		Degraded and still degrading	IFM	IFM
		Secondary growing	No change	Degradation

1. Accounting for carbon stock increase in the project scenario is optional and can conservatively be omitted.
2. If the baseline is not deforestation, the change in carbon stocks is not covered in this methodology.

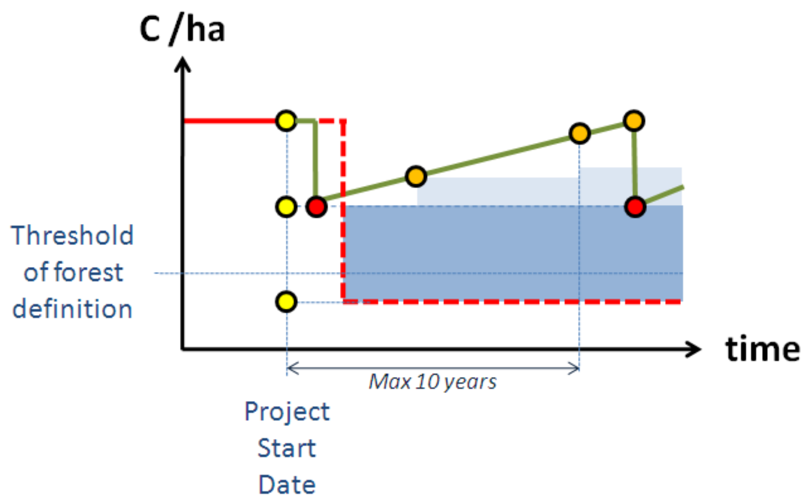
Figure 2. Categories included in the scope of this methodology



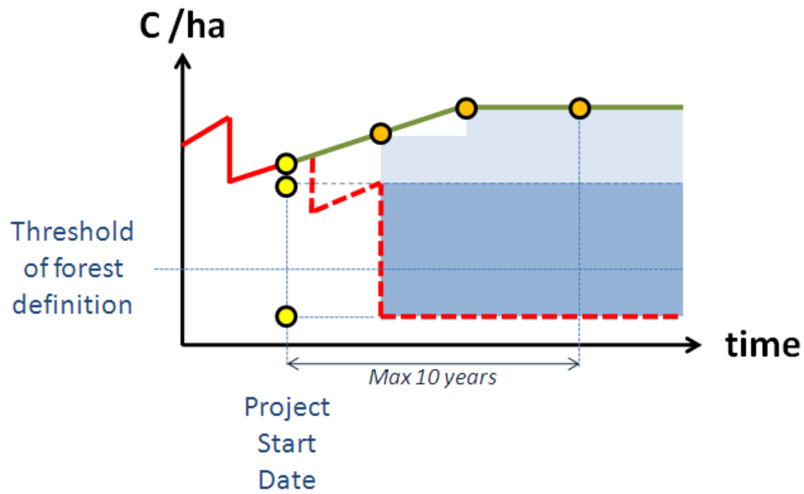
A - Avoided Deforestation without Logging



B – Avoided Deforestation with Logging in the Project Case
+ Carbon Stock Increase (optional)

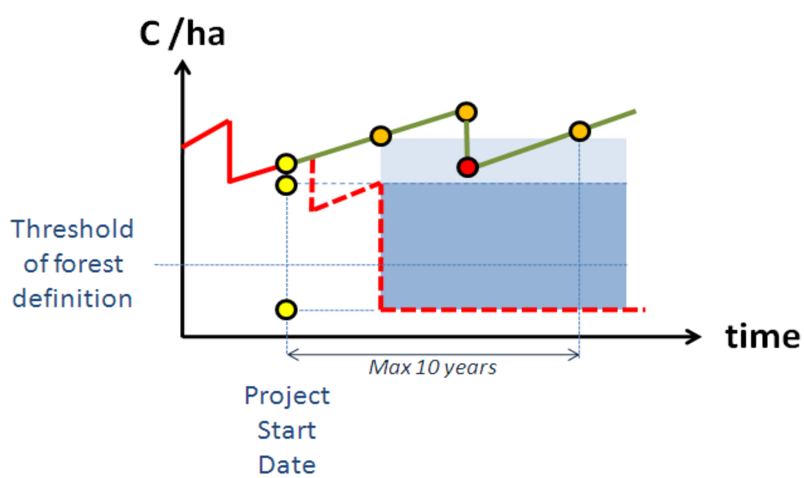


C – Avoided Deforestation with Logging Suppression
+ Carbon Stock Increase (optional)



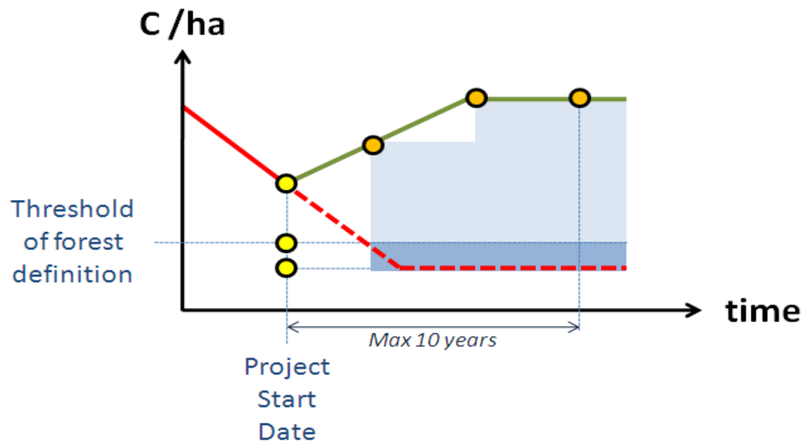
Note: Avoided degradation occurring prior to deforestation is conservatively not claimed.

D – Avoided Deforestation with Logging in the Baseline and Project Cases
+ Carbon Stock Increase (optional)



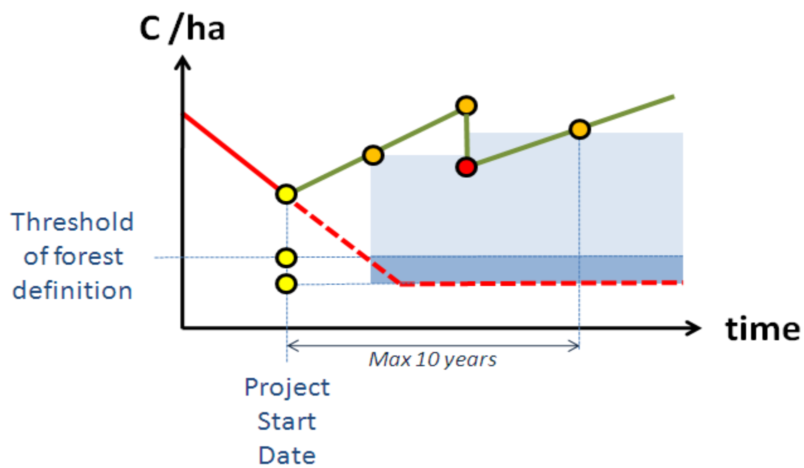
Note: Avoided degradation occurring prior to deforestation is conservatively not claimed.

E - Avoided Deforestation of Degrading Forest
+ Carbon Stock Increase (optional)



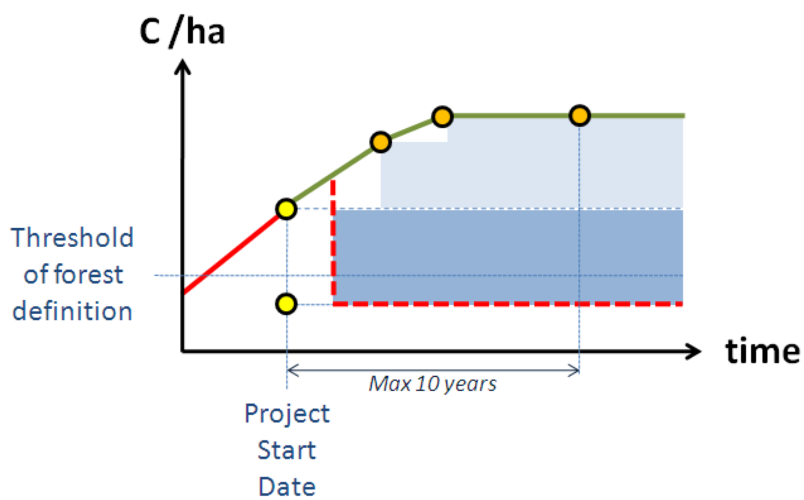
<u>Note:</u> Avoided degradation occurring prior to deforestation is conservatively not claimed.

F - Avoided Deforestation of Degrading Forest with Logging in the Project Case
+ Carbon Stock Increase (optional)

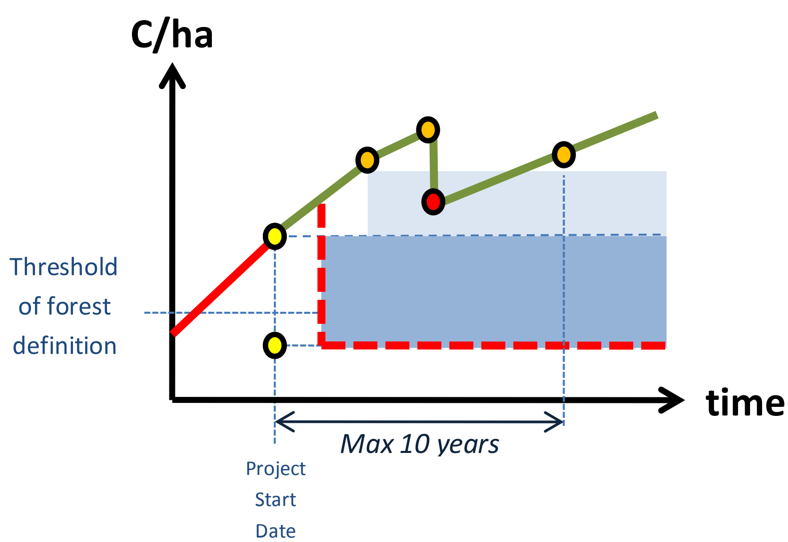


<u>Note:</u> Avoided degradation occurring prior to deforestation is conservatively not claimed.

G – Avoided Deforestation of Secondary Forest
+ Carbon Stock Increase (optional)



H – Avoided Deforestation of Secondary Forest
with Logging in the Project Case
+ Carbon Stock Increase (optional)



2 APPLICABILITY CONDITIONS

The methodology has no geographic restrictions and is applicable globally under the following conditions:

a) Baseline activities may include planned or unplanned logging for timber, fuel-wood collection, charcoal production, agricultural and grazing activities as long as the category is unplanned deforestation according to the most recent VCS AFOLU requirements.

b) Project activities may include one or a combination of the eligible categories defined in the description of the scope of the methodology (table 1 and figure 2).

c) The project area can include different types of forest, such as, but not limited to, old-growth forest, degraded forest, secondary forests, planted forests and agro-forestry systems meeting the definition of "forest".

d) At project commencement, the project area shall include only land qualifying as "forest" for a minimum of 10 years prior to the project start date.

e) The project area can include forested wetlands (such as bottomland forests, floodplain forests, mangrove forests) as long as they do not grow on peat. Peat shall be defined as organic soils with at least 65% organic matter and a minimum thickness of 50 cm. If the project area includes a forested wetlands growing on peat (e.g. peat swamp forests), this methodology is not applicable.

Demonstrate that the methodology is applicable to the proposed AUD project activity.

3 ADDITIONALITY

Additionality of the proposed AUD project activity must be demonstrated using either the most recent VCS-approved *VT0001Tool for the Demonstration and Assessment of Additionality in VCS AFOLU Project Activities*[4] noting the following:

The earliest start date of the proposed AUD project activity is January 1st, 2002. However, the start date can be earlier than January 1st, 2002, provided the requirements for projects with a start date prior to 2002, as set out in the most recent version of the VCS Standard, are met.

PART 2 - METHODOLOGY STEPS FOR EX-ANTE ESTIMATION OF GHG EMISSION REDUCTIONS

The nine methodology steps that will lead to the calculation of *ex ante* net anthropogenic GHG emission reductions are summarized in Figure 3. In the PD refer to each of these steps and sub-steps using the same titles and numbers so that the application of the methodology can transparently be validated.

---

[4] Available at www.v-c-s.org

Figure 3. *Ex ante* methodology steps

Step 1. Definition of the boundaries of the proposed AUD project activity: spatial boundaries, temporal boundaries, carbon pools and sources of greenhouse gas

↓

Step 2. Analysis of historical land-use and land-cover change in the reference region going back about 10-15 years from present.

↓

Step 3. Analysis of agents, drivers and underlying causes of deforestation, and sequencing of the typical chain of events leading to land-use and land-cover change.

↓

Step 4. Projection of the annual areas and location of deforestation in the reference region in the without project case.

↓

Step 5. Identification of forest classes in the areas that will be deforested under the baseline scenario and of post-deforestation land-use classes in the project area.

↓

Step 6. Estimation of baseline carbon stock changes and, where forest fires are included in the baseline assessment, of non-CO_2 emissions from biomass burning.

↓

Step 7. *Ex ante* estimation of actual carbon stock changes and non-CO_2 emissions under the project scenario.

↓

Step 8. *Ex ante* estimation of leakage associated to leakage prevention measures and activity displacement.

↓

Step 9. *Ex ante* calculation of net anthropogenic GHG emission reductions.

1 STEP 1: DEFINITION OF BOUNDARIES

The purpose of this step is to define the following categories of project boundaries:

1.1 Spatial boundaries;

1.2 Temporal boundaries;

1.3 Carbon pools; and

1.4 Sources of emissions of greenhouse gases (other than carbon stock changes).

1.1 Spatial boundaries

Define the boundaries of the following spatial features:

1.1.1 Reference region;

1.1.2 Project area;

1.1.3 Leakage belt;

1.1.4 Leakage management areas; and

1.1.5 Forest.

The reference region is the largest unit of land and the project area, leakage belt and leakage management areas are subsets of the reference region. For each spatial feature, the criteria used to define their boundaries must be described and justified in the PD. Vector or raster files in a common projection and GIS software formats shall be provided in order to allow the identification of the boundaries unambiguously.

1.1.1 Reference region

The boundary of the reference region is the spatial delimitation of the analytic domain from which information about rates, agents, drivers, and patterns of land-use and land-cover change (LU/LC-change) will be obtained, projected into the future and monitored.

The reference region should contain strata with agents, drivers and patterns of deforestation that in the 10-15 year period prior to the start date of the proposed AUD project activity are similar to those expected to exist within the project area.

The boundary of the reference region shall be defined as follows:

1. If sub-national or national baselines exist, that meet VCS specific guidance on applicability of existing baselines, such baselines must be used. Any pre-existing baseline should be analyzed and if it meets the criteria listed in table 2, it should be used. In both cases, the existing baseline will determine the boundary of the reference region.
2. If no such applicable sub-national or national baseline is available, the national and, where applicable, sub-national government shall be consulted to determine whether the country or sub-national region has been divided in spatial units for which deforestation baselines will be developed. If such divisions exist and are endorsed by the national or sub-national government, they must be used to determine the boundary of the reference region.
3. If such divisions do not exist, a baseline must be developed for a reference region encompassing the project area, the leakage belt and any other geographic area (stratum *i*) that is relevant to determine the baseline of the project area.
4. A geographic area is relevant for determining the baseline of the project area when agents, drivers and overall deforestation patterns observed in it during the 10-15 year period preceding the start date of the proposed AUD project activity represent a credible proxy for possible future deforestation patterns in the project area.

Table 2. Criteria determining the applicability of existing baselines

Applicability criteria	
1	The existing baseline must cover a broader geographical region than the project area. If a leakage belt must be defined[1], the broader region must include the leakage belt area.
2	The existing baseline must cover at least the duration of the first fixed baseline period and is not outdated[2].
3	The existing baseline must depict the location of future deforestation on a yearly base.
4	The spatial resolution of the existing baseline must be equal or finer than the minimum mapping unit of "forest land" that will be used for monitoring deforestation during the fixed baseline period.
5	Methods used to develop the existing baseline must be transparently documented and be consistent with a VCS approved and applicable baseline methodology.

1. If the project area is located within a jurisdictional program the most recent VCS *JNR Requirements* must be applied to determine whether a leakage belt is required. In all other cases, a leakage belt is required.
2. A baseline is considered outdated 10 years after its establishment.

The reference region may include one or several discrete areas. It must be larger[5] than the project area and include the project area.

Where the current situation within the project area is expected to change (e.g. because of population growth, infrastructure development or any other plausible reason), the reference region should be divided in *i* strata, each representing proxies for the chrono-sequence of current and future conditions within the project area. The boundary of such strata may be static (fixed during a fixed baseline period) or dynamic[6] (changing every year), depending on the modeling approaches used.

Three main criteria are relevant to demonstrate that the conditions determining the likelihood of deforestation within the project area are similar or expected to become similar to those found within the reference region

- **Agents and drivers of deforestation** expected to cause deforestation within the project area in absence of the proposed AUD project activity must exist or have existed elsewhere in the reference region. The following requirements are to be met:

---

[5] Brown *et al*. (2007) suggest the following rule of thumb:

- For projects above 100,000 ha, the reference region should be about 5-7 times larger than the project area.
- For projects below 100,000 ha, the reference region should be 20-40 times the size of the project area.

These figures are indicatives; the exact ratio between the two areas depends on the particular regional and project circumstances. Where a project activity deals with an entire island, the reference region must include other islands or forested landscapes with similar conditions.

[6] Dynamic = with shifting boundaries, according to modeled changes at the level of driver variables such as population, infrastructure and other to be determined by the project proponent.

- **Agent groups**: Deforestation agent´s groups (as identified in step 3) expected to encroach into the project area must exist or have existed and caused deforestation elsewhere in the reference region during the historical reference period.
- **Infrastructure drivers.** If new or improved infrastructure (such as roads, railroads, bridges, hydroelectric reservoirs, etc.) is expected to develop near or inside the project area[7], the reference region must include a stratum where such infrastructure was built in the past and where the impact on forest cover was similar to the one expected from the new or improved infrastructure in the project area.
- **Other spatial drivers expected to influence the project area**. Any spatial deforestation driver considered relevant according to the analysis of step 3 (e.g. resettlement programs, mining and oil concessions, etc.) must exist or have existed elsewhere in the reference region. The historical impact of such drivers must have been similar to the one expected in the project area.

- **Landscape configuration and ecological conditions:** At least three of the following four conditions must be satisfied:
  - **Forest/vegetation classes:** At least 90% of the project area must have forest classes or vegetation types that exist in at least 90% of the rest of the reference region.
  - **Elevation:** At least 90% of the project area must be within the elevation range of at least 90% of the rest of the reference region.
  - **Slope:** The average slope of at least 90% of the project area shall be within ± 10% of the average slope of at least 90% of the rest of the reference region.
  - **Rainfall:** The average annual rainfall in at least 90% of the project area shall be within ± 10% of the average annual rainfall of at least 90% of the rest of the reference region.
- **Socio-economic and cultural conditions:** The following conditions must be met:
  - **Legal status of the land**: The legal status of the land (private, forest concession, conservation concession, etc.) in the baseline case within the project area must exist elsewhere in the reference region. If the legal status of the project area is a unique case, demonstrate that legal status is not biasing the baseline of the project area (e.g. by demonstrating that access to the land by deforestation agents is similar to other areas with a different legal status).
  - **Land tenure**: The land-tenure system prevalent in the project area in the baseline case is found elsewhere in the reference region.
  - **Land use:** Current and projected classes of land-use in the project area are found elsewhere in the reference region.
  - **Enforced policies and regulations**: The project area shall be governed by the same policies, legislation and regulations that apply elsewhere in the reference region.

[7] Areas of planned deforestation in the baseline case must be excluded from the project area.

1.1.2 Project area

The project area is the area or areas of land under the control of the project proponent on which the project proponent will undertake the project activities. At the project start date, the project area must include only forest land.

Any area affected by planned deforestation due to the construction of planned infrastructure (except if such planned infrastructure is a project activity) must be excluded from the project area.

The project area must include areas projected to be deforested in the baseline case and may include some other areas that are not threatened according to the first baseline assessment (see figure 1). Such areas will not generate carbon credits, but they may be included if the project proponent considers that future baseline assessments, which have to be carried out at least every 10 years, are likely to indicate that a future deforestation threat will exist, also the demonstration is not possible at the time of validation.

Where less than 80 percent of the total proposed area of the project is under control at validation, new discrete units of land may be integrated into an existing project area if included in the monitoring report at the time of the first verification. For the full rules and requirements regarding control over the entire project area at validation, please see the most recent version of the VCS AFOLU requirements.

The boundary of the project area shall be defined unambiguously as follows:

- Name (or names, as appropriate) of the project area.
- Physical boundary of each discrete area of land included in the project area (using appropriate GIS software formats).
- Description of current land-tenure and ownership, including any legal arrangement related to land ownership and the AUD project activity.
- List of the project participants and brief description of their roles in the proposed AUD project activity.

1.1.3 Leakage belt

If the project area is located within a jurisdictional program, leakage may not have be assessed and a leakage belt may not be required because any decrease in carbon stocks or increase in GHG emissions outside the project area would be measured, reported, verified and accounted under the jurisdictional program[8]. In such cases, the most recent VCS *JNR Requirements* shall be applied. In all other cases, leakage is subject to MRV-A in an area called "leakage belt" in this methodology.

The leakage belt is the land area or land areas surrounding or adjacent to the project area in which baseline activities could be displaced due to the project activities implemented in the project area.

To define the boundary of the leakage belt, two methodological options can be used:

- Opportunity cost analysis (Option I); and
- Mobility analysis (Option II).

Under both options, the boundary of the leakage belt must be revisited at the end of each fixed baseline period, as opportunity costs and mobility parameters are likely to change over time. In addition, the

8 In such cases, the sub-national or national government may define specific sub-national or national policies and regulations to deal with the issue of leakage.

boundary of the leakage belt may have to be revisited when other VCS-AFOLU projects are registered nearby the project area, as further explained below.

If mobility parameters or opportunity costs are projected for each future year, the boundary of the leakage belt that will remain static for the whole duration of the fixed baseline period shall be the one determined for the last year of the fixed baseline period.

Option I: Opportunity cost analysis

This option is applicable where economic profit is an important driver of deforestation. To demonstrate that Option I is applicable, use historical records, i.e. demonstrate that at least 80% of the area deforested in the reference region (or some of its strata) during the historical reference period[9] has occurred at locations where deforesting was profitable (i.e. for at least one product, $PPx_l \geq 1$). Alternatively, use literature studies, surveys and other credible and verifiable sources of information. If Option I is not applicable, use Option 2.

If the main motivation is economic profit, agents not allowed to deforest within the project area will only displace deforestation outside the project area if doing so brings economic benefits to them. Based on this rationale leakage can only occur on land outside the project area where the total cost of establishing and growing crops or cattle and transporting the products to the market is less than the price of the products (i.e. opportunity costs are > 0).To identify this land area do the following:

a) List the main land-uses that deforestation agents are likely to implement within the project area in the baseline case, such as cattle ranching and/or different types of crops.

b) Find credible and verifiable sources of information on the following variables:

- *S$x* = Average selling price per ton of the main product *Px* (or product mixture in case of agro-forestry or mixed production systems) that would be established in the project area in the baseline case (meat, crop type A, crop type B, etc.);
- SPx_l = Most important selling points (spatial locations) for each main product *Px* in the reference region.
- PCx_i = Average *in situ* production costs per ton of product. Stratify the reference region as necessary in *i* strata, as production costs may vary depending on local conditions (soil, technology available to the producer, etc.).
- TC_v = Average transport cost per kilometer for one ton of product *Px* transported on different types of land-uses (e.g. pasture, cropland, forest), roads, railroads, navigable rivers, etc. using the most typical transport technology available to the producer.

Note: For simplicity, current prices and costs can be used to project opportunity costs. Price and cost projections shall only be used if reliable and verifiable sources of information are available.

c) Using a GIS, generate for each main product a surface representing the least transport cost of one ton of product to the most important selling points within the reference region. Do this by considering the most typical transport technology available to deforestation agents.

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9 See section 1.2.1 for the definition of "historical reference period."

d) For each main product, add to the surface created in the previous step the average *in situ* cost for producing one ton of product. The result is a surface representing the total cost of producing and bringing to the market one ton of product.

e) For each main product, subtract from the average price of one ton of product the total cost surface created in the previous step. The result is a surface representing potential profitability of each product.

<u>Note:</u> If several products exist and can be produced on the same site, the maximum value of all potential profitability surfaces will represent the opportunity cost of conserving the forest.

f) The leakage belt is the area where the surface created in the previous step (potential profitability) has a positive value at the last year of the fixed baseline period.

The above methodology procedure can be summarized as follows:

A land unit (pixel or polygon *l*) is inside the leakage belt if the potential profitability of at least one product (PPx_l) is positive, where PPx_l is calculated as follows:

$$PPx_l = S\$x - PCx_i - \sum_{v=1}^{V}(TDv * TCv) \qquad (1)$$

Where:

PPx_l	Potential profitability of product *Px* at location *l* (pixel or polygon); $/t
S$x	Selling price of product *Px*; $/t
PCx_i	Average *in situ* production costs for one ton of product *Px* in stratum *i*; $/t
TCv	Average transport cost per kilometer for one ton of product *Px* on land, river or road of type *v*; $/t/km
TDv	Transport distance on land, river or road of type *v*; km
v	1, 2, 3 *…V,* type of surface to on which transport occurs; dimensionless

<u>Note:</u> Option I is based on the assumption that deforestation agents in the project area will not displace their activities beyond the reference region, where other forested areas with potentially positive opportunity costs may exist. Demonstrate that this assumption is credible using expert opinion, participative rural appraisal (PRA), literature and/or other verifiable sources of information. If the evidence collected is not convincing, use Option II (mobility analysis).

Option II: Mobility analysis

Mobility analysis can always be used but must be used where Option I is not applicable, i.e. when less than 80% of the area deforested in the reference region (or some of its strata) during the historical reference period has occurred at locations where deforesting was profitable. With this option, the potential mobility of deforestation agents is assessed using multi-criteria analysis. The following methodology steps shall be applied:

a) Using historical data, expert opinion, participative rural appraisal (PRA), literature and/or other verifiable sources of information list all relevant criteria that facilitate (at least one criterion) and constrain (at least one criterion) the mobility of the main deforestation agents identified in step 3. The overall suitability of the land for the activities of deforestation agents shall be considered.

b) For each criterion, generate a map using a GIS.

c) Using multi-criteria analysis, determine the boundary of the leakage belt. Justify any assumption and weight assigned to the individual criteria.

d) Methods used to perform the analysis shall be transparently documented and presented to VCS verifiers at the validation.

Consideration of other VCS AFOLU projects

If the leakage belt area of the proposed AUD project includes the area or part of the areas of other VCS AFOLU projects, do the following to avoid double counting of emissions:

- Exclude from the leakage belt area of the proposed AUD project the project area of the other VCS AFOLU project(s).
  a) The exclusion shall enter into force at the registration date of the other project
  b) Carbon accounting shall consider the exclusion of the project area of the other project beginning with the start date of the other projects
  c) An excluded area shall again be included in the leakage belt area of the proposed AUD project at the time the other project has not verified its emission reductions for more than five consecutive years, or when it ends its project crediting period under the VCS.
- If the leakage belt overlaps with the leakage belt of other VCS AFOLU projects, do the following:
  a) Identify the carbon pools and sources of GHG emissions that are monitored by the other projects. Only for common carbon pools and sources of GHG emissions the boundary of the leakage belt area can be modified as further explained below.
  b) Analyze the overlapping area(s) with the proponents of each of the other VCS AFOLU projects and come to an agreement with them on the location of the boundaries of the different leakage belts, so that there will be no overlaps and gaps between the different leakage belt areas as well as carbon pools and GHG sources.
  c) As an indicative rule, the percentage of forest land area within the leakage belt of a project relative to the total forest area of all leakage belts shall be similar to the percentage of baseline deforestation of the project relative to the total baseline deforestation of all projects:

$$\%LKBA = BLDA / (BLDA + BLDB + \ldots + BLDN) \quad (2.a)$$

$$\%LKBB = BLDB / (BLDA + BLDB + \ldots + BLDN) \quad (2.b)$$

…

$$\%LKBN = BLDN / (BLDA + BLDB + \ldots + BLDN) \quad (2.n)$$

Where:

%LKBA Percentage of the overlapping leakage belts area to be assigned to Project A; %

%LKBB Percentage of the overlapping leakage belts area to be assigned to Project B; %

%LKBN Percentage of the overlapping leakage belts area to be assigned to Project N; %

BLDA Total area of projected baseline deforestation during the fixed baseline period of Project A (see PD of project A); ha

BLDB Total area of projected baseline deforestation during the fixed baseline period of Project B (see PD of project B); ha

BLDN Total area of projected baseline deforestation during the fixed baseline period of Project N (see PD of Project N); ha

Note: The proponents of the different projects shall agree on the criteria used to define the boundaries of their leakage belts in the overlapping areas and are not required to use the above rule. However, if they decide to use this rule, the area of the overlapping leakage belts assigned to Project A shall be the closest to the boundary of Project A; the area of the overlapping leakage belts assigned to Project B shall be the closest to the boundary of Project B and so on (the area of the overlapping leakage belts assigned to Project N shall be the closest to the boundary of Project N).

d) The final boundary of the leakage belt of each project is subject to validation and periodical verification. A project may report a smaller leakage belt only if another VCS registered project has included in its leakage belt the portion left out.

e) If the proponents of the different projects do not agree on how to split the overlapping leakage belt area, each project will have to include in its leakage belt the overlapping areas.

f) A "Leakage Belt Agreement" between the proponents of the different projects must be signed and presented to VCS verifiers at the time of validation/verification. The agreement shall contain the maps of the agreed leakage belts and each project shall have a digital copy of these maps in the projection and GIS software formats used in each project.

g) If a project ends or has not presented a verification to the VCS for more than five consecutive years, the other projects participating in the "leakage belt agreement" shall amend the agreement in order to ensure that the whole area of the originally overlapping leakage belts is always subject to MRV-A. The amendment is subject to VCS verification. If no amendment is made, the proposed project will have to include in its leakage belt the land area that is no longer be subject to MRV-A by a another VCS project.

1.1.4 Leakage management areas

These are non-forest areas located outside the project boundary in which the project proponent intends to implement activities that will reduce the risk of activity displacement leakage, such as afforestation, reforestation or enhanced crop and grazing land management. The boundary of such areas must be defined according to existing management plans or other plans related to the proposed AUD project activity. Such plans shall be made available to the VCS Validation/Verification Body (VVB) at the time of validation. The boundary of leakage management areas must be clearly defined using the common projection and GIS software formats used in the project and shall be reassessed and validated at each fixed baseline period

1.1.5 Forest

The boundary of the forest is dynamic and will change over time. It must be defined using an explicit and consistent forest definition over different time periods.

In the baseline case, changes in the boundary of forest land will be projected, and the baseline projections must be reassessed at least every 10 years. In the project area and leakage belt, the *ex post* boundary of forest land will be subject to periodical monitoring, verification and reporting (MRV).

To define the boundary of the forest, specify:

- The definition of forest that will be used for measuring deforestation during the project crediting period (see appendix 1 for criteria to define "forest").
- The Minimum Mapping Unit (MMU). The MMU size of the LULC maps created using RS impagery shall not be more than one hectare irrespective of forest definition.

An initial Forest Cover Benchmark Map is required to report only gross deforestation going forward. It should depict the locations where forest land exists at the project start date. The baseline projections in step 4.2 will generate one such map for each future year of the fixed baseline period and, optionally, project crediting period.

Areas covered by clouds or shadows should be analyzed by complementing the analysis of optical sensor data with non-optical sensor data. However, if some obscured areas remain for which no spatially explicit and verifiable information on forest cover can be found or collected (using ground-based or other methods), such areas shall be excluded (masked out). This exclusion would be:

- **Permanent**, unless it can reasonably be assumed that these areas are covered by forests (e.g. due to their location).
- **Temporal** in case information was available for the historical reference period, but not for a specific monitoring period. In this case, the area with no information must be excluded from the calculation of net anthropogenic GHG emission reductions of the current monitoring period, but not for subsequent periods, when information may become available again. When information becomes available again, and the land appears with vegetation parameters below the thresholds for defining "forest", the land should be considered as "deforested".

1.2 Temporal boundaries

Define the temporal boundaries listed below.

1.2.1 Starting date and end date of the historical reference period

The starting date should not be more than 10-15 years in the past and the end date as close as possible to the project start date. The project start date is the date at which the additional AUD project activities have or are to be started.

1.2.2 Starting date of the project crediting period of the AUD project activity

The length of the project crediting period shall be established as set out on the most recent version of the VCS Standard.

1.2.3 Starting date and end date of the first fixed baseline period

The fixed baseline period shall be 10 years. The starting and end dates must be defined.

1.2.4 Monitoring period

The minimum duration of a monitoring period is one year and the maximum duration is one fixed baseline period.

1.3 Carbon pools

The six carbon pools listed in table 3 are considered in this methodology.

Table 3. Carbon pools included or excluded within the boundary of the proposed AUD project activity

Carbon pools	Included / TBD[1]/ Excluded	Justification / Explanation of choice
Above-ground	Tree: Included	Carbon stock change in this pool is always significant
	Non-tree: TBD	Must be included in categories with final land cover of perennial crop
Below-ground+	TBD	Optional and recommended but not mandatory
Dead wood+	TBD	Recommended only when significant
Harvested wood products+	Included	To be included when significant
Litter	TBD	Recommended only when significant.
Soil organic carbon+	TBD	Recommended when forests are converted to cropland. Not to be measured in conversions to pasture grasses and perennial crop according to VCS Program Update of May 24th, 2010.

1. TBD = To Be Decided by the project proponent. The pool can be excluded only when its exclusion does not lead to a significant over-estimation of the net anthropogenic GHG emission reductions of the AUD project activity.
2. The VCS defines as "significant" those carbon pools and sources that account more than 5% of the total GHG benefits generated (VCS 2007.1, 2008 p.17). To determine significance, the most recent version of the "Tool for testing significance of GHG emissions in A/R CDM project activities" shall be used[10].
3. + = The VCS *AFOLU Requirements* require methodologies to consider the decay of carbon in soil carbon, belowground biomass, dead wood and harvested wood products. Note that the immediate release of carbon from these pools in the baseline case must not be assumed.

- Carbon pools that are expected to decrease their carbon stocks in the project scenario compared to the baseline case must be included if the exclusion would lead to a significant overestimation of the net anthropogenic GHG emission reductions generated during the fixed baseline period.

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[10] Available at: http://cdm.unfccc.int/EB/031/eb31_repan16.pdf

- Carbon pools considered insignificant according to the latest VCS AFOLU requirements can always be neglected.
- Above-ground biomass of trees must always be selected because it is in this pool that the greatest carbon stock change will occur.
- Non-tree biomass must be included if the carbon stock in this pool is likely to be relatively large in the baseline compared to the project scenario such as when short-rotation woody corps are commonly planted in the region where the project area is located. The significance criterion shall apply.
- Below-ground biomass of trees is recommended, as it usually represents between 15% and 30% of the above-ground biomass.
- Harvested wood products must be included if removal of timber is associated with significantly more carbon stored in long-term wood products in the baseline case compared to the project scenario. The significance criterion shall apply. When included, short-lived fraction (decaying in less than 3 years) is assumed to decay inmidiatly at the year of deforestation ($t = t^*$), the medium-lived fraction (decaying in 3-100 years) is assumed to decay in a 20-year period and the long-term fraction is assumed to never decay (*i.e.* it never results in an emission). Thus, it is conservative to assume that 100% of the carbon stock in wood products is long-lived.
- In most cases the exclusion of a carbon pool will be conservative, except when the carbon stock in the pool is higher in the baseline compared to the project scenario.
- The inclusion of a carbon pool is recommended (but not mandatory) where the pool is likely to represent an important proportion (> 10%) of the total carbon stock change attributable to the project activity (“expected magnitude of change”).
- For excluded pools, briefly explain why the exclusion is conservative.
- When the exclusion of a carbon pool is not conservative, demonstrate that the exclusion will not lead to a significant overestimation of the net anthropogenic GHG emission reduction. If the exclusion is significant, the pool must be included.
- Carbon pools that are excluded or not significant according to the *ex ante* assessment do not need to be monitored *ex post*.
- In most cases the same carbon pools shall be considered for all categories of LU/LC change. However, including different carbon pools for different categories of LU/LC change is allowed depending on “significance”, “conservativeness” and “expected magnitude of change”. For instance, harvested wood products may only be considered in the categories where this pool exists.
- The final selection of carbon pools per category is done in step 2.3. Within a category of LU/LC-change, the same carbon pools must be selected for the two classes involved. Table 1 in appendix 2 provides an indication of the level of priority for including different carbon pools depending on the category of LU/LC change.
- If a pool is conservatively excluded at validation, project proponent cannot in subsequent monitoring and verification periods decide to measure, report and verify the excluded carbon pool. However, the reverse is possible i.e., if a pool is included at validation, it may be conservatively excluded in subsequent monitoring and verification periods provided all methodology requirements are applied to carry out the estimations and these are independently verified. Further guidance on the selection of

carbon pools can be found in the most recent version of the GOFC-GOLD sourcebook for REDD[11] and further details are given in appendix 3.

1.4 Sources of GHG emissions

The two sources of GHG emissions listed in table 4 are considered in this methodology.

Table 4. Sources and GHG included or excluded within the boundary of the proposed AUD project activity

Sources	Gas	Included/TBD[1]/ excluded	Justification / Explanation of choice
Biomass burning	CO_2	Excluded	Counted as carbon stock change
	CH_4	TBD	See guidance below
	N_2O	Excluded	Considered insignificant according to VCS Program Update of May 24th, 2010
Livestock emissions	CO_2	Excluded	Not a significant source
	CH_4	TBD	See guidance below
	N_2O	TBD	See guidance below

1. TBD = To Be Decided by the project proponent. The source can be excluded only when its exclusion does not lead to a significant over-estimation of the net anthropogenic GHE emission reductions of the AUD project activity.
2. The VCS defines as "significant" those carbon pools and sources that account more than 5% of the total GHG benefits generated (VCS 2007.1, 2008 p.17). To determine significance, the most recent version of the "Tool for testing significance of GHG emissions in A/R CDM project activities" shall be used[12].

- Sources of emissions that are expected to increase in the project scenario compared to the baseline case must be included if the exclusion would lead to a significant overestimation of the total net anthropogenic GHG emission reductions generated during the fixed baseline period.
- Sources considered insignificant according to the latest VCS AFOLU requirements can always be neglected.
- The inclusion of a source is recommended (but not mandatory) where the source is likely to represent an important proportion (> 10%) of the total emissions reductions attributable to the project activity ("expected magnitude of change").
- The exclusion of a source is allowed only if the omission is conservative or the source is insignificant.
- Sources of GHG emissions that are not significant according to the *ex ante* assessment do not need not to be monitored *ex post*.

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[11] GOFC-GOLD, 2012. A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gains and losses of carbon stocks in forests remaining forests and forestation. Available at: http://www.gofc-gold.uni-jena.de/redd/

[12] Available at: http://cdm.unfccc.int

- For excluded sources, briefly explain why the exclusion is conservative.
- In the baseline scenario: Non-CO_2 emissions from fires used to clear forests can be counted when sufficient data are available to estimate them. However, accounting for these emissions can conservatively be omitted. GHG emissions from land-uses implemented on deforested lands (including from biomass burning) are conservatively omitted in this methodology.
- In the project scenario: It is reasonable to assume that the project activity, including when harvest activities are planned (such as logging for timber, fuel-wood collection and charcoal production), produces less emissions of GHG than the baseline activities implemented prior and after deforestation on the deforested lands. Therefore, the omission of certain sources of GHG emissions, such as the consumption of fossil fuels, will not cause an overestimation of the net anthropogenic GHG emission reductions. However, non-CO_2 emissions from forest fires must be counted in the project scenario when they are significant.
- In the estimation of leakage: GHG emissions by sources that are attributable to leakage prevention measures (e.g. those implemented in leakage management areas) and that are increased compared to pre-existing GHG emissions count as leakage and should be estimated and counted if they are significant. Non-CO_2 emissions from displaced baseline activities, which are conservatively omitted in the baseline, can be ignored, as in the worst case scenario they would be similar to baseline emissions. However, if non-CO_2 emissions from forest fires used to clear forests are counted in the baseline, they must also be counted in the estimation of activity displacement leakage.

2 STEP 2: ANALYSIS OF HISTORICAL LAND-USE AND LAND-COVER CHANGE

The goal of this step is to collect and analyze spatial data in order to identify current land-use and land-cover conditions and to analyze LU/LC change during the historical reference period within the reference region and project area. The tasks to be accomplished are the following:

2.1 Collection of appropriate data sources;

2.2 Definition of classes of land-use and land-cover;

2.3 Definition of categories of land-use and land-cover change;

2.4 Analysis of historical land-use and land-cover change;

2.5 Map accuracy assessment; and

2.6 Preparation of a methodology annex to the PD.

2.1 Collection of appropriate data sources

Collect the data that will be used to analyze land-use and land-cover change during the historical reference period within the reference region and project area. It is good practice to do this for at least three time points, about 3-5 years apart. For areas covered by intact forests, it is sufficient to collect data for one single date, which must be as closest as possible to the project start date ($\leq$ 2 years).

As a minimum requirement:

- Collect medium resolution spatial data[13] (from 10m x 10m up to a maximum of 100m x 100m resolution) from optical and non-optical sensor systems, such as (but not limited to) Landsat[14], SPOT, ALOS, AVNIR2, ASTER, IRS sensor data) covering the past 10-15 years.
- Collect high resolution data from remote sensors (< 5 x 5 m pixels) and/or from direct field observations for ground-truth validation of the posterior analysis. Describe the type of data, coordinates and the sampling design used to collect them.
- In tabular format (table 5), provide the following information about the data collected:

Table 5. Data used for historical LU/LC change analysis

Vector (Satellite or airplane)	Sensor	Resolution		Coverage	Acquisition date	Scene or point identifier	
		Spatial	Spectral	(km^2)	(DD/MM/YY)	Path / Latitude	Row / Longitude

Where already interpreted data of adequate spatial and temporal resolution are available, with some caution[15] these can also be considered for posterior analysis.

2.2 Definition of classes of land-use and land-cover

Identify and describe the land-use and land-cover (LU/LC) classes present in the reference region at the project start date. A LU/LC class is a unique combination of land-use and land-cover for which:

a) The boundary can be defined at hand of remotely sensed data and/or other sources of information, such as maps of vegetation, soil, elevation, management category, etc., as defined by the project proponent to unambiguously define a LU/LC class; and

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13 Guidance on the selection of data sources (such as remotely sensed data) can be found in chapter 3A.2.4 of the IPCC 2006 GL AFOLU and in the latest version of the GOFC-GOLD sourcebook on REDD.

14 On May 31, 2003, the scan-line-corrector (SLC) aboard Landsat 7 failed, producing horizontal zero-filled wedges in 22% of scenes from that point on. The nadir portion of full scene images is usually intact, though both east and west of nadir gaps extend to the scene edges. Gap-filling functions have been created, but algorithmic mechanisms that blur, average, or otherwise change spatial relationships between pixels spanning these gaps to existing pixels in the scene being filled are unsatisfactory from the perspective of the spatial modeling needs of REDD. Instead, users should fill in these gaps post-processing with spatially and spectrally satisfactory classifications from other sources (such as other complimentary optical and radar platforms).

15 Existing maps should be used with caution because they often do not report documentation, error estimates, whether they were of the site or region in question or extracted from a national map, or whether they were obtained by change detection techniques rather than by static map comparison, etc. If data about historical LU/LC and/or LU/LC-change is already available, information about the minimum mapping unit, the methods used to produce these data, and descriptions of the LU/LC classes and/or LU/LC-change categories must be compiled, including on how these classes may match with IPCC classes and categories.

b) Carbon stocks per hectare (tCO_2-e ha^{-1})[16] within each class are about homogeneous across the landscape. Carbon stocks must only be estimated for classes inside the project area, leakage belt and leakage management areas, which will be done in step 6.

The following criteria shall be used to define the LU/LC classes:

- The minimum classes shall be "Forest Land" and "Non-Forest Land".
- "Forest-land" will in most cases include strata with different carbon stocks. Forest-land must therefore be further stratified in forest classes having different average carbon densities within each class.
- "Non-Forest Land" may be further stratified in strata representing different non-forest classes. IPCC classes used for national GHG inventories may be used to define such classes (Crop Land, Grass Land, Wetlands, Settlements, and Other Land). See IPCC 2006 GL AFOLU Chapter 3, Section 3.2, p. 3.5 for a description of these classes. However, where appropriate to increase the accuracy of carbon stock estimates, additional or different sub-classes may be defined.
- The description of a LU/LC class must include criteria and thresholds that are relevant for the discrimination of that class from all other classes. Select criteria and thresholds allowing a transparent definition of the boundaries of the LU/LC polygons of each class. Such criteria may include spectral definitions as well as other criteria used in post-processing of image data, such as elevation above sea level, aspect, soil type, distance to roads[17] and existing vegetation maps. Where needed, in the column "description" of table 6 refer to more detailed descriptions in the methodological annex to be prepared in step 2.6.
- For all forest classes present in the project area, specify whether logging for timber, fuel wood collection or charcoal production are happening in the baseline case. If different combinations of classes and baseline activities are present in the project area, define different classes for each combination, even if carbon stocks are similar at the project start date.
- If a forest class has predictably growing carbon stocks (i.e. the class is a secondary forest) and the class is located both in the project area and leakage belt, two different classes must be defined (see step 6.1 for explanations).
- In most cases one single Land-Use and Land-Cover Map representing the spatial distribution of forest classes at the project start date will be sufficient. However, where certain areas of land are expected to undergo significant changes in carbon stock due to growth or degradation in the baseline case, a sequence of Land-Use and Land-Cover Maps representing the mosaic of forest-classes of each future year may be generated.

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16 The carbon stock per hectare is sometimes referred to as "carbon density" in the literature.

17 Some classes may be defined using indirect criteria (e.g. "Intact old-growth forest" = Forest at more than 500 m from the nearest road; "Degraded forest" = Forest within 500 m from the nearest road. In this example, the assumption is made that logging activities usually do not occur, or are of very low intensity, when the trees are at more than 500 m from the nearest road). The use of indirect criteria shall be briefly justified in the PD at hand of verifiable information, such as independent studies, literature, etc. Using a definition of "degraded forest" as in this example, the boundary of the polygon class "degraded forest" would be a function of how the road network develops over time, which implies that such development will have to be monitored.

- The generation of such a sequence of maps is mandatory only for areas within the project boundary that are undergoing degradation in the baseline case, i.e. categories C, D, E and/or F are present in the project area (see table 1 and figure 2).
- Any assumption on changing carbon stocks in the baseline case must be documented at hand of credible and verifiable sources of information, such as measurements in plots representing a chrono-sequence, published literature, and other sources, as appropriate.
- List the resulting final LU/LC-classes in table 6.

Table 6. List of all land use and land cover classes existing at the project start date within the reference region

Class Identifier		Trend in Carbon stock[1]	Presence in[2]	Baseline activity[3]			Description (including criteria for unambiguous boundary definition)
ID_{cl}	Name			LG	FW	CP	
1							
2							
…							
Cl							

1. Note if “decreasing”, “constant”, “increasing”
2. RR = Reference region, LK = Leakage belt, LM = Leakage management Areas, PA = Project area
3. LG = Logging, FW = Fuel-wood collection; CP = Charcoal Production (yes/no)
4. Each class shall have a unique identifier (ID_{cl}). The methodology sometimes uses the notation *icl* (= 1, 2, 3, … *Icl*) to indicate “initial” (pre-deforestation) classes, which are all forest classes; and *fcl* (= 1, 2, 3, … *Fcl*) to indicate final” (post-deforestation) classes. In this table all classes (“initial” and “final”) shall be listed.

2.3 Definition of categories of land-use and land-cover change

Identify all LU/LC-change categories that could occur within the project area and leakage belt during the project crediting period in both, the baseline and project case. This can be done by analyzing a land-use change matrix that combines all LU/LC-classes previously defined.

List the resulting LU/LC-change categories in table 7.a and 7.b:

Table 7.a. Potential land-use and land-cover change matrix

		Initial LU/LC class			
	ID_{cl}	*I1*	*I2*	*I…*	*In*
Final LU/LC class	*F1*	I1/F1	I2/F1	I…/F1	In/F1
	F2	I1/F2	I2/F2	I…/F2	In/F2
	F…	I1/F…	I2/F…	I…/F3	In/F…
	Fn	I1/Fn	I2/Fn	I…/Fn	In/Fn

Table 7.b. List of land-use and land-cover change categories

ID_{ct}	Name	Trend in Carbon stock	Presence in	Activity in the baseline case			Name	Trend in Carbon stock	Presence in	Activity in the project case		
				LG	FW	CP				LG	FW	CP
I1/F1												
I1/F2												
I1/F…												
I2/F1												
I2/F2												
I2/F…												
I…/F1												
I…/F2												
I…/F…												

2.4 Analysis of historical land-use and land-cover change

Using the data collected in step 2.1, divide the reference region in polygons[18] representing the LU/LC-classes and LU/LC-change categories defined in steps 2.2 and 2.3. In the case of the project area, LU/LC-change analysis is required to exclude any area with forests that are less than 10 years old at the project start date.

Use existing LU/LC or LU/LC-change maps if the classes and categories are well described in these maps, so that they can be used for completing steps 2.2 and 2.3.

Where processed data of good quality are not available, unprocessed remotely sensed data must be analyzed to produce LU/LC maps and LU/LC-change maps. Given the heterogeneity of methods, data sources and image processing software, LU/LC-change detection should be performed by trained interpreters.

Typically, the analysis of LU/LC-change involves performing the following three tasks:

2.4.1 Pre-processing;

2.4.2 Interpretation and classification; and

2.4.3 Post-processing.

2.4.1 Pre-processing

Pre-processing typically includes:

a) Geometric corrections to ensure that images in a time series overlay properly to each other and to other GIS maps used in the analysis (i.e. for post-classification stratification). The average location error between two images should be < 1 pixel.

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18 Raster or grid data formats are allowed.

b) Cloud and shadow removal using additional sources of data (e.g. radar, aerial photographs, field-surveys).

c) Radiometric corrections may be necessary (depending on the change-detection technique used) to ensure that similar objects have the same spectral response in multi-temporal datasets.

d) Reduction of haze, as needed.

See the most recent version of the GOFC-GOLD sourcebook for REDD or consult experts and literature for further guidance on pre-processing techniques.

Duly record all pre-processing steps for later reporting.

2.4.2 Interpretation and classification

Two main categories of change detection exist and can be used (see IPCC 2006 GL AFOLU, Chapter 3A.2.4):

(1) Post-classification change detection: Two LU/LC maps are generated for two different time points and then compared to detect LU/LC changes. The techniques are straightforward but are also sensitive to inconsistencies in interpretation and classification of the LU/LC classes.

(2) Pre-classification change detection: These are more sophisticated approaches to LU/LC-change detection. They also require more pre-processing of the data (i.e. radiometric corrections). The basic approach is to compare by statistical methods the spectral response of the ground using two data sets acquired at different dates to detect the locations where a change has occurred and then to allocate different patterns of spectral change to specific LU/LC-change categories. This approach is less sensitive to interpretation inconsistencies but the methods involved are less straightforward and require access to the original unclassified remotely sensed data.

As several methods are available to derive LU/LC and LU/LC-change maps from multi-temporal data sets, the methodology does not prescribe any specific method. As a general guidance:

- Automated classification methods should be preferred because the interpretation is more efficient and repeatable than a visual interpretation.
- Independent interpretation of multi-temporal images should be avoided (but is not forbidden).
- Interpretation is usually more accurate when it focuses on change detection with interdependent assessment of two multi-temporal images together. A technique that may be effective is image segmentation followed by supervised object classification.
- Minimum mapping unit size shall not be more than one hectare irrespective of forest definition.
- See the most recent version of the GOFC-GOLD sourcebook on REDD or consult experts and literature for further guidance on methods to analyze LU/LC-change using remotely sensed data.

Duly record all interpretation and classification steps for later reporting.

2.4.3 Post-processing

Post-processing includes the use of non-spectral data to further stratify LU/LC-classes with heterogeneous carbon density in LU/LC classes with homogenous carbon density. Post-classification stratification can be performed efficiently using a Geographical Information System (GIS).

Current remote sensing technology is unable to discriminate carbon density classes, although some progress is being made using lidar and other technologies that combined with field-surveys can be used under this methodology. Some forest types (e.g. broadleaved forest, coniferous forests, mangroves) can be discriminated with high accuracy using remotely-sensed data only.

LU/LC-classes that cannot be stratified further using remote sensing techniques but that are likely to contain a broad range of carbon density classes should be stratified using:

- Biophysical criteria (e.g. climate or ecological zone, soil and vegetation type, elevation, rainfall, aspect, etc.)[19];
- Disturbance indicators (e.g. vicinity to roads; forestry concession areas; etc.); age (in cases of plantations and secondary forests);
- Land management categories (e.g. protected forest, indigenous reserve, etc.); and/or
- Other criteria relevant to distinguish carbon density classes.

See the most recent version of the GOFC-GOLD sourcebook for REDD and IPCC 2006 GL AFOLU for further guidance on stratification. The criteria finally used should be reported transparently in the PD and referenced to in table 6. Some iteration between steps 2.2, 2.3, and 2.4.3 may be necessary.

Duly record all post-processing steps for later reporting.

At the end of step 2, the following products should be prepared for the reference region and project area:

a) A <u>Forest Cover Benchmark Map</u> for at least the most recent date (±2 years from the project start date) and 10 (± 2) years[20] prior to the project start date, showing only “forest” and “non-forest”.

b) A <u>Land-Use and Land-Cover Map</u> for at least the most recent date (±2 years from the project start date) depicting the LU/LC-classes defined in step 2.2. If such a map cannot be generated at the levels of accuracy required by this methodology (see step 2.5), areas of the different LU/LC-classes may be estimated by sampling techniques (e.g. by overlaying a grid of dots on the satellite image and then counting the points falling in each LU/LC-class, or by sampling the landscape with higher resolution images and then classifying the sampled images), or by using other sources of data, such as official statistical data on land-use (e.g. agricultural census data):

c) A <u>Deforestation Map</u> for each sub-period analyzed, depicting at least the category “deforestation”. Many projects will have some level of no-data areas because of cloud-cover. In this case change rates should be calculated for each time step based only on areas that were not cloud-obscured in either date in question. Then, a maximum possible forest cover map should be made for the most recent year (±2 years from the project start date). The historical rate in % should be

[19] IPCC 2006 Guidelines for National GHG Inventories provide default climate and soil classification schemes in Annex 3A.5 and guidance on stratifying LU/LC areas in Section 3.3.2.

[20] This is to exclude from the project area forests that are less than 10 years old at the project start date.

multiplied by the maximum forest cover area at the start of the period for estimating the total area of deforestation during the period.

d) A Land-Use and Land-Cover Change Map for at least the most recent period analyzed (3-5 years) depicting the LU/LC-change categories defined in step 2.3. In most cases, this map will be prepared by combining the Deforestation Map of the most recent period (3-5 years) with the most recent Land-Use and Land-Cover Map. If the area of the LU/LC-classes was estimated using sampling techniques or other sources of information, a LU/LC-Change Map is not required.

e) A Land-Use and Land-Cover Change Matrix for at least the most recent period analyzed, derived from the LU/LC-change map or the Deforestation Map and the post-deforestation land-use data mentioned above, showing activity data for each LU/LC-change category. See appendix 2, table 4 for an example of a LU/LC change matrix.

2.5 Map accuracy assessment

A verifiable accuracy assessment of the maps produced in the previous step is necessary to produce a credible baseline[21].

The accuracy must be estimated on a class-by-class (LU/LC map) and, where applicable, category-by-category (LU/LC-change map) basis, respectively. A number of sample points on the map and their corresponding correct classification (as determined by ground-surveys or interpretation of higher resolution data as collected in step 2.1) can be used to create an error matrix with the diagonal showing the proportion of correct classification and the off-diagonal cells showing the relative proportion of misclassification of each class or category into the other class or, respectively, categories. Based on the error matrix (also called confusion matrix), a number of accuracy indices can be derived (see e.g. Congalton, 1991 and Pontius, 2000).

The minimum overall accuracy of the Forest Cover Benchmark Map should be 90%.

The minimum classification accuracy of each class or category in the Land-Use and Land-Cover Map and Land-Use and Land-Cover Change Map, respectively, should be 80%. If the classification of a class or category is lower than 80%:

- Consider merging the class/category with other classes/categories[22]; or
- Exclude from the Forest Cover Benchmark Map the forest-classes that are causing the greatest confusion with non-forest classes according to the error matrix (e.g. initial secondary succession and heavily degraded forest may be difficult to distinguish from certain types of grassland or cropland, such as agro-forestry and silvo-pastoral systems not meeting the definition of "forest"). This implies conservatively reducing the area of the Forest Cover Benchmark Map.
- Both commission errors (false detection of a class/category, such as "deforestation") and omission errors (non-detection of actual class/category, such as "deforestation") should be estimated and reported.

[21] See Chapter 5 of IPCC 2003 GPG, Chapter 3A.2.4 of IPPC 2006 Guidelines for AFOLU, and the most recent version of the GOFC-GOLD Sourcebook on REDD for guidance on map accuracy assessment.

[22] The tradeoff of merging classes or categories is that carbon estimates will be subject to a higher degree of variability.

- If ground-truthing data are not available for time periods in the past, the accuracy can be assessed only at the most recent date, for which ground-truthing data can be collected.

Where the assessment of map accuracy requires merging or eliminating classes or categories to achieve the required map accuracy, the definitions in the previous sub-steps must be adjusted accordingly. The final maps and the class/category definitions must be consistent.

2.6 Preparation of a methodology annex to the PD

LU/LC-change analysis is an evolving field and will be performed several times during the project crediting period. A consistent time-series of LU/LC-change data must emerge from this process.

In general, the same source of remotely sensed data and data analysis techniques must be used within a period for which the baseline is fixed (fixed baseline period). However, if remotely sensed data have become available from new and higher resolution sources (e.g. from a different sensor system) during this period, these can only be used if the images based on interpretation of the new data overlap the images based on interpretation of the old data by at least 1 year and they cross calibrate to acceptable levels based on commonly used methods in the remote sensing community.

To achieve a consistent time-series, the risk of introducing artifacts from method change must be minimized. For this reason, the detailed methodological procedures used in pre-processing, classification, post classification processing, and accuracy assessment of the remotely sensed data, must be carefully documented in an Annex to the PD. In particular, the following information must be documented:

a) Data sources and pre-processing: Type, resolution, source and acquisition date of the remotely sensed data (and other data) used; geometric, radiometric and other corrections performed, if any; spectral bands and indexes used (such as NDVI); projection and parameters used to geo-reference the images; error estimate of the geometric correction; software and software version used to perform pre-processing tasks; etc.

b) Data classification and post-processing: Definition of the LU/LC classes and LU/LC-change categories; classification approach and classification algorithms; coordinates and description of the ground-truthing data collected for training purposes; ancillary data used in the classification, if any; software and software version used to perform the classification; additional spatial data and analysis used for post-classification analysis, including class subdivisions using non-spectral criteria, if any; etc.

c) Classification accuracy assessment: Accuracy assessment technique used; coordinates and description of the ground-truth data collected for classification accuracy assessment; post-processing decisions made based on the preliminary classification accuracy assessment, if any; and final classification accuracy assessment.

3 STEP 3: ANALYSIS OF AGENTS, DRIVERS AND UNDERLYING CAUSES OF DEFORESTATION AND THEIR LIKELY FUTURE DEVELOPMENT

Understanding “who” is deforesting the forest (the “agent”) and what drives land-use decisions (“drivers” and “underlying causes”) is necessary for two mains reasons: (i) Estimating the quantity and location of future deforestation; and (ii) Designing effective measures to address deforestation, including leakage prevention measures.

This analysis is performed through the following five sub-steps[23]:

3.1 Identification of agents of deforestation;

3.2 Identification of deforestation drivers;

3.3 Identification of underlying causes;

3.4 Analysis of chain of events leading to deforestation; and

3.5 Conclusion

3.1 Identification of agents of deforestation

Identify the main agent groups of deforestation (farmers, ranchers, loggers, etc.) and their relative importance (i.e. the amount of historical LU/LC-change that can be attributed to each of them). To do this identification, use existing studies, the maps prepared in step 2, expert-consultations, field-surveys and other verifiable sources of information, as needed.

Sometimes, the relative importance of each agent can be determined from the LU/LC-change matrix developed in step 2.4, since each agent usually converts forests for a specific purpose (cattle ranching, cash-crop production, subsistence farming, etc.).

If the relative importance of different agents is spatially correlated (e.g. small farmers are concentrated in the hills, while ranchers on the planes) it may be useful to stratify the reference region, the project area and the leakage belt accordingly (in I_{RR} strata), and to continue the baseline assessment for each stratum *i* separately in order to increase the accuracy of the projections.

For each identified agent group, provide the following information:

a) Name of the main agent group or agent;

b) Brief description of the main social, economic, cultural and other relevant features of each main agent group. Limit the description to aspects that are relevant to understand why the agent group is deforesting;

c) Brief assessment of the most likely development of the population size of the identified main agent groups in the reference region, project area and leakage belt;

d) Statistics on historical deforestation attributable to each main agent group in the reference region, project area and leakage belt.

3.2 Identification of deforestation drivers

For each identified agent group, analyze factors that drive their land-use decisions. The goal is to identify the immediate causes of deforestation.

Two sets of driver variables have to be distinguished:

a) Driver variables explaining the quantity (hectares) of deforestation (to be used in step 4.1 and 4.3, as appropriate), such as:
   - Prices of agricultural products;

[23] See Angelsen and Kaimowitz (1999) and Chomiz *et al*. (2006) for comprehensive analysis of deforestation agents and drivers.

- Costs of agricultural inputs;
- Population density;
- Rural wages;
- Etc.

b) Driver variables explaining the location of deforestation, also called “predisposing factors” (de Jong, 2007) (to be used in step 4.2), such as:
   - Access to forests (such as vicinity to existing roads, railroads, navigable rivers and coastal lines);
   - Slope;
   - Proximity to markets;
   - Proximity to existing or industrial facilities (e.g. sawmills, pulp and paper mills, agricultural products processing facilities, etc.);
   - Proximity to forest edges;
   - Proximity to existing settlements;
   - Spatial variables indicating availability within the forest of land with good ecological conditions to expand agricultural activities, such as soil fertility and rainfall;
   - Management category of the land (e.g. national park, indigenous reserve, etc.);
   - Etc.

For each of these two sets of variables:

1) List the 1 to 5 key driver variables and provide any relevant source of information that provides evidence that the identified variables have been a driver for deforestation during the historical reference period.

2) Briefly describe for each main agent group identified in step 3.1 how the key driver variables have and will most likely impact on each agent group’s decision to deforest.

3) For each identified key driver variable provide information about its likely future development[24], by providing any relevant source of information.

4) For each identified driver variable briefly describe the project measures that will be implemented to address them[33], if applicable.

3.3 Identification of underlying causes of deforestation

The agents’ characteristics and decisions are themselves determined by broader forces, the underlying causes of deforestation, such as:

- Land-use policies and their enforcement;
- Population pressure;
- Poverty and wealth;
- War and other types of conflicts;
- Property regime;
- Etc.

[24] This does not apply to spatial variables, such slope, elevation etc.

1) List the 1 to 5 key underlying causes and cite any relevant source of information that provides evidence that the identified variables have been an underlying cause for deforestation during the historical reference period.

2) Briefly describe how each key underlying cause has determined and will most likely determine the key drivers identified in step 3.2 and the decisions of the main agent groups identified in step 3.1.

3) For each identified key underlying cause provide information about its likely future development, by citing any relevant source of information.

4) For each identified underlying cause describe the project measures that will be implemented to address them, if applicable.

3.4 Analysis of chain of events leading to deforestation

Based on the historical evidence collected, analyze the relations between main agent groups, key drivers and underlying causes and explain the sequence of events that typically has lead and most likely will lead to deforestation. Consult local experts, literature and other sources of information, as necessary. Briefly summarize the results of this analysis in the PD.

3.5 Conclusion

The analysis of step 3 must conclude with a statement about whether the available evidence about the most likely future deforestation trend within the reference region and project area is:

- Inconclusive or
- Conclusive.

"Conclusive" evidence in this methodology means that the hypothesized relationships between agent groups, driver variables, underlying causes and historical levels of deforestation can be verified at hand of statistical tests, literature studies, or other verifiable sources of information, such as documented information provided by local experts, communities, deforestation agents and other groups with good knowledge about the project area and the reference region.

To arrive at an overall "conclusive" conclusion when multiple agents and drivers are present, the evidence obtained for each of them must lead to a "conclusive" decision for all.

When the evidence is conclusive, state whether the weight of the available evidence suggests that the overall trend in future baseline deforestation rates will be:

- Decreasing;
- About constant;
- Increasing.

Then proceed to step 4.

When the evidence is inconclusive and the historical deforestation trend has been decreasing or about constant, additional analysis must be carried out under step 3, such as more literature reviews, expert consultations, and, as the case may be, additional field surveys, until conclusive evidence on the most likely future deforestation trend is found, otherwise it will not be possible to continue with the next steps of the methodology. If the historical deforestation trend has been increasing and the evidence is inconclusive, the deforestation rate to be used in the projections will be the average historical rate (see step 4.1.1). Alternatively, additional analysis could be carried out under step 3 until finding conclusive evidence.

Where different strata have been considered in the analysis, a conclusion and statement of trend is needed for each stratum. For a conservative baseline projection, the project proponent shall consider that in all the scenarios the agents and drivers of the deforestation activities are realistic and conservative, based on published and reliable data, and consistent with existing concrete actions and enforced laws avoiding deforestation, such as effective surveillance and law enforcement.

4 STEP 4: PROJECTION OF FUTURE DEFORESTATION

This step is the core of the baseline methodology. Its objective is to locate in space and time the baseline deforestation expected to occur within the reference region during the first fixed baseline period and, optionally, the project crediting period.

Where a baseline has already been defined for a geographic area that includes the project area and its leakage belt and this baseline is applicable according to the most recent VCS requirements on regional baselines or the criteria specified in table 2, the existing baseline must be used and the methodology continues with step 5.

4.1 Projection of the quantity of future deforestation

This sub-step is to determine the quantity of baseline deforestation (in hectares) for each future year within the reference region.

Where appropriate, the reference region can be stratified according to the findings of step 3 and different deforestation rates be estimated for each stratum[25]. If the reference region is stratified, the rationale for the stratification must be explained and a map of the strata provided. Briefly summarize the stratification criteria, and the strata using table 8:

Table 8. Stratification of the reference region

Stratum ID		Description	Area at year[1]			
			1	2	…	*T*
ID_i	Name		ha	ha	ha	ha
1						
2						
..						
n						
I_{RR}						

1. If the boundary of the strata is dynamic, explain the rationale and provide the estimated annual area of each stratum in the table.

If a jurisdiction (national or sub-national government) has adopted a VCS or UNFCCC registered (and VCS endorsed) baseline deforestation rate that is applicable to the reference region, project area and

25 Strata may be static (with fixed boundaries) or dynamic (with boundaries shifting over time).

leakage belt according to the most recent VCS *JNR Requirements*, the adopted rate must be used and no further analysis is required under this sub-step (continue with step 4.2).

Where the above condition does not exist, a projected deforestation rate must be determined by the project proponent taking into account possible future changes at the level of agents, drivers and underlying causes of deforestation, as well as the remaining forest area that is potentially available for conversion to non-forest uses. This task is performed through the following three analytical sub-steps:

4.1.1 Selection of the baseline approach;

4.1.2 Quantitative projection of future deforestation.

4.1.1 Selection of the baseline approach

To project future deforestation three baseline approaches are available:

a) Historical average approach: Under this approach, the rate of baseline deforestation is assumed to be a continuation of the average annual rate measured during the historical reference period within the reference region or, where appropriate, within different strata of the reference region.

b) Time function approach: With this approach, the rate of baseline deforestation is estimated by extrapolating the historical trend observed within the reference region (or its strata) as a function of time using either linear regression, logistic regression or any other statistically sound regression technique (see step 4.1.3). This approach requires multiple deforestation measurements during the past 10-15 years.

c) Modeling approach: With this approach, the rate of baseline deforestation will be estimated using a model that expresses deforestation as a function of driver variables selected by the project proponents. Such driver variables may be spatial and consistency with the analysis of step 3 must exist.

Select and justify the most appropriate baseline approach following the decision criteria described below. Different approaches can be used in different strata of the reference region, where appropriate.

1. The deforestation rates measured in different historical sub-periods in the reference region (or a stratum of it) do not reveal any trend (decreasing, constant or increasing deforestation) and:

   1.1 No conclusive evidence emerges from the analysis of agents and drivers explaining the different historical deforestation rates: do additional assessments under step 3, such as more literature reviews, expert consultations, and, as the case may be, additional field surveys, until finding conclusive evidence.

   1.2 Conclusive evidence emerges from the analysis of agents and drivers explaining the different historical deforestation rates: use approach "c" if there is at least one variable that can be used to project the deforestation rate, otherwise use approach "a".

2. The deforestation rates measured in different historical sub-periods in the reference region (or a stratum of it) reveal a clear trend and this trend is:

   2.1 A decrease of the deforestation rate and:

   - Conclusive evidence emerges from the analysis of agents and drivers explaining the decreasing trend and making it likely that this trend will continue in the future: use approach "b".

- Conclusive evidence emerges from the analysis of agents and drivers explaining the decreasing trend and this evidence also suggest that the decreasing trend will change in the future due to predictable changes at the level of agents and drivers: use approach "c".

- No conclusive evidence emerges from the analysis of agents and drivers explaining the decreasing trend: do additional assessments under step 3, such as more literature reviews, expert consultations, and, as the case may be, additional field surveys, until finding conclusive evidence, then use approach "b".

2.2 A constant deforestation rate and:

- Conclusive evidence emerges from the analysis of agents and drivers explaining the historical trend and making it likely that this trend will continue in the future: use approach "a".

- Conclusive evidence emerges from the analysis of agents and drivers explaining the historical trend and this evidence also suggests that the historical trend will change in the future due to predictable changes at the level of agents and drivers: use approach "c".

- No conclusive evidence emerges from the analysis of agents and drivers explaining the historical trend: do additional assessments under step 3, such as more literature reviews, expert consultations, and, as the case may be, additional field surveys, until finding conclusive evidence, then use approach "a".

2.3 An increase of the deforestation rate and:

- Conclusive evidence emerges from the analysis of agents and drivers explaining the increased trend and making it likely that this trend will continue in the future: use approach "b". If the future deforestation trend is likely to be higher than predicted with approach "b", use approach "c".

- Conclusive evidence emerges from the analysis of agents and drivers explaining the increased trend but this evidence also suggests that the future trend will change: use approach "a" or develop a model (approach "c").

- No conclusive evidence emerges from the analysis of agents and drivers explaining the increasing trend: use approach "a".

4.1.2 Quantitative projection of future deforestation

The methodology procedure is to first project the annual areas or rates of baseline deforestation within the reference region (or – where appropriate – within different strata of the reference region), then to analyze the spatial location of these annual areas in the reference region (step 4.2), and finally, to determine the annual areas and location of deforestation in the project area and leakage belt.

4.1.2.1 Projection of the annual areas of baseline deforestation in the reference region

The method to be used depends on the baseline approach selected.

Approach "a": Historical average

The annual baseline deforestation area that applies at year *t* to stratum *i* within the reference region is calculated as follows:

$$ABSLRR_{i,t} = ARR_{i,t-1} * RBSLRR_{i,t} \quad (3)$$

Where:

$ABSLRR_{i,t}$	Annual area of baseline deforestation in stratum *i* within the reference region at year *t*; ha yr^{-1}
$ARR_{i,t-1}$	Area with forest cover in stratum *i* within the reference region at year *t-1*: ha
$RBSLRR_{i,t}$	Deforestation rate[26] applicable to stratum *i* within the reference region at year *t*; %
t	1, 2, 3 … *T,* a year of the proposed project crediting period; dimensionless
i	1, 2, 3 … I_{RR}, a stratum within the reference region; dimensionless

Approach "b": Time function

The annual area of baseline deforestation that applies at a year *t* to stratum *i* within the reference region during the first $Toptimal_i$ years is calculated using one of the following equations:

- Linear regression: $ABSLRR_{i,t} = a + b*t$ (4.a)
- Logistic regression: $ABSLRR_{i,t} = ARR_i / (1+e^{-k*t})$ (4.b)
- Other types of regression: $ABSLRR_{i,t} = f(t)$ (4.c)

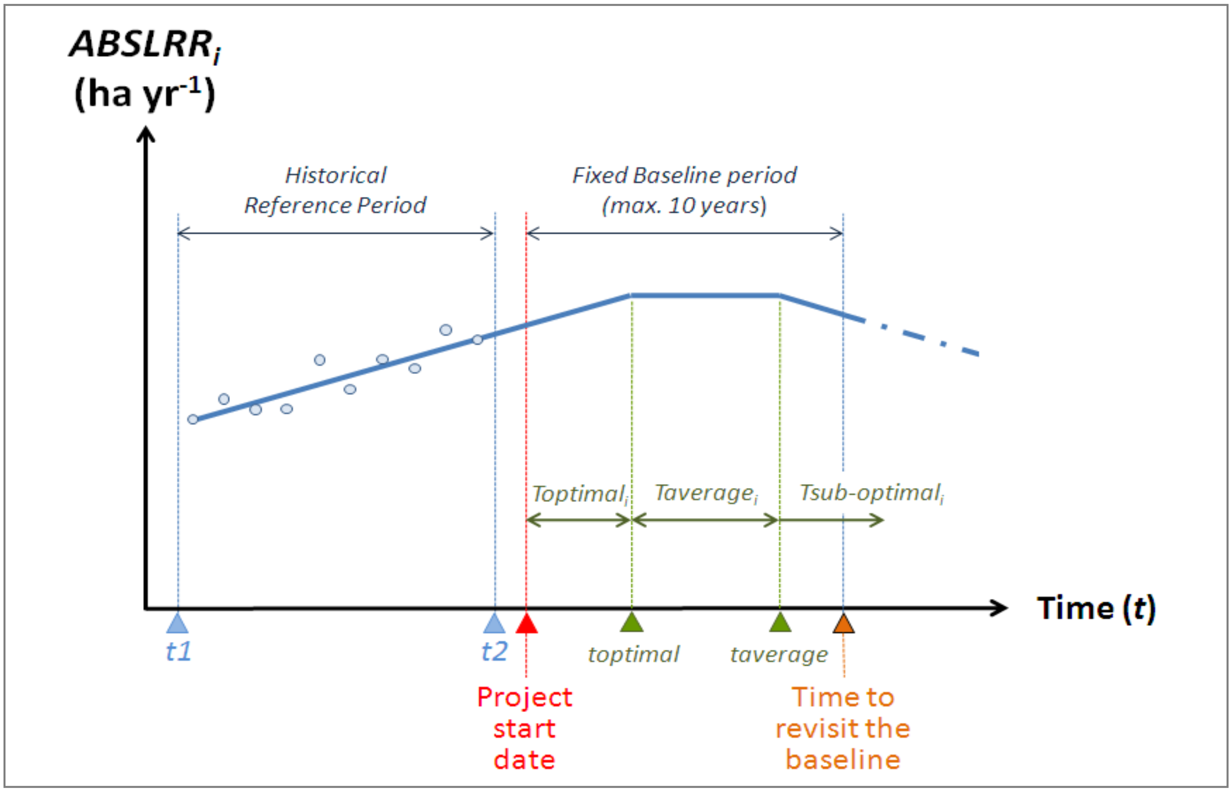
Where:

$ABSLRR_{i,t}$	Annual area of baseline deforestation in stratum *i* within the reference region at a year *t*; ha yr^{-1}
a	Estimated intercept of the regression line; ha yr^{-1}
b	Estimated coefficient of the time variable (or slope of the linear regression); ha yr^{-1}
e	Euler number (2,71828); dimensionless
k	Estimated parameter of the logistic regression; dimensionless
ARR_i	Total forest area in stratum *i* within the reference region at the project start date; ha
$f(t)$	A function of time
t	1, 2, 3 … *T,* a year of the proposed project crediting period; dimensionless
i	1, 2, 3 … I_{RR}, a stratum within the reference region; dimensionless

The model and its parameters are derived from data obtained from the historical reference period and are used to project future deforestation trends as shown in the figure 4 below.

26 See Puyravaud, J.-P., 2003. Standardizing the calculation of the annual rate of deforestation. Forest Ecology and Management, 177: 593-596

Figure 4. Approach "b" for modeling *ABSLRR*$_i$



The model must demonstrably comply with statistical good practice, and evidence that such requirement has been met shall be provided to VCS verifiers at the time of validation.

If $ABSLRR_{i,t}$ decreases as a function of time, $Toptimal_i$ is the period of time during which $ABSLRR_{i,t}$ yields a positive value. After that period of time, $ABSLRR_{i,t} = 0$.

If $ABSLRR_{i,t}$ increases as a function of time, $Toptimal_i$ is the period of time between $t = 1$ and $t = toptimal_i$, the latter being the year at which the following condition is satisfied:

$$Aoptimal_i = \sum_{t=1}^{toptimal_i} ABSLRR_{i,t} \qquad (5)$$

Where:

$Aoptimal_i$	Area of "optimal" forest land suitable for conversion to non-forest land within stratum *i* (see below); ha
$ABSLRR_{i,t}$	Annual area of baseline deforestation in stratum *i* within the reference region at a year *t*; ha yr^{-1}
t	1, 2, 3 … *T,* a year of the proposed project crediting period; dimensionless
i	1, 2, 3 … I_{RR}, a stratum within the reference region; dimensionless
$toptimal_i$	Year at which $Toptimal_i$ ends; yr

If: $Toptimal_i \geq$ Project crediting period: $ABSLRR_{i,t}$ calculated with equations 4 is applicable during the entire project crediting period.

If: $Toptimal_i <$ Project crediting period: $ABSLRR_{i,t}$ calculated with equations 4 is applicable only to the first $Toptimal_i$ years. For the following $Taverage_i$ years use value of $ABSLRR_{i,t}$ calculated for the year $t = Toptimal_i$: $Taverage_i$ is the period of time between $t = toptimal_i$ and $t = taverage_i$, the latter being the year at which the following condition is satisfied:

$$Aaverage_i = \sum_{t=toptimal_i}^{taverage_i} ABSLRR_{i,t} \qquad (6)$$

Where:

$Aaverage_i$	Area of "average" forest land suitable for conversion to non-forest land within stratum *i* (see below); ha
$ABSLRR_{i,t}$	Annual area of baseline deforestation in stratum *i* within the reference region at a year *t*; ha yr^{-1}
t	1, 2, 3 … *T,* a year of the proposed project crediting period; dimensionless
i	1, 2, 3 … I_{RR}, a stratum within the reference region; dimensionless
$toptimal_i$	Year at which $Toptimal_i$ ends; yr
$taverage_i$	Year at which $Taverage_i$ ends; yr

If: $Toptimal_i + Taverage_i \geq$ Project crediting period: $ABSLRR_{i,t}$ calculated for the year $t = toptimal_i$ is applicable during the period of time between $t = toptimal_i$ and $t = taverage_i$.

If: $Toptimal_i + Taverage_i <$ Project crediting period: $ABSLRR_{i,t}$ calculated for the year $t = toptimal_i$ is applicable only to the first $Taverage_i$ years following after year $toptimal_i$. For the following 20 years assume a linear decrease of $ABSLRR_{i,t}$ down to zero hectares per year in t=*faverage*+20.

$$ABSLRR_{i,t} = ABSLRR_{taverage,i}\ (1 - 1/20\ * (t - taverage_i)) \qquad (7)$$

Where:

$ABSLRR_{i,t}$	Annual area of baseline deforestation in stratum *i* within the reference region at a year *t*; ha yr^{-1}
$ABSLRR_{taverage,i}$	Annual area of baseline deforestation in stratum *i* within the reference region at a year $taverage_i$; ha yr^{-1}
$taverage_i$	Year at which $Taverage_i$ ends; yr
t	1, 2, 3 … *T,* a year of the proposed project crediting period; dimensionless
i	1, 2, 3 … I_{RR}, a stratum within the reference region; dimensionless

Note: After $taverage_i$ + 20 years $ABSLRR_{i,t}$ will be zero hectares per year in all cases..

Calculation of $Aoptimal_i$ and $Aaverage_i$ under Approach "b"

$Aoptimal_i$ (area of "optimal" forest land suitable for conversion to non-forest land within stratum *i*) and $Aaverage_i$ (area of "average" forest land suitable for conversion to non-forest land within stratum *i*) must be determined to avoid non-conservative projections of baseline deforestation when "increasing deforestation" is projected under Approach "b". Deforestation can increase in the future only if there are no constraints to the conversion of forest land to non-forest land. This is typically the case when the project area is located in a country or region still with significant forest cover (Olander *et al*., 2006).

To assess whether there is scarcity of forest land that is accessible to deforestation agents and potentially exposed to the risk of deforestation do the following:

1) Identify land-use constraints: Identify the appropriate biophysical constraints (e.g. soil, climate, elevation and/or slope) and appropriate socio-economic constraints (e.g, mobility, land-use rights and/or areas with presence of conflicts and crime) that limit the geographical area where deforestation agents could expand their land-use activities in currently forested areas. Consider the constraints as they are perceived by the main groups of deforestation agents, taking into consideration their socio-economic conditions. To determine how constraints are perceived by the main groups of deforestation agents, determine the threshold conditions under which they have deforested historically (for example, range of slopes, types of soil, minimum/maximum rainfall, and/or elevation range, are relevant to determine the range where main types of crops and animals could survive). Use spatial data, literature, surveys, and/or participative rural appraisal (PRA) as appropriate.
2) Estimate the remaining forest area that could be converted to non-forest land: Using the constraints identified above, develop a Maximum Potential Deforestation Map, which maps the area currently covered by forests that is potentially available for the further expansion of non-forest uses in the reference region.
3) Stratify the Maximum Potential Deforestation Map in broad suitability classes: Considering the constraints identified above, define criteria and thresholds that delineate "optimal", "average" and "sub-optimal" conditions for each of the main land uses implemented by the main agent groups (e.g. by defining ranges of slope, rainfall or types of soils, or ranges of deforestation risks according to the deforestation risk map created for the spatial model (See step 4.2)). Select thresholds that are relevant from the point of view of the deforestation agents. Using the selected criteria and thresholds stratify the Maximum Potential Deforestation Map in three broad suitability classes representing "optimal", "average" and "sub-optimal" areas for non-forest uses. When available from other sources, use existing maps.
4) $Aoptimal_i$ will be the area of the "optimal" suitability class within stratum *i;* and $Aaverage_i$ will be the area of the "average" suitability class within stratum *i.*

Approach "c": Modeling

The annual area of baseline deforestation that applies at year *t* in stratum *i* within the reference region is estimated using a statistical model, such as simple regression, multiple regressions, logistic regression, or any other possible model to be proposed and justified by the project proponent. The proposed model must demonstrably comply with statistical good practice, and evidence that such requirement has been met shall be provided to VCS verifiers at the time of validation.

The following equations are given for illustration purposes only:

$$ABSLRR_{i,t} = a + b1_i * V1_{i,t} \quad (8.a)$$

$$ABSLRR_{i,t} = a + b1_i * V1_{i,t} + b2_i * V2_{i,t} \quad (8.b)$$

$$ABSLRR_{i,t} = ARR_i / (1 + e^{-k * V1_{i,t}}) \quad (8.c)$$

Where:

$ABSLRR_{i,t}$	Annual area of baseline deforestation in stratum *i* within the reference region at a year *t*; ha yr^{-1}
$a; b1_i; b2_i; \ldots; bn_i; k$	Estimated coefficients of the model
e	Euler number (2,71828); dimensionless
$V1_{i,t}; V2_{i,t}; \ldots; Vn_{i,t}$	Variables included in the model
ARR_i	Total forest area in stratum *i* within the reference region at the project start date; ha
t	1, 2, 3 … *T,* a year of the proposed project crediting period; dimensionless
i	1, 2, 3 … I_{RR}, a stratum within the reference region; dimensionless

The model may also be constructed with the annual area deforested ($ABSLRR_{i,t}$), or the deforestation rate ($RBSLRR_{i,t}$ = percentage of remaining forest area at year *t-1* in stratum *i* to be deforested at year *t*) as the dependent variable, and independent variable(s) (e.g. population density in stratum *i* at time *t*, average opportunity costs in stratum *i* at time *t*, etc.) from which the annual areas of deforestation ($ABSLRR_{i,t}$) or the deforestation rates ($RBSLRR_{i,t}$) are inferred from changes in the independent variables.

For each of the selected independent variables, there must be a description of the historical data (including source), an explanation of the rationale for using the variable(s), and a credible future projection based on documented and verifiable sources. To determine the future values of the variables included in the model, official projections, expert opinion, other models, and any other relevant and verifiable source of information must be used. Justify with logical and credible explanations any assumption about future trends of the driver variables and use values that yield conservative estimates of the projected deforestation ($ABSLRR_{i,t}$ or $RBSLRR_{i,t}$).

The model and its rationale must be explained by the project proponent using logical arguments and verifiable sources of information and must be consistent with the analysis of step 3.The model must demonstrably comply with statistical good practice, and evidence that such requirement has been met shall be provided to VCS verifiers at the time of validation.

4.1.2.2 Projection of the annual areas of baseline deforestation in the project area and leakage belt

Location analysis of future deforestation within reference region is required to determine the annual areas of deforestation within the project area and leakage belt (step 4.2). Once location analysis is completed, the portion of annual areas of baseline deforestation of each stratum *i* within the project area and leakage belt must be determined using a GIS.

To do this step, step 4.2.4 must be completed first.

4.1.2.3 Summary of step 4.1.2

Present the results of the previous assessments in Tables 9.a and 9.b. Do this at least for the fixed baseline period and, optionally, for the entire project crediting period.

Table 9.a. Annual areas of baseline deforestation in the reference region

Project year *t*	Stratum *i* in the reference region				Total	
	1	2	…	i_{RR}	annual	cumulative
	$ABSLRR_{i,t}$	$ABSLRR_{i,t}$	$ABSLRR_{i,t}$	$ABSLRR_{i,t}$	$ABSLRR_t$	$ABSLRR$
	ha	ha	ha	ha	ha	ha
0						
1						
2						
. . .						
T						

Table 9.b. Annual areas of baseline deforestation in the project area

Project year *t*	Stratum *i* of the reference region in the project area				Total	
	1	2	…	i_{RR}	annual	cumulative
	$ABSLPA_{i,t}$	$ABSLPA_{i,t}$	$ABSLPA_{i,t}$	$ABSLPA_{i,t}$	$ABSLPA_t$	$ABSLPA$
	ha	ha	ha	ha	ha	ha
0						
1						
2						
. . .						
T						

Table 9.c. Annual areas of baseline deforestation in the leakage belt

Project year *t*	Stratum *i* of the reference region in the leakage belt				Total	
	1	2	…	I_{RR}	annual	cumulative
	$ABSLLK_{i,t}$	$ABSLLK_{i,t}$	$ABSLLK_{i,t}$	$ABSLLK_{i,t}$	$ABSLLK_t$	$ABSLLK$
	ha	ha	ha	ha	ha	ha
0						
1						
2						
. . .						
T						

4.2 Projection of the location of future deforestation

Step 4.1 was to estimate the annual areas of baseline deforestation in the reference region. Step 4.2 is to analyze where future deforestation is most likely to happen in the baseline case in order to match the location of the projected deforestation with carbon stocks and determine the annual areas of baseline deforestation in the project area and leakage belt.

Step 4.2 is based on the assumption that deforestation is not a random event but a phenomenon that occurs at locations that have a combination of bio-geophysical and economic attributes that is particularly attractive to the agents of deforestation. For example, a forest located on fertile soil, flat land, and near to roads and markets for agricultural commodities is likely to be at greater risk of deforestation than a forest located on poor soil, steep slope, and far from roads and markets. Locations at higher risk are assumed to be deforested first. This hypothesis can be tested empirically by analyzing the spatial correlation between historical deforestation and geo-referenced bio-geophysical and economic variables. In the previous example, soil fertility, slope, distance to roads and distance to markets are the hypothesized spatial driver variables (SDV_i) or “predisposing factors” (De Jong, 2007). These variables can be represented in a map (or “Factor Map”) and overlaid to a map showing historical deforestation using a Geographical Information System (GIS). From the combined spatial dataset information is extracted and analyzed statistically in order to produce a map that shows the level of deforestation risk at each spatial location (“pixel” or “grid cell”). The deforestation risk (or probability of deforestation) at a given spatial location changes at the time when one or more of the spatial driver variables change their values due to projected changes, e.g. when population density increases within a certain area, when a road is build nearby, or when areas recently deforested are coming closer, etc.

The basic tasks to perform the analysis described above are:

4.2.1 Preparation of factor maps;

4.2.2 Preparation of risk maps for deforestation;

4.2.3 Selection of the most accurate deforestation risk map; and

4.2.4 Mapping of the locations of future deforestation.

Several model/software are available and can be used to perform these tasks in slightly different ways, such as Geomod, Idrisi Taiga, Dinamica Ego, Clue, and Land-Use Change Modeler. The model/software used must be peer-reviewed and must be consistent with the methodology (to be proven at validation).

4.2.1 Preparation of factor maps

Based on the analysis of step 3 and step 4.1, identify the spatial variables that most likely explain the patterns of baseline deforestation in the reference region. Obtain spatial data for each variable and create digital maps representing the Spatial Features of each variable (i.e. the shape files representing the point, lines or polygon features or the raster files representing surface features). Some models will require producing Distance Maps from the mapped features (e.g. distance to roads or distance to already deforested lands) or maps representing continuous variables (e.g. slope classes) and categorical variables (e.g. soil quality classes). If the model/software allows working with dynamic Distance Maps (i.e. the software can calculate a new Distance Maps at each time step), these should be used. For simplicity, these maps are called "Factor Maps". Other models do not require Factor Maps for each variable, and instead analyze all the variables and deforestation patterns together to produce a risk map.

Where some of the spatial variables are expected to change, collect information on the expected changes from credible and verifiable sources of information. Then prepare Factor Maps that represent the changes that will occur in different future periods. Sometimes, projected changes can be represented by a dynamic spatial model that may change in response to deforestation.

In case of planned infrastructure (e.g. roads, industrial facilities, settlements) provide documented evidence that the planned infrastructure will actually be constructed and the time table of the construction. In case of planned new roads, road improvements, or railroads provide credible and verifiable information on the planned construction of different segments (e.g. how many kilometers will be constructed, where and when). Evidence includes: approved plans and budgets for the construction, signed construction contracts or at least an open bidding process with approved budgets and finance. If such evidence is not available exclude the planned infrastructure from the factors considered in the analysis.

Any area affected by planned deforestation due to the construction of planned infrastructure must be excluded from the project area.

In case of unplanned infrastructure (e.g. secondary roads), provide evidence that the unplanned infrastructure will actually develop, e.g. from historical developments. Specifically, from a wall-to-wall assessment (or at least five randomly sampled observations in the reference region) or from literature sources appropriate to the reference region, estimate the average annual length[27] of new unplanned infrastructure per square kilometer[28] that was constructed during the historical reference period. Alternatively, determine the historical rate of change as related to variables for which there are good projections (e.g. km of new unplanned infrastructure as related to population). To avoid projecting unplanned infrastructure in areas where geographic and socio-economic conditions are unfavorable for infrastructure developments (e.g. areas with steep slopes, swampy soils, low opportunity costs, etc.), develop a map representing a proxy of the suitability for future infrastructure development. For each

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27 Other parameters relevant for modeling the construction of secondary roads may also be measured in this analysis, such as distance between roads, number of destinations per year, etc. Parameters to be assessed are dependent on the modeling approach used to project the development of the road network and are therefore not further specified here.

28 Or per km of official new road constructed, or per other landscape features that can be mapped (such as new industrial facilities, settlements, mining concessions etc.), as appropriate.

"suitability" class or gradient (using a minimum of two classes, e.g. suitable, not suitable), determine the most plausible rate of unplanned infrastructure development. To do this, apply the following steps:

a) Using historical data, expert opinion, participative rural appraisal (PRA), literature and/or other verifiable sources of information list all relevant criteria that facilitate (at least one criterion) and constrain (at least one criterion) the development of new unplanned infrastructure.

b) For each criterion, generate a map using a GIS.

c) Using multi-criteria analysis, determine the most likely rate of unplanned infrastructure development (e.g. km km^{-2} yr^{-1} or a similar indicator) per different sectors (suitability classes or gradients) within the reference region.

Projections of unplanned infrastructure development shall be conservative, in particular projections in forested areas shall meet this requirement.

To create the Factor Maps use one of the following two approaches:

- **Empirical approach:** Categorize each Distance Map in a number of predefined distance classes (e.g. class 1 = distance between 0 and 50 m; class 2 = distance between 50 and 100 m, etc.). In a table describe the rule used to build classes and the deforestation likelihood assigned to each distance class[29]. The deforestation likelihood is estimated as the percentage of pixels that were deforested during the period of analysis (i.e. the historical reference period).

- **Heuristic approach**: Define "value functions" representing the likelihood of deforestation as a function of distance from point features (e.g., saw mills) or linear features (e.g., roads), or as a function of polygon features representing classes (e.g. of soil type, population density) based on expert opinion or other sources of information. Specify and briefly explain each value function in the PD.

  For Distance Maps, a useful approach to estimate value functions is to sample spatially uncorrelated points and their corresponding location in the maps representing historical deforestation (Land-Use and Land-Cover Change Maps produced with step 2) and to use regression techniques[30] to define the probability of deforestation as a function of "distance".

The empirical approach should be preferred over the heuristic approach. Use the heuristic approach only where there is insufficient information about the spatial location of historical deforestation or where the empirical approach does not produce accurate results when validated against a historical period.

4.2.2 Preparation of deforestation risk maps

A Risk Map shows at each pixel location l the risk (or "probability") of deforestation in a numerical scale (e.g., 0 = minimum risk; 255 = maximum risk).

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[29] When building classes of continuous variables it is important to build classes that are meaningful in terms of deforestation risk. This implies the parameterization of a "value function" based on specific measurements. For instance, the criterion "distance to roads" might not have a linear response to assess the deforestation risk: a forest located at 50 km from the nearest road may be subject to the same deforestation risk of a forest located at 100 km, while at 0.5 km the risk may be twice as much as at 1.0 km. Data to model the value function and build meaningful classes can be obtained by analyzing the distribution of sample points taken from historically deforested areas.

[30] e.g. logistic regression.

Models use different techniques to produce Risk Maps and algorithms may vary among the different modeling tools. Algorithms of internationally peer-reviewed modeling tools are eligible to prepare deforestation risk maps, provided they are shown to conform to the methodology at time of validation.

Several Risk Maps should be produced using different combinations of Factor Maps and modeling assumptions in order to allow comparison and select the most accurate map.

A list of Factor Maps, including the maps used to produce them and the corresponding sources shall be presented in the PD (table 10) together with a flow-chart diagram illustrating how the Risk Map is generated.

Table 10. List of variables, maps and factor maps

Factor Map		Source	Variable represented		Meaning of the categories or pixel value		Other Maps and Variables used to create the Factor Map		Algorithm or Equation used	Comments
ID	File Name		Unit	Description	Range	Meaning	ID	File Name		

4.2.3 Selection of the most accurate deforestation risk map

Confirming the quality of the model output (generally referred to as model validation in the modeling community) is needed to determine which of the deforestation risk maps is the most accurate. A good practice to confirm a model output (such as a risk map) is "calibration and validation", referred to here as "calibration and confirmation" (so as not to be confused with validation as required by the VCS).

Two options are available to perform this task: (a) calibration and confirmation using two historical sub-periods; and (b) calibration and confirmation using tiles. Option (b) should be preferred where recent deforestation trends have been different from those in the more distant past.

a) Where two or more historical sub-periods have shown a similar deforestation trend, data from the most recent period can be used as the "confirmation" data set, and those from the previous period as the "calibration" data set.

   Using only the data from the calibration period, prepare for each Risk Map a Prediction Map of the deforestation for the confirmation period. Overlay the predicted deforestation with locations that were actually deforested during the confirmation period. Select the Prediction Map with the best fit and identify the Risk Map that was used to produce it. Prepare the final Risk Map using the data from the calibration and the confirmation period.

b) Where only one historical sub-period is representative of what is likely to happen in the future, divide the reference region in tiles and randomly select half of the tiles for the calibration data set and the other half for the confirmation set. Do the analysis explained above (see Castillo-Santiago *et al.,* 2007).

The Prediction Map with the best fit is the map that best reproduced actual deforestation in the confirmation period. The best fit must be assessed using appropriate statistical techniques. Most peer-reviewed modeling tools, such as Geomod, Idrisi Taiga, Land Use Change Modeler, and Dinamica Ego, include in the software package appropriate assessment techniques, which can be used under this methodology. Preference should be given to techniques that assess the accuracy of the prediction at the polygon level, such as the predicted quantity of total deforestation within the project area as compared to the observed one.

One of the assessment techniques that can be used is the "Figure of Merit" (*FOM*) that confirms the model prediction in statistical manner (Pontius *et al*. 2008; Pontius *et al*. 2007)[31].

The *FOM* is a ratio of the intersection of the observed change (change between the reference maps in time 1 and time 2) and the predicted change (change between the reference map in time 1 and simulated map in time 2) to the union of the observed change and the predicted change (equation 9). The FOM ranges from 0.0, where there is no overlap between observed and predicted change, to 1.0 where there is a perfect overlap between observed and predicted change. The highest percent FOM must be used as the criterion for selecting the most accurate Deforestation Risk Map to be used for predicting future deforestation.

$$FOM = B / (A+B+C) \quad (9)$$

Where:

FOM	"Figure of Merit"; dimensionless
A	Area of error due to observed change predicted as persistence; ha
B	Area correct due to observed change predicted as change; ha
C	Area of error due to observed persistence predicted as change; ha

The minimum threshold for the best fit as measured by the Figure of Merit (FOM) shall be defined by the net observed change in the reference region for the calibration period of the model. Net observed change shall be calculated as the total area of change being modeled in reference region during the calibration period as percentage of the total area of the reference region. The FOM value shall be at least equivalent to this value. If the FOM value is below this threshold, the project proponent must demonstrate that at least three models have been tested, and that the one with the best FOM is used.

4.2.4 Mapping of the locations of future deforestation

Future deforestation is assumed to happen first at the pixel locations with the highest deforestation risk value. To determine the locations of future deforestation do the following:

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31 Pontius, R. G., Jr, W Boersma, J-C Castella, K Clarke, T de Nijs, C Dietzel, Z Duan, E Fotsing, N Goldstein, K Kok, E Koomen, C D Lippitt, W McConnell, A Mohd Sood, B Pijanowski, S Pithadia, S Sweeney, T N Trung, A T Veldkamp, and P H Verburg. 2008. Comparing input, output, and validation maps for several models of land change. Annals of Regional Science, 42(1): 11-47. Pontius, R G, Jr, R Walker, R Yao-Kumah, E Arima, S Aldrich, M Caldas and D Vergara. 2007. Accuracy assessment for a simulation model of Amazonian deforestation. Annals of Association of American Geographers, 97(4): 677-695

- In the most accurate Deforestation Risk Map select the pixels with the highest value of deforestation probability. Add the area of these pixels until their total area is equal to the area expected to be deforested in the reference region in project year one according to table 9.a. The result is the Map of Baseline Deforestation for Year 1.
- Repeat the above pixel selection procedure for each successive project year *t* to produce a series of Maps of Baseline Deforestation for each future project year. Do this at least for the upcoming fixed baseline period and, optionally, for the entire project crediting period.
- Add all yearly (baseline deforestation maps in one single map showing the expected Baseline Deforestation for the fixed baseline period and, optionally, for the entire project crediting period. Present this map in the PD.

The described pixel selection procedure and production of annual maps of baseline deforestation can be programmed in most state of the art modeling tools/software.

To obtain the annual areas of baseline deforestation within the project area, combine the annual maps of baseline deforestation for the reference region with a map depicting only the polygon corresponding to the project area. After this step, table 9.b can be filled-out. The same must be done for the leakage belt area to fill-out table 9.c.

5 STEP 5: DEFINITION OF THE LAND-USE AND LAND-COVER CHANGE COMPONENT OF THE BASELINE

The goal of this step is to calculate activity data[32] of the initial forest classes (*icl*) that will be deforested and activity data of the post-deforestation classes (*fcl*) that will replace them in the baseline case.

After step 4, the area and location of future deforestation are both known and pre-deforestation carbon stocks can be determined by matching the predicted location of deforestation with the location of forest classes with known carbon stocks.

Pre-deforestation carbon stocks shall be those existing or projected to exist at the year of the projected deforestation. This implies that forest classes in areas undergoing degradation in the baseline case will not be the ones existing at the project start date, but the ones projected to exist at the year of deforestation.

Post-deforestation carbon stocks can either be determined as the historical area-weighted average carbon stock, or using location analysis (modeling).

Apply the following sub-steps:

5.1 Calculation of baseline activity data per forest class;

5.2 Calculation of baseline activity data per post-deforestation class; and

5.3 Calculation of baseline activity data per LU/LC change category.

Sub-step 5.3 applies only if the location of post-deforestation classes is known (i.e. the location of post-deforestation classes has been modeled).

[32] Activity data = hectares per year

5.1 Calculation of baseline activity data per forest class

Combine the Maps of Annual Baseline Deforestation of each future year produced in the previous step with the Land-Use and Land-Cover Map produced for the current situation in step 2 to produce a set of maps showing for each forest class the polygons that that would be deforested each year in absence of the AUD project activity. Extract from these maps the number of hectares of each forest class that would be deforested and present the results in table 11 (11.a for the reference region[33], 11.b for the project area and 11.c for the leakage belt area). Do this at least for the fixed baseline period and, optionally, for the project crediting period.

In most cases one single Land-Use and Land-Cover Map representing the spatial distribution of forest classes at the project start date will have been produced in step 2. However, where certain areas of land are expected to undergo significant changes in carbon stocks due to growth or degradation in the baseline case, a sequence of Land-Use and Land-Cover Maps representing the mosaic of forest-classes of each future year may have been generated in step 2, in which case it must be used this step.

Table 11.a Annual areas deforested per forest class *icl* within the reference region in the baseline case (baseline activity data per forest class)

Area deforested per forest class *icl* within the reference region					Total baseline deforestation in the reference region	
ID_{icl}>	1	2	…	*Icl*		
Name >					$ABSLRR_t$	*ABSLRR*
					annual	cumulative
Project year *t*	ha	ha	ha	ha	ha	ha
0						
1						
2						
. . .						
T						

Table 11.b Annual areas deforested per forest class *icl* within the project area in the baseline case (baseline activity data per forest class)

Area deforested per forest class *icl* within the project area					Total baseline deforestation in the project area	
ID_{icl}>	1	2	…	*Icl*		
Name >					$ABSLPA_t$	*ABSLPA*
					annual	cumulative
Project year *t*	ha	ha	ha	ha	ha	ha
0						
1						
2						
. . .						
T						

[33] Table 11.a is optional

Table 11.c Annual areas deforested per forest class *icl* within the leakage belt area in the baseline case (baseline activity data per forest class)

Area deforested per forest class *icl* within the leakage belt area					Total baseline deforestation in the leakage belt area	
ID_{icl}>	1	2	…	*Icl*		
Name >					*$ABSLLK_t$* annual	*ABSLLK* cumulative
Project year *t*	ha	ha	ha	ha	ha	ha
0						
1						
2						
. . .						
T						

5.2 Calculation of baseline activity data per post-deforestation forest class

Two methods are available to project the LU/LC classes that will replace forests in the baseline case; (1) "Historical LU/LC-change" and (2) "Modeling".

Method 1: Historical LU/LC-change

Historical LU/LC-changes are assumed to be representative for future trends. Hence, post-deforestation land-uses are allocated to the projected areas of annual deforestation in same proportions as those observed on lands deforested during the historical reference period in the reference region.

Divide the reference region (or at least the area encompassing the project area, leakage belt and leakage management areas) in *Z* zones (at least one zone), each representing different combinations of possible post-deforestation land uses (zone 1, zone 2, etc.) taking into account the historical location of post-deforestation LU/LC-classes and the requirements (climate, soil, economic factors) that different classes have to be established within a given zone in the baseline case.

If more than one zone exists, include in the PD a map showing the location of these zones (Map of Zones of Post-Deforestation Land Uses) and provide a brief explanation of the rationale of the zoning. In Table 12, report the area of each zone and the areas of each post-deforestation LU/LC class present in each zone (based in the maps and data produced in step 2).

Table 12. Zones of the reference region* encompassing different combinations of potential post-deforestation LU/LC classes

Zone		Name:		Name:		Name:		Total of all other LU/LC classes present in the Zone		Total area of each Zone	
		ID_{fcl}	1	*ID_{fcl}*	2	*ID_{fcl}*	*Fcl*				
		Area	% of Zone	Area	% of Zone	Area	% of Zone	Are a	%of Zone	Are a	% of Zone
IDz	*Name*	ha	%	ha	%	ha	%	ha	%	ha	%
1	Zone 1										
2	Zone 2										
…	Zone …										
Z	Zone Z										
Total area of each class *fcl*		-									

* A smaller area than the reference region can be considered, but this smaller area must at least contain the project area, the leakage belt and the leakage management areas.

Calculate the area projected to be deforested in each zone and report the result in table 13.b (for the project area) and 13.c (for the leakage belt). Do this at least for the fixed baseline period and, optionally, for the entire project crediting period. Doing the same for the reference region (table 13.a) is optional.

Table 13.a. Annual areas deforested in each zone within the reference region in the baseline case (baseline activity data per zone)

					Total baseline deforestation in the reference region	
IDz >	1	2	…	*Z*		
Name >	Zone 1	Zone 2	Zone 3	Zone Z	$ABSLRR_t$	*ABSLRR*
Project year *t*	ha	ha	ha		ha	ha
0						
1						
2						
3						
T						

Table 13.b. Annual areas deforested in each zone within the project area in the baseline case (baseline activity data zone)

Area established after deforestation per zone within the project area					Total baseline deforestation in the project area	
IDz >	1	2	…	*Z*		
Name >	Zone 1	Zone 2	Zone 3	Zone Z	$ABSLPA_t$	*ABSLPA*
Project year *t*	ha	ha	ha		ha	ha
0						
1						
2						
3						
T						

Table 13.c. Annual areas deforested in each zone within the leakage belt in the baseline case (baseline activity data per zone)

					Total baseline deforestation in the leakage belt	
IDz >	1	2	…	Z		
Name >	Zone 1	Zone 2	Zone 3	Zone Z	$ABSLLK_t$	*ABSLLK*
Project year *t*	ha	ha	ha		ha	ha
0						
1						
2						
3						
T						

Method 2: Modeling

The future spatial distribution of post-deforestation LU/LC classes is determined using a spatial model. Two modeling techniques can be used:

a) Projection of LU/LC-change categories: Some deforestation modeling tools can be used to project several LU/LC-change categories at the same time, instead of just the broad category "deforestation". In such cases, the non-forest classes are determined by each projected category of change. Methods discussed in section 4.2.3 shall be used to select the most accurate prediction map.

b) Suitability modeling:

- Criteria must be identified determining the suitability of each main post-deforestation LU/LC class, such as soil type, elevation, slope, etc. (as selected and justified by the project proponent).
- Using multi-criteria analysis the suitability of each post-deforestation LU/LC class is determined for each spatial location. At each spatial location the class with the highest suitability value is assumed to be the one that deforestation agents will implement in absence of the AUD project activity.

- Show the results obtained in maps and summarize the results in tables 13.b and 13.c above (13.a is optional). Note that by using Method 2, each post-deforestation LU/LC class *fcl* will represent one and only one "zone" *z* (i.e. "*fcl*" = "*z*")
- The model must demonstrably comply with statistical good practice, and evidence that such requirement has been met shall be provided to VCS verifiers at the time of validation.

5.3 Calculation of baseline activity data per LU/LC change category

This sub-step is only applicable in conjunction with the Method 2 described above. The goal of this sub-step is to identify the categories of LU/LC-change (*ct*) and the level of activity data of each of these categories. This is performed as follows:

- Combine the maps showing the polygons of forest classes (*icl*) that would be deforested during each future year produced in step 4.2.4 with the map showing the post-deforestation LU/LC classes (*fcl*) prepared in step 5.2.
- From the combined datasets produce a new set of maps showing the polygons of the categories of LU/LC change (*ct*) for each future year. Some spatial modeling tools can produce these maps directly.
- Extract from the maps produced above the number of hectares (i.e., activity data) corresponding to each future year.
- Summarize the results in table 14.a (optional), 14.b and 14.c for the fixed baseline period and, optionally, for the project crediting period.

Table 14.a. Baseline activity data for LU/LC change categories (*ct*) in the reference region

Activity data per LU/LC category *ct* within the reference region					Total baseline deforestation in the reference region	
ID_{ct}	1	2	…	*Ict*		
Name >					*$ABSLRR_t$* annual	*ABSLRR* cumulative
Project year *t*	ha	ha	ha	ha	ha	ha
0						
1						
2						
. . .						
T						

Table 14.b. Baseline activity data for LU/LC change categories (*ct*) in the project area

Activity data per LU/LC category *ct* within the project area					Total baseline deforestation in the project area	
ID_{ct}	1	2	…	*Ict*		
Name >					$ABSLPA_t$ annual	*ABSLPA* cumulative
Project year *t*	ha	ha	ha	ha	ha	ha
0						
1						
2						
. . .						
T						

Table 14.c. Baseline activity data for LU/LC change categories (*ct*) in the leakage belt

Activity data per LU/LC category *ct* within the Leakage belt					Total baseline deforestation in the leakage belt	
ID_{ct}	1	2	…	*Ict*		
Name >					$ABSLLK_t$ annual	*ABSLLK* cumulative
Project year *t*	ha	ha	ha	ha	ha	ha
0						
1						
2						
. . .						
T						

6 STEP 6: ESTIMATION OF BASELINE CARBON STOCK CHANGES AND NON-CO_2 EMISSIONS

The goal of this step is to finalize the baseline assessment by calculating:

6.1 Baseline carbon stock changes; and (optionally)

6.2 Baseline non-CO_2 emissions from forest fires used to clear forests.

6.1 Estimation of baseline carbon stock changes

Before calculating the baseline carbon stock changes it is necessary to estimate the average carbon stock (tCO_2-e ha^{-1}) of each LU/LC class.

6.1.1 Estimation of the average carbon stocks of each LU/LC class

Average carbon stocks must be estimated only for:

- the forest classes existing within the project area[34];

[34] In most cases the forest classes existing within the project area at the project start date will remain the same in the baseline case. However, where certain areas within the project boundary are subject to baseline degradation

- the forest classes existing within the leakage belt[35];
- the post-deforestation classes projected to exist in the project area in the baseline case;
- the post-deforestation classes projected to exist in the leakage belt in the project case; and
- the non-forest classes existing in leakage management areas.

Collect existing carbon-stock data for these classes from local published studies and existing forest and carbon inventories. Do additional field measurements for the classes for which there is insufficient information. Follow the guidance below:

a) Assess the existing data collected and, where appropriate, use them. It is likely that some existing data could be used to quantify the carbon stocks of one or more classes. These data could be derived from a forest inventory or perhaps from scientific studies. Analyze these data and use them if the following criteria are fulfilled:

   - The data are less than 10 years old;
   - The data are derived from multiple measurement plots;
   - All species above a minimum diameter are included in the inventories;
   - The minimum diameter for trees included is 30 cm or less at breast height (DBH);
   - Data are sampled from good coverage of the classes over which they will be extrapolated.

   Existing data that meet the above criteria shall only be applied across the classes from which they were representatively sampled and not beyond that. See the latest version of the GOFC-GOLD sourcebook on REDD and Gillespie, *et al.* (1992) for methods to analyze these data.

b) Collect missing data. For the classes for which no existing data are available it will be necessary to either obtain the data from field measurement or to use conservative estimates from the literature.

   Field measurements:

   - Locate the sampling sites. If the locations of future deforestation are known at the time of field measurements, the sample sites should be located at the locations expected to be deforested to achieve maximum accuracy of the carbon stock estimates.
   - Design the sampling framework and conduct the field measurements following the guidance of appendix 3 (see also chapter 4.3 of GPG LULUCF and in the sourcebook for LULUCF by Pearson *et al*., 2005). Summarize the sampling design in the PD and provide a map and the coordinates of all sampled locations.

   Literature estimates:

   - The use of carbon stock estimates in similar ecosystems derived from local studies, literature and IPCC defaults is permitted[36], provided the accuracy and conservativeness of the estimates are demonstrated.

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due to unsustainable logging, fuel wood collection, charcoal production and other reasons, the decrease in carbon stocks must be projected. If carbon stocks are subject to enhancement, the projection is optional and can conservatively be omitted.

[35] In most cases the forest classes existing at the project start date within the leakage belt will remain the same in the baseline case. However, where certain areas within the leakage belt are subject to enhancement in the baseline case, carbon stocks must be projected for each year. If carbon stocks are subject to baseline degradation, projecting the changes in carbon stocks is optional and can conservatively be omitted.

- When defaults are used, the lowest value of the range given in the literature source (or the value reduced by 30%) must be used for the forest classes, and the highest value (or the value augmented by 30%) for non-forest classes.

c) Calculate the carbon stocks existing in each forest class in the project area prior to the year of baseline deforestation. For all years preceding the year in which the projected baseline deforestation will occur (*t* <= *t**) carbon stocks and boundaries of the forest-classes are assumed to remain the same, except in the following cases:

- If in the baseline case the forest within certain polygons of the project area is degrading and loosing carbon stocks, a map sequence showing the spatial and temporal sequence of forest classes with successively lower carbon stocks must be prepared to account for the degradation occurring prior to deforestation. If the boundary of the forest classes undergoing degradation is fixed (i.e. does not change over time) it is sufficient to show the estimated changes in carbon stocks in a table (Table 15a and Table 15b). To do the projection, use credible and verifiable sources of data from existing studies, or measure field plots in degraded forests of different known age.
- If in the baseline case the forest within certain polygons of the project area has increasing carbon stocks, changes in carbon stocks can conservatively be omitted. If a projection is done, use credible and verifiable sources of data from existing studies, or measure field plots in secondary forests of different known age.
- If carbon stocks in the project area are decreasing more in the project case than in the baseline case (e.g. when the project activity involves logging for timber, fuel-wood collection or charcoal production in areas not subject to such activities in the baseline case), this will have to be accounted in the project case.
- If logging activities are present in the baseline, the harvested wood product carbon pool must be estimated and, if significantly higher in the baseline compared to the project scenario, it will have to be accounted.
- Report the results of the estimations in Table 15.a (estimated values) and Table 15.b (values used in calculations after considering discounts for uncertainties according to "f" below).
- Carbon stocks in the harvested wood products carbon pool must be estimated as the sum of planned and unplanned harvesting activities in the baseline case and the additional volume harvested prior to the deforestation event in year *t** (if applicable).

d) Calculate the carbon stocks existing in each forest class in the leakage belt prior to the year of baseline deforestation (*t* = *t**): For all years preceding the year in which the projected baseline deforestation will occur (*t* > *t**) carbon stocks and boundaries of the forest-classes are assumed to remain the same, except in the following cases:

- If in the baseline case the forest within certain polygons of the leakage belt is growing and carbon stocks are increasing, a map sequence showing the spatial and temporal sequence of forest classes with successively higher carbon stocks must be prepared to account for the

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[36] Attention must be paid on data units. In this methodology calculations are done in tCO_2-e while IPCC tables often provide data in tC (1 tC = 44/12 t CO_2-e)

carbon stock enhancement. To do the projection, use credible and verifiable sources of data from existing studies, or measure field plots in secondary forests of different known age.

- If in the baseline case the forest within certain polygons of the leakage belt is degrading and loosing carbon stocks, changes in carbon stocks can conservatively be omitted and preparing a map sequence is optional for these polygons.
- Report the results of the estimations in Table 15.a (estimated values) and Table 15.b (values used in calculations after considering discounts for uncertainties according to "f" below).

Table 15. Carbon stocks per hectare of initial forest classes *icl* existing in the project area and leakage belt (the selection of carbon pools is subject to the latest VCS requirements on this matter, see Table 3)

Table 15.a. Estimated values

(In this table, forest classes not undergoing degradation or carbon stock enhancement will have a constant carbon stock value each year)

Project year *t*	Initial forest class *icl* Name: ID $_{icl}$ Average carbon stock per hectare ± 90% CI																			
	Cab $_{icl}$		***Cbb*** $_{icl}$		***Cdw*** $_{icl}$		***Cl*** $_{icl}$		***Csoc*** $_{icl}$		***Cwp*** $_{icl}$ (3) short lived *		medium lived **		long lived ***		***Ctot*** $_{icl}$	
	C stock t CO_2e ha^{-1}	± 90% CI t CO_2e ha^{-1}	*C stock* t CO_2e ha^{-1}	± 90% CI t CO_2e ha^{-1}	*C stock* t CO_2e ha^{-1}	± 90% CI t CO_2e ha^{-1}	*C stock* t CO_2e ha^{-1}	± 90% CI t CO_2e ha^{-1}	*C stock* t CO_2e ha^{-1}	± 90% CI t CO_2e ha^{-1}	*C stock* t CO_2e ha^{-1}	± 90% CI t CO_2e ha^{-1}	*C stock* t CO_2e ha^{-1}	± 90% CI t CO_2e ha^{-1}	*C stock* t CO_2e ha^{-1}	± 90% CI t CO_2e ha^{-1}	*C stock* t CO_2e ha^{-1}	± 90% CI t CO_2e ha^{-1}
0																				
1																				
2																				
…																				
T																				

* 0-3 years ** 3-100 years *** > 100 years
(3) = Total carbon stocks in wood products supposed to be harvested at year *t** (year in which deforestation occurs)

For space reasons only the sum of CWP_{icl} (3) is shown in the table above. This is the sum of two components, as shown below (the same applies to Table 15.b.):

Project year *t*	Average carbon stock per hectare ± 90% CI																	
	Cwp $_{icl}$ (1)						***Cwp*** $_{icl}$ (2)						***Cwp*** $_{icl}$ (3)					
	short lived *		*medium lived* **		*long lived* ***		*short lived* *		*medium lived* **		*long lived* ***		*short lived* *		*medium lived* **		*long lived* ***	
	C stock	± 90% CI	*C stock*	± 90% CI	*C stock*	± 90% CI	*C stock*	± 90% CI	*C stock*	± 90% CI	*C stock*	± 90% CI	*C stock*	± 90% CI	*C stock*	± 90% CI	*C stock*	± 90% CI
	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$
0																		
1																		
2																		
…																		
T																		

(1) = C stock in wood products of planned and unplanned baseline activities (degradation)

(2) = C stock in wood products extracted in addition to those extracted in planned/unplanned degradation activities in case of deforestation (*t* = *t**)

(3) = Total carbon stocks in wood products supposed to be harvested at year *t** (year in which deforestation occurs)

Table 15.b. Values to be used after discounts for uncertainties (see 6.1.1.f, and Appendix 2)

Project year *t*	Initial forest class *icl*																	
	Name:																	
	ID $_{icl}$																	
	Average carbon stock per hectare ± 90% CI																	
	Cab $_{icl}$		***Cbb*** $_{icl}$		***Cdw*** $_{icl}$		***Cl*** $_{icl}$		***Csoc*** $_{icl}$		***Cwp*** $_{icl}$ (3)						***Ctot*** $_{icl}$	
											short lived *		*medium lived* **		*long lived* ***			
	C stock	*C stock change*	*C stock*	*C stock change*	*C stock*	*C stock change*	*C stock*	*C stock change*	*C stock*	*C stock change*	*C stock*	*C stock change*	*C stock*	*C stock change*	*C stock*	*C stock change*	*C stock*	*C stock change*
	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$	$t CO_2e ha^{-1}$
0																		
1																		
2																		
…																		
T																		
Notes																		

* 0-3 years ** 3-100 years *** > 100 years

(3) = Total carbon stocks in wood products supposed to be harvested at year *t** (year in which deforestation occurs)

The space "Notes" in table 15.1.2 is intended to insert explanations (or references to explanations) about how uncertainties have been considered.

Where:

Cab_{icl}	Average carbon stock per hectare in the above-ground biomass carbon pool of class *icl*; tCO_2-e ha^{-1}
Cbb_{icl}	Average carbon stock per hectare in the below-ground biomass carbon pool of class *icl*; tCO_2-e ha^{-1}
Cdw_{icl}	Average carbon stock per hectare in the dead wood biomass carbon pool of class *icl*; tCO_2-e ha^{-1}
Cl_{icl}	Average carbon stock per hectare in the litter carbon pool of LU/LC class *icl*; tCO_2-e ha^{-1}
$Csoc_{icl}$	Average carbon stock per hectare in the soil organic carbon pool of LU/LC class *icl*; tCO_2-e ha^{-1}
Cwp_{icl}	Average carbon stock per hectare accumulated in the harvested wood products carbon pool between project start and the year of deforestation of class *icl*; tCO_2-e ha^{-1}

Note: In the baseline case, Cwp_{cl} must be subtracted from the sum of the other pools in the calculation of $Ctot_{cl}$

$Ctot_{icl}$	Average carbon stock per hectare in all accounted carbon pools of LU/LC *icl*; tCO_2-e ha^{-1}

e) Calculate the long-term (20-years) average carbon stocks of post-deforestation classes: These classes often do not have a stable carbon stock because different land uses may be implemented in a time sequence or because the land use after deforestation implies carbon stocks changes over time (e.g. in case of tree plantations). The carbon stock of post-deforestation classes must be estimated as the long-term (20 years) average carbon stock and can be determined from measurements in plots of known age, long-term studies and other verifiable sources.

For each post-deforestation LU/LC class, report the calculation of the long-term (20-year) average carbon stock using Table 16.

f) Do an uncertainty assessment of all carbon stock estimates following the methods described in appendix 2, Box 2. If the uncertainty of the total average carbon stock ($Ctot_{cl}$) of a class *cl* is less than 10% of the average value, the average carbon stock value can be used. If the uncertainty is higher than 10%, the lower boundary of the 90% confidence interval must be considered in the calculations if the class is an initial forest class in the project area or a final non-forest class in the leakage belt, and the higher boundary of the 90% confidence interval if the class is an initial forest class in the leakage belt or a final non-forest class in the project area.

g) Calculate the area-weighted average carbon stocks of the post-deforestation LU/LC classes existing within each zone using Table 17.

Table 16. Long-term (20-years) average carbon stocks per hectare of post-deforestation LU/LC classes present in the reference region (the selection of carbon pools is subject to the latest VCS requirements on this matter, see table 3)

Porject year	Post deforestation class *fcl* Name: ID *fcl* Average carbon stock per hectare ± 90% CI															
	$C_{ab\,fcl}$		$C_{bb\,fcl}$		$C_{dw\,fcl}$		$C_{l\,fcl}$		$C_{soc\,fcl}$		$C_{wp\,fcl}$ (4) short lived *		medium lived **		long lived ***	
	average stock	± 90% CI	average stock	± 90% CI	average stock	± 90% CI	average stock	± 90% CI	average stock	± 90% CI	C stock	± 90% CI	C stock	± 90% CI	C stock	± 90% CI	$C_{tot\,fcl}$ average stock	± 90% CI
t	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}
*t**											0	0	0	0	0	0		
*t**+1											0	0	0	0	0	0		
*t**+2											0	0	0	0	0	0		
*t**+19											0	0	0	0	0	0		
Average											0	0	0	0	0	0		
Average to be used in calculations*																		

* After discounts for uncetainties (see 6.1.1.f, and Appendix 2)

* 0-3 years ** 3-100 years *** > 100 years
(4) = Total carbon stocks in wood products in post-deforestation land-uses is considered insignificant a priori in VM0015, V2.0

Table 17. Long-term (20-years) area weighted average carbon stock per zone[37]

Zone		Post -deforestation LU/LC-classes *fcl* Name: ID *fcl* 1						Name: ID *fcl* *Fcl*						Area weighted long-term (20 years) average carbon stocks per zone *z*						
		$C_{ab\,fcl}$	$C_{bb\,fcl}$	$C_{dw\,fcl}$	$C_{l\,fcl}$	$C_{soc\,fcl}$	$C_{wp\,fcl}$	$C_{ab\,fcl}$	$C_{bb\,fcl}$	$C_{dw\,fcl}$	$C_{l\,fcl}$	$C_{soc\,fcl}$	$C_{wp\,fcl}$	$C_{ab\,z}$	$C_{bb\,z}$	$C_{dw\,z}$	$C_{l\,z}$	$C_{soc\,z}$	$C_{wp\,z}$	$C_{tot\,z}$
		C stock	C stock	C stock	C stock	C stock	C stock	C stock	C stock	C stock	C stock	C stock	C stock	C stock	C stock	C stock	C stock	C stock	C stock	C stock
IDz	Name	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}	t CO_2e ha^{-1}
1	Zone 1																			
2	Zone 2																			
…	Zone 3																			
Z	Zone Z																			

(Insert as many *flc* classes as needed)

37 If Method 2 was used in step 5.2, then each zone will have only one post-deforestacion class *fcl*.

6.1.2 Calculation of carbon stock change factors

The *AFOLU Requirements* requires methodologies to consider the decay of carbon stock in soil carbon, below-ground biomass, dead wood and harvested wood products in the baseline case.

In this methodology default linear functions are applied to account for the decay of carbon stock in initial forest classes (*icl*) and increase in carbon stock in post-deforestation classes. This is done as follows:

a) Above-ground biomass:

- Initial forest classes (*icl*): immediate release of 100% of the carbon stock (as estimated in Table 15.b) is assumed to happen at the end of year $t = t^*$ (= year in which deforestation occurs).
- Post-deforestation classes (*fcl*) (or their area weighted average per zone *z*): linear increase from 0 tCO_2-e/ha in year $t = t^*$ to 100% of the long-term (20-years) average carbon stock (as estimated in Table 17) in year $t = t^*+9$ is assumed to happen in the 10-years period following deforestation (i.e. $1/10^{th}$ of the final carbon stock is accumulated each year).

b) Below-ground biomass:

- Initial forest classes (*icl*): an annual release of $1/10^{th}$ of the initial carbon stock (as estimated in Table 15.b) is assumed to happen each year between $t = t^*$ and $t = t^*+9$.
- Post-deforestation classes (*fcl*) (or their area weighted average per zone *z*): linear increase from 0 tCO_2-e/ha in year $t = t^*$ to 100% of the long-term (20-years) average carbon stock (as estimated in Table 17) in year $t = t^*+9$ is assumed to happen in the 10 years period following deforestation (i.e. $1/10^{th}$ of the final carbon stock is accumulated each year).

c) Litter:

- Initial forest classes (*icl*): immediate release of 100% of the carbon stock (as estimated in Table 15.b) is assumed to happen at the end of year $t = t^*$.
- Post-deforestation classes (*fcl*) (or their area weighted average per zone *z*): a linear increase from 0 tCO_2-e/ha in year $t = t^*$ to 100% of the long-term (20-years) average carbon stock (as estimated in Table 17) in year $t = t^*+9$ is assumed to happen in the 10-years period following deforestation (i.e. $1/10^{th}$ of the final carbon stock is accumulated each year).

d) Dead wood:

- Initial forest classes (*icl*): an annual release of $1/10^{th}$ of the initial carbon stock (as estimated in Table 15.b) is assumed to happen each year between $t = t^*$ and $t = t^*+9$.
- Post-deforestation classes (*fcl*) (or their area weighted average per zone *z*): a linear increase from 0 tCO_2-e/ha in year $t = t^*$ to 100% of the long-term (20-years) average carbon stock (as estimated in Table 17) in year $t = t^*+9$ is assumed to happen in the 10-years period following deforestation (i.e. $1/10^{th}$ of the final carbon stock is accumulated each year).

e) Wood products:

- Initial forest classes (*icl*): Three fractions are considered:

  1) Fraction decaying in less than three years: This short-lived fraction is assumed to be released 100% at the end of year t^* (i.e. 100% of the stock estimated in Table 15.b).

2) Fraction decaying between 3 and 100 years: This medium-lived fraction is assumed to linearly decay in 20 years (i.e. each year 1/20 of the stock estimated in Table 15.b).

3) Fraction decaying in more than 100 years: This long-lived fraction is assumed to never decay (i.e. never be released into the atmosphere).

- Post-deforestation classes (*fcl*) (or their area weighted average per zone *z*): it is assumed that carbon stocks in wood products are always insignificant (i.e. carbon stock in all wood products is zero).

f) Soil organic carbon:

- It is assumed that in a 20-years period the carbon stock changes from the level estimated for the initial forest classes (*icl*) (in Table 15.b) to the level estimated for the post-deforestation class *fcl* (or their area weighted average per zone *z*). The change occurs linearly and can be either a decrease or an increase, depending on the carbon stock estimated for the initial forest class and for the final post-deforestation class *fcl* or zone *z*.

- If carbon stocks in the soil organic carbon pool are included in the baseline, it will be necessary to calculate activity data per category (*ct*). This is because the linear decay (or increase) function is category-dependent. If method 2 was used in Step 5.3, Table 14 will provide the information on activity data per category *ct*. If method 1 was used, it will be necessary to define categories (from initial forest classes *icl* to zones *z*). Use Table 18.a and 18.b to describe these categories and combine the Map of Zones of Post-Deforestation Land Uses with the map of initial forest classes and the annual maps of projected deforestation to calculate activity data of these categories (*ctz*). Report the results in Tables 19.a, 19.b and 19.c. Do this at least for the fixed baseline period and the project area and leakage belt and, optionally, for the entire project crediting period and for the reference region.

Tables 20.a, 20.b and 20.c summarize how carbon stock change factors are calculated.

Table 18.a Potential land-use and land-cover change matrix

			Initial LU/LC class *icl*					
		ID_{cl}	1	2	…	…	…	*Fcl*
	ID_z	Name						
Zone *z*	1	Zone 1						
	2	Zone 2						
	…	Zone ..						
	…	Zone …						
	…	Zone …						
	Z	Zone Z						

Table 18.b List of land-use and land-cover change categories (*ctz*)

LU/LC-Change Category		Initial Forest Class		Post-Deforestation Zone	
ID_{ctz}	Name	ID_{icl}	Name	ID_{icl}	Name
1					
2					
…					
Ctz					

Table 19.a Annual areas deforested in each category *ctz* within the reference region in the baseline case (baseline activity data per category (*ctz*)[38]

	Activity data per LU/LC category *ctz* within the reference region					Total baseline deforestation in the reference region	
ID_{ct} >	1	2	3	…	*Ctz*	$ABSLRR_t$	*ABSLRR*
Name >						annual	cumulative
Project year *t*	ha	ha	ha	ha	ha	ha	ha
0							
1							
1							
T							

Table 19.b Annual areas deforested in each category *ctz* within the project area in the baseline case (baseline activity data per category (*ctz*)

	Activity data per LU/LC category *ctz* within the reference region					Total baseline deforestation in the reference region	
ID_{ct} >	1	2	3	…	*Ctz*	$ABSLPA_t$	*ABSLPA*
Name >						annual	cumulative
Project year *t*	ha	ha	ha	ha	ha	ha	ha
0							
1							
1							
T							

38 This table is optional

Table 19.c Annual areas deforested in each category *ctz* within the leakage belt area in the baseline case (baseline activity data per category (*ctz*)

	Activity data per LU/LC category *ctz* within the reference region					Total baseline deforestation in the reference region	
ID_{ct} >	1	2	3	…	*Ctz*	$ABSLLK_t$	*ABSLLK*
Name >						annual	cumulative
Project year *t*	ha	ha	ha	ha	ha	ha	ha
0							
1							
1							
T							

6.1.3 Calculation of baseline carbon stock changes

The choice of the method to calculate carbon stock changes depends on whether activity data are available for classes or for categories. If soil organic carbon is included in the baseline only Method 2 can be used (i.e. activity data must be defined for categories).

If activity data are available for classes (Method 1), the total baseline carbon stock change in the project area at year *t* is calculated as follows:

$$\Delta CBSLPA_t = \sum_{p=1}^{P}\Bigg(\sum_{icl=1}^{Icl} ABSLPA_{icl,t} * \Delta Cp_{icl,t=t*} - \sum_{z=1}^{Z} ABSLPA_{z,t} * \Delta Cp_{z,t=t*}$$
$$+ \sum_{icl=1}^{Icl} ABSLPA_{icl,t-1} * \Delta Cp_{icl,t=t*+1} - \sum_{z=1}^{Z} ABSLPA_{z,t-1} * \Delta Cp_{z,t=t*+1}$$
$$+ \sum_{icl=1}^{Icl} ABSLPA_{icl,t-2} * \Delta Cp_{icl,t=t*+2} - \sum_{z=1}^{Z} ABSLPA_{z,t-2} * \Delta Cp_{z,t=t*+2} \quad + \cdots$$
$$+ \sum_{icl=1}^{Icl} ABSLPA_{icl,t-19} * \Delta Cp_{icl,t=t*+19} - \sum_{z=1}^{Z} ABSLPA_{z,t-19} * \Delta Cp_{z,t=t*+19}\Bigg) \tag{10}$$

Where:

$\Delta CBSLPA_t$	Total baseline carbon stock change within the project area at year *t*; tCO_2-e
$ABSLPA_{icl,t}$	Area of initial forest class *icl* deforested at time *t* within the project area in the baseline case; ha
$ABSLPA_{icl,t-1}$	Area of initial forest class *icl* deforested at time *t*-1 within the project area in the baseline case; ha

…

$ABSLPA_{icl,t=t-19}$	Area of initial forest class *icl* deforested at time *t*-19 within the project area in the baseline case; ha
$\Delta Cp_{icl,t=t^*}$	Average carbon stock change factor for carbon pool *p* in the initial forest class *icl* applicable at time *t* (as per Table 20.a); tCO_2-e ha^{-1}
$\Delta Cp_{icl,t=t^*+1}$	Average carbon stock change factor for carbon pool *p* in the initial forest class *icl* applicable at time *t*=*t**+1 (= 2nd year after deforestation, as per Table 20.a); tCO_2-e ha^{-1}
…	
$\Delta Cp_{icl,t=t^*+19}$	Average carbon stock change factor for carbon pool *p* in the initial forest class *icl* applicable at time *t*=*t**+19 (20th year after devorestation, (as per Table 20.a); tCO_2-e ha^{-1}
$ABSLPA_{z,t}$	Area of the zone *z* “deforested” at time *t* within the project area in the baseline case; ha
$ABSLPA_{z,t-1}$	Area of the zone *z* “deforested” at time *t*-1 within the project area in the baseline case; ha
…	
$ABSLPA_{z,t-19}$	Area of the zone *z* “deforested” at time *t* -19 within the project area in the baseline case; ha
$\Delta Cp_{z,t=t^*}$	Average carbon stock change factor for carbon pool *p* in zone *z* applicable at time *t* = *t** (as per Table 20.b); tCO_2-e ha^{-1}
$\Delta Cp_{z,t=t^*+1}$	Average carbon stock change factor for carbon pool *p* in zone *z* applicable at time *t* = *t**+1 ((= 2nd year after deforestation, as per Table 20.b); tCO_2-e ha^{-1}
…	
$\Delta Cp_{z,t=t^*+19}$	Average carbon stock change factor for carbon pool *p* in zone *z* applicable at time *t* = *t**+19 ((= 20th year after deforestation, as per Table 20.b); tCO_2-e ha^{-1}
icl	1, 2, 3 … *Icl* initial (pre-deforestation) forest classes; dimensionless
z	1, 2, 3 … *Z* zones; dimensionless
p	1, 2, 3 ... *P* carbon pools included in the baseline; dimensionless
t	1, 2, 3 … *T,* a year of the proposed project crediting period; dimensionless
*t**	the year at which the area $ABSLPA_{icl,t}$ is deforested in the baseline case.

Notes:

Equation 10 can be applied to all carbon pools, except soil organic carbon. Separate calculation of each carbon pool is necessary to do the significance analysis of each pool in Step 9.1.

Equation 10 should also be applied to the leakage belt area and, optionally, to the reference region. Calculations must be made at least for the fixed baseline period and, optionally, for the entire project crediting period.

Report the result of the calculations in Tables 21.a 1-6 (for the reference region); Tables 21.b.1-6 (for the project area); and Tables 21.c1-6 (for the leakage belt area).

Table 20.a. Carbon stock change factors for initial forest classes *icl* (Method 1)

Year after deforestation		$\Delta Cab_{icl,t}$	$\Delta Cbb_{icl,t}$	$\Delta Cdw_{icl,t}$	$\Delta Cl_{icl,t}$	$\Delta Csoc_{icl,t}$	$\Delta Cwp_{icl,t}$		
							short-lived	medium-lived	long-lived
1	t*	$-Cab_{icl,t}$	$-1/10*Cbb_{icl,t=t*}$	$-1/10*Cdw_{icl,t=t*}$	$-Cl_{icl,t}$	use method 2	$-Cwp_{icl,t=t*}$	$-1/20*Cwp_{icl,t=t*}$	0
2	t*+1	0	$-1/10*Cbb_{icl,t=t*}$	$-1/10*Cdw_{icl,t=t*}$	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
3	t*+2	0	$-1/10*Cbb_{icl,t=t*}$	$-1/10*Cdw_{icl,t=t*}$	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
4	t*+3	0	$-1/10*Cbb_{icl,t=t*}$	$-1/10*Cdw_{icl,t=t*}$	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
5	t*+4	0	$-1/10*Cbb_{icl,t=t*}$	$-1/10*Cdw_{icl,t=t*}$	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
6	t*+5	0	$-1/10*Cbb_{icl,t=t*}$	$-1/10*Cdw_{icl,t=t*}$	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
7	t*+6	0	$-1/10*Cbb_{icl,t=t*}$	$-1/10*Cdw_{icl,t=t*}$	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
8	t*+7	0	$-1/10*Cbb_{icl,t=t*}$	$-1/10*Cdw_{icl,t=t*}$	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
9	t*+8	0	$-1/10*Cbb_{icl,t=t*}$	$-1/10*Cdw_{icl,t=t*}$	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
10	t*+9	0	$-1/10*Cbb_{icl,t=t*}$	$-1/10*Cdw_{icl,t=t*}$	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
11	t*+10	0	0	0	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
12	t*+11	0	0	0	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
13	t*+12	0	0	0	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
14	t*+13	0	0	0	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
15	t*+14	0	0	0	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
16	t*+15	0	0	0	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
17	t*+16	0	0	0	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
18	t*+17	0	0	0	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
19	t*+18	0	0	0	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
20	t*+19	0	0	0	0	use method 2	0	$-1/20*Cwp_{icl,t=t*}$	0
21-T	t*+20, …	0	0	0	0	0	0	0	0

Table 20.b. Carbon stock change factors for final classes *fcl* or zones *z* (Method 1)

Year after deforestation		$\Delta Cab_{z,t}$	$\Delta Cbb_{z,t}$	$\Delta Cdw_{z,t}$	$\Delta Cl_{z,t}$	$\Delta Csoc_{z,t}$	$\Delta Cwp_{z,t}$		
							short-lived	medium-lived	long-lived
1	t*	+ 1/10*Cab_z	+1/10*Cbb_z	+1/10*Cdw_z	+1/10*Cl_z	use method 2	0	0	0
2	t*+1	+ 1/10*Cab_z	+1/10*Cbb_z	+1/10*Cdw_z	+1/10*Cl_z	use method 2	0	0	0
3	t*+2	+ 1/10*Cab_z	+1/10*Cbb_z	+1/10*Cdw_z	+1/10*Cl_z	use method 2	0	0	0
4	t*+3	+ 1/10*Cab_z	+1/10*Cbb_z	+1/10*Cdw_z	+1/10*Cl_z	use method 2	0	0	0
5	t*+4	+ 1/10*Cab_z	+1/10*Cbb_z	+1/10*Cdw_z	+1/10*Cl_z	use method 2	0	0	0
6	t*+5	+ 1/10*Cab_z	+1/10*Cbb_z	+1/10*Cdw_z	+1/10*Cl_z	use method 2	0	0	0
7	t*+6	+ 1/10*Cab_z	+1/10*Cbb_z	+1/10*Cdw_z	+1/10*Cl_z	use method 2	0	0	0
8	t*+7	+ 1/10*Cab_z	+1/10*Cbb_z	+1/10*Cdw_z	+1/10*Cl_z	use method 2	0	0	0
9	t*+8	+ 1/10*Cab_z	+1/10*Cbb_z	+1/10*Cdw_z	+1/10*Cl_z	use method 2	0	0	0
10	t*+9	+ 1/10*Cab_z	+1/10*Cbb_z	+1/10*Cdw_z	+1/10*Cl_z	use method 2	0	0	0
11	t*+10	0	0	0	0	use method 2	0	0	0
12	t*+11	0	0	0	0	use method 2	0	0	0
13	t*+12	0	0	0	0	use method 2	0	0	0
14	t*+13	0	0	0	0	use method 2	0	0	0
15	t*+14	0	0	0	0	use method 2	0	0	0
16	t*+15	0	0	0	0	use method 2	0	0	0
17	t*+16	0	0	0	0	use method 2	0	0	0
18	t*+17	0	0	0	0	use method 2	0	0	0
19	t*+18	0	0	0	0	use method 2	0	0	0
20	t*+19	0	0	0	0	use method 2	0	0	0
21-T	t*+20, ..	0	0	0	0	0	0	0	0

Table 20.c. Carbon stock change factors for land-use change categories (*ct* or ctz) (Method 2)

Year after deforestation		$\Delta Cab_{ctz,t}$	$\Delta Cbb_{ctz,t}$	$\Delta Cdw_{ctz,t}$	$\Delta Cl_{ctz,t}$	$\Delta Csoc_{ctz,t}$	$\Delta Cwp_{ctz,t}$		
							short-lived	medium-lived	long-lived
1	t*	-Cabicl,t + 1/10*Cab_z	-1/10*Cbbicl,t=t* +1/10*Cbb_z	-1/10*Cdwicl,t=t* +1/10*Cdw_z	-Clicl,t +1/10*Cl_z	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	-$Cwp_{icl,t=t*}$	-1/20*$Cwp_{icl,t=t*}$	0
2	t*+1	+ 1/10*Cab_z	-1/10*Cbbicl,t=t* +1/10*Cbb_z	-1/10*Cdwicl,t=t* +1/10*Cdw_z	+ 1/10*Cl_z	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
3	t*+2	+ 1/10*Cab_z	-1/10*Cbbicl,t=t* +1/10*Cbb_z	-1/10*Cdwicl,t=t* +1/10*Cdw_z	+ 1/10*Cl_z	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
4	t*+3	+ 1/10*Cab_z	-1/10*Cbbicl,t=t* +1/10*Cbb_z	-1/10*Cdwicl,t=t* +1/10*Cdw_z	+ 1/10*Cl_z	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
5	t*+4	+ 1/10*Cab_z	-1/10*Cbbicl,t=t* +1/10*Cbb_z	-1/10*Cdwicl,t=t* +1/10*Cdw_z	+ 1/10*Cl_z	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
6	t*+5	+ 1/10*Cab_z	-1/10*Cbbicl,t=t* +1/10*Cbb_z	-1/10*Cdwicl,t=t* +1/10*Cdw_z	+ 1/10*Cl_z	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
7	t*+6	+ 1/10*Cab_z	-1/10*Cbbicl,t=t* +1/10*Cbb_z	-1/10*Cdwicl,t=t* +1/10*Cdw_z	+ 1/10*Cl_z	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
8	t*+7	+ 1/10*Cab_z	-1/10*Cbbicl,t=t* +1/10*Cbb_z	-1/10*Cdwicl,t=t* +1/10*Cdw_z	+ 1/10*Cl_z	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
9	t*+8	+ 1/10*Cab_z	-1/10*Cbbicl,t=t* +1/10*Cbb_z	-1/10*Cdwicl,t=t* +1/10*Cdw_z	+ 1/10*Cl_z	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
10	t*+9	+ 1/10*Cab_z	-1/10*Cbbicl,t=t* +1/10*Cbb_z	-1/10*Cdwicl,t=t* +1/10*Cdw_z	+ 1/10*Cl_z	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
11	t*+10	0	0	0	0	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
12	t*+11	0	0	0	0	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
13	t*+12	0	0	0	0	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
14	t*+13	0	0	0	0	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
15	t*+14	0	0	0	0	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
16	t*+15	0	0	0	0	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
17	t*+16	0	0	0	0	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
18	t*+17	0	0	0	0	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
19	t*+18	0	0	0	0	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
20	t*+19	0	0	0	0	1/20*($Csoc_{icl,t*}$-$Csoc_z$)	0	-1/20*$Cwp_{icl,t=t*}$	0
21-T	t*+20, …	0	0	0	0	0	0	0	0

Tables 21.a. **Baseline carbon stock change in the reference region**[39]
(Calculated with Method 1: Activity data per category initial classes *icl* and post-deforestation classes *fcl* or zones *z*)

Table 21.a.1. Baseline carbon stock change in the above-ground biomass in the reference region

Carbon stock changes in the above-ground biomass per initial forest class *icl*					Total carbon stock change in the above-ground biomass of the initial forest classes in the reference region		**Carbon stock changes in above-ground biomass per post-deforestation zone *z***					Total carbon stock change in the above-ground biomass of post-deforestation zones in the reference region		Total net carbon stock change in the above-ground biomass of the reference region	
ID_{icl}>	1	2	…	Icl	$\Delta Cab\ BSLRR_{icl,t}$ annual	$\Delta Cab\ BSLRR_{icl}$ cumulative	ID_{iz}>	1	2	…	z	$\Delta Cab\ BSLRR_{z,t}$ annual	$\Delta Cab\ BSLRR_{z}$ cumulative	$\Delta Cab\ BSLRR_{t}$ annual	$\Delta Cab\ BSLRR$ cumulative
Name >							Name >								
Project year *t*	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	Project year *t*	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
0	0	0	0	0	-	-	0	0	0	0	0	-	-	-	-
1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
…	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
T	-	-	-	-	-	-	*T*	-	-	-	-	-	-	-	-

Note: Prepare a similar table for all selected carbon pools (Table 21.a.2 for below-ground biomass; Table 21.a.3 for dead wood; Table 21.a.4 for litter; Table 21.a.6 for wood products – Use Method 2 if soil organic carbon is included).

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39 These tables are optional.

Tables 21.b. Baseline carbon stock change in the project area

(Calculated with Method 1: Activity data per category initial classes *icl* and post-deforestation classes *fcl* or zones *z*)

Table 21.b.1. Baseline carbon stock change in the above-ground biomass in the project area

Carbon stock changes in the above-ground biomass per initial forest class *icl*					Total carbon stock change in the above-ground biomass of the initial forest classes in the project area	
ID_{icl}>	1	2	...	*Icl*	$\Delta Cab\ BSLPA_{icl,t}$	$\Delta Cab\ BSLPA_{icl}$
Name >					annual	cumulative
Project year *t*	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
0	0	0	0	0	-	-
1	-	-	-	-	-	-
2	-	-	-	-	-	-
...	-	-	-	-	-	-
T	-	-	-	-	-	-

Carbon stock changes in above-ground biomass per post-deforestation zone *z*					Total carbon stock change in the above-ground biomass of post-deforestation zones in the project area	
ID_{iz}>	1	2	...	z	$\Delta Cab\ BSLPA_{z,t}$	$\Delta Cab\ BSLPA_{z}$
Name >					annual	cumulative
Project year *t*	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
0	0	0	0	0	-	-
1	-	-	-	-	-	-
2	-	-	-	-	-	-
3	-	-	-	-	-	-
T	-	-	-	-	-	-

Total net carbon stock change in the above-ground biomass of the project area	
$\Delta Cab\ BSLPA_{t}$	$\Delta Cab\ BSLPA$
annual	cumulative
tCO_2-e	tCO_2-e
-	-
-	-
-	-
-	-
-	-

Note: Prepare a similar table for all selected carbon pools (Table 21.b.2 for below-ground biomass; Table 21.b.3 for dead wood; Table 21.b.4 for litter; and Table 21.b.6 for wood products– Use Method 2 if soil organic carbon is included).

Tables 21.c. Baseline carbon stock change in the leakage belt area
(Calculated with Method 1: Activity data per category initial classes *icl* and post-deforestation classes *fcl* or zones *z*)

Table 21.c.1. Baseline carbon stock change in the above-ground biomass in the leakage belt area

Carbon stock changes in the above-ground biomass per initial forest class *icl*					Total carbon stock change in the above-ground biomass of the initial forest classes in the project area	
ID_{icl}>	1	2	...	*Icl*	$\Delta Cab\ BSLLK_{icl,t}$	$\Delta Cab\ BSLLK_{icl}$
Name >					annual	cumulative
Project year *t*	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
0	0	0	0	0	-	-
1	-	-	-	-	-	-
2	-	-	-	-	-	-
...	-	-	-	-	-	-
T	-	-	-	-	-	-

Carbon stock changes in above-ground biomass per post-deforestation zone *z*					Total carbon stock change in the above-ground biomass of post-deforestation zones in the project area	
ID_{iz}>	1	2	...	z	$\Delta Cab\ BSLLK_{z,t}$	$\Delta Cab\ BSLLK_{z}$
Name >					annual	cumulative
Project year *t*	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
0	0	0	0	0	-	-
1	-	-	-	-	-	-
2	-	-	-	-	-	-
...	-	-	-	-	-	-
T	-	-	-	-	-	-

Project year *t*	Total net carbon stock change in the above-ground biomass of the project area	
	$\Delta Cab\ BSLLK_{t}$	$\Delta Cab\ BSLLK$
	annual	cumulative
	tCO_2-e	tCO_2-e
0	-	-
1	-	-
2	-	-
...	-	-
T	-	-

Note: Prepare a similar table for all selected carbon pools (Table 21.c.2 for below-ground biomass; Table 21.c.3 for dead wood; Table 21.c.4 for litter; and Table 21.c.6 for wood products– Use Method 2 if soil organic carbon is included).

<u>If activity data are available for categories (Method 2),</u> first calculate the carbon stock change factors of each category as shown in table 20.c and then calculate the baseline carbon stock changes for the reference region (optional), project area and leakage belt area by multiplying activity data with their corresponding emission factors. Do this at least for the fixed baseline period and, optionally, for the entire project crediting period.

Report the result of the calculations in Tables 22.a 1-6 (for the reference region); Tables 22.b.1-6 (for the project area); and Tables 22.c1-6 (for the leakage belt area).

Note: It is possible (and simpler) to calculate baseline carbon stock changes using Method 1 for all carbon pools (except soil organic carbon) and, if soil organic carbon is included, using Method 2 just for this pool.

Tables 22.a. Baseline carbon stock change in the reference region[40]
(Calculated with Method 2: Activity data per category *ct* or *ctz*)

Table 22.a.1. Baseline carbon stock change in the above-ground biomass in the reference region

Project year t	Activity data per category x Carbon stock change factor for above-ground biomass in the reference region								Total baseline carbon stock change in the reference region	
	ID_{ct} = 1		ID_{ct} = 2		ID_{ct} = . . .		ID_{ct} = Ct		annual	cumulative
	$ABSLRR_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLRR_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLRR_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLRR_{ct,t}$	$\Delta Cab_{ct,t}$	$\Delta CabBSLRR_t$	$\Delta CabBSLRR$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
0										
1										
2										
. . .										
T										

Note: Prepare a similar table for all selected carbon pools (Table 22.a.2 for below-ground biomass; Table 22.a.3 for dead wood; Table 22.a.4 for litter; Table 22.a.5 for soil organic carbon; and Table 22.a.6 for wood products).

Tables 22.b. Baseline carbon stock change in the project area
(Calculated with Method 2: Activity data per category *ct* or *ctz*)

Table 22.b.1. Baseline carbon stock change in the above-ground biomass in the project area

Project year t	Activity data per category x Carbon stock change factor for above-ground biomass in the project area								Total baseline carbon stock change in the project area	
	ID_{ct} = 1		ID_{ct} = 2		ID_{ct} = . . .		ID_{ct} = Ct		annual	cumulative
	$ABSLPA_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLPA_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLPA_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLPA_{ct,t}$	$\Delta Cab_{ct,t}$	$\Delta CabBSLPA_t$	$\Delta CabBSLPA$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
0										
1										
2										
. . .										
T										

Note: Prepare a similar table for all selected carbon pools (Table 22.b.2 for below-ground biomass; Table 22.b.3 for dead wood; Table 22.b.4 for litter; Table 22.b.5 for soil organic carbon; and Table 22.b.6 for wood products).

[40] These tables are optional.

Tables 22.c. Baseline carbon stock change in the leakage belt area
(Calculated with Method 2: Activity data per category *ct* or *ctz*)

Table 22.c.1. Baseline carbon stock change in the above-ground biomass in the leakage belt area

Project year *t*	Activity data per category x Carbon stock change factor for above-ground biomass in the leakage belt area								Total baseline carbon stock change in the leakage belt area	
	ID_{ct} = 1		ID_{ct} = 2		ID_{ct} = . . .		ID_{ct} = Ct		annual	cumulative
	$ABSLLK_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLLK_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLLK_{ct,t}$	$\Delta Cab_{ct,t}$	$ABSLLK_{ct,t}$	$\Delta Cab_{ct,t}$	$\Delta CabBSLLK_t$	$\Delta CabBSLLK$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
0										
1										
2										
. . .										
T										

Note: Prepare a similar table for all selected carbon pools (Table 22.c.2 for below-ground biomass; Table 22.c.3 for dead wood; Table 22.c 4 for litter; Table 22.c.5 for soil organic carbon; and Table 22.c.6 for wood products).

6.2 Baseline non-CO_2 emissions from forest fires

Emissions from fires used to clear forests in the baseline can always be omitted.

Conversion of forest to non-forest involving fires is a source of emissions of non-CO_2 gases (CH_4 and N_2O). When sufficient data on such forest fires are available from the historical reference period and the project proponent considers that these emissions are an important component of the baseline, CH_4 emissions from biomass burning can be estimated. Where such data are unavailable, or of insufficient accuracy, emissions from biomass burning should not be considered (which is conservative).

The effect of fire on carbon emissions is counted in the estimation of carbon stock changes; therefore CO_2 emissions from forest fires should be ignored to avoid double counting.

To estimate non-CO_2 emissions from forest fires, it is necessary to estimate the average percentage of the deforested area in which fire was used, the average proportion of mass burnt in each carbon pool ($Pburnt_{,p}$), and the average combustion efficiency of each pool (CE_p). These average percentage values are estimated for each forest class (*icl*) and are assumed to remain the same in the future.

Based on revised IPCC 1996 GL LULUCF, GHG emissions from biomass burning can be estimated as follows.

$$EBBtot_{icl,t} = EBBN2O_{icl,t} + EBBCH4_{icl,t} \quad (11)$$

Where:

$EBBtot_{icl,t}$ Total GHG emission from biomass burning in forest class *icl* at year *t*; tCO_2-e ha^{-1}

$EBBN2O_{icl,t}$	N_2O emission from biomass burning in forest class *icl* at year *t*; tCO_2-e ha^{-1}
$EBBCH4_{icl,t}$	CH_4 emission from biomass burning in forest class *icl* at year *t*; tCO_2-e ha^{-1}

$$EBBN2O_{icl,t} = EBBCO2_{icl,t} * 12/44 * NCR*ER_{N2O}*44/28*GWP_{N2O} \quad (12)$$

$$EBBCH4_{icl,t} = EBBCO2_{icl,t} * 12/44 * ER_{CH4}*16/12*GWP_{CH4} \quad (13)$$

Where:[41]

$EBBCO2_{icl,t}$	Per hectare CO_2 emission from biomass burning in slash and burn in forest class *icl* at year *t*; tCO_2-e ha^{-1}
$EBBN2O_{icl,t}$	Per hectare N_2O emission from biomass burning in slash and burn in forest class *icl* at year *t*; tCO_2-e ha^{-1}
$EBBCH4_{icl,t}$	Per hectare CH_4 emission from biomass burning in slash and burn in forest class *icl* at year *t*; tCO_2-e ha^{-1}
NCR	Nitrogen to Carbon Ratio (IPCC default value = 0.01); dimensionless
ER_{N2O}	Emission ratio for N_2O (IPCC default value = 0.007)
ER_{CH4}	Emission ratio for CH_4 (IPCC default value = 0.012)
GWP_{N2O}	Global Warming Potential for N_2O (IPCC default value = 310 for the first commitment period)
GWP_{CH4}	Global Warming Potential for CH_4 (IPCC default value = 21 for the first commitment period)

$$EBBCO2_{icl,t} = Fburnt_{icl} * \sum_{p=1}^{P} (C_{p,icl,t} * Pburnt_{p.icl} * CE_{p,icl}) \quad (14)$$

Where:

$EBBCO2_{icl,t}$	Per hectare CO_2 emission from biomass burning in the forest class *icl* at year *t*; tCO_2-e ha^{-1}
$Fburnt_{icl}$	Proportion of forest area burned during the historical reference period in the forest class *icl*; %
$C_{p,icl,t}$	Average *carbon stock* per hectare in the carbon pool *p* burnt in the forest class *icl* at year *t*; tCO_2-e ha^{-1}
$Pburnt_{p,icl}$	Average proportion of mass burnt in the carbon pool *p* in the forest class *icl*; %
$CE_{p,icl}$	Average combustion efficiency of the carbon pool *p* in the forest class *icl*; dimensionless
p	Carbon pool that could burn (above-ground biomass, dead wood, litter)

[41] Refers to table 5.7 in 1996 Revised IPCC Guideline for LULUCF and equation 3.2.19 in IPCC GPG-LULUCF

icl	1, 2, 3, …*Icl* (pre-deforestation) forest classes
t	1, 2, 3 … *T,* a year of the proposed project crediting period; dimensionless

The combustion efficiencies may be chosen from table 3.A.14 of IPCC GPG LULUCF. If no appropriate combustion efficiency can be used, the IPCC default of 0.5 should be used. The Nitrogen to Carbon Ratio (*NCR*) is approximated to be about 0.01. This is a general default value that applies to leaf litter, but lower values would be appropriate for fuels with greater woody content, if data are available. Emission factors for use with above equations are provided in Tables 3.A 15 and 3.A.16 of IPCC GPG LULUCF.

Report the values of all estimated parameters in the following table.

Table 23. Parameters used to calculate non-CO_2 emissions from forest fires

Initial Forest Class		**Parameters**																
		$Fburnt_{icl}$	*Cab*	*Cdw*	*Cl*	$Pburnt_{ab,icl}$	$Pburnt_{dw,icl}$	$Pburnt_{l,icl}$	$CE_{ab,icl}$	$CE_{dw,icl}$	$CE_{l,icl}$	*ECO2-ab*	*ECO2-dw*	*ECO2-l*	*EBBCO2-tot*	$EBBnN2O_{icl}$	$EBBCH4_{icl}$	$EBBtot_{icl}$
IDcl	Name	%	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	%	%	%	%	%	%	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$	$tCO_2e\ ha^{-1}$
1																		
2																		
. . .																		
Icl																		

Finally, using the parameters specified in table 23 and the projected activity data for forest classes calculate the projected total non-CO_2 emissions from forest fires and report the results in table 24.

Table 24. Baseline non-CO_2 emissions from forest fires in the project area
(The selection of gases is subject to the latest VCS guidance on this matter, see table 4)

Project year *t*	Emissions of non-CO_2 gasses from baseline forest fires								Total baseline non-CO_2 emissions from forest fires in the project area	
	ID_{icl} = 1		ID_{icl} = 2		ID_{icl} = . . .		ID_{icl} = Icl		annual	cumulative
	$ABSLPA_{icl,t}$	$EBBBSLtot_{icl}$	$ABSLPA_{icl,t}$	$EBBBSLtot_{icl}$	$ABSLPA_{icl,t}$	$EBBBSLtot_{icl}$	$ABSLPA_{icl,t}$	$EBBBSLtot_{icl}$	$EBBBSLPA_t$	$EBBBSLPA$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
0										
1										
2										
. . .										
T										

7 STEP 7: *EX ANTE* ESTIMATION OF ACTUAL CARBON STOCK CHANGES AND NON-CO_2 EMISSIONS IN THE PROJECT AREA

The goal of this step is to provide an *ex ante* estimate of future carbon stock changes and non-CO_2 emissions from forest fires under the project scenario (“actual”). Since actual carbon stock changes and GHG emissions will be subject to MRV-A, the rationale of estimating them at the beginning of a fixed baseline period is to assist in guiding optimal implementation of emission reduction measures, and to allow reasonable projections of revenue to be made.

7.1 *Ex ante* estimation of actual carbon stock changes

These are due to the following:

7.1.1 Planned activities within the project area.

7.1.2 Unplanned deforestation that cannot be avoided.

Carbon stock changes due to possible future catastrophic events cannot be predicted and are therefore excluded from the *ex ante* assessment.

7.1.1 *Ex ante* estimation of actual carbon stock changes due to planned activities

It is possible that certain discrete areas of forest within the project area will be subject to project activities that will change the carbon stocks of these areas compared to the baseline. Such activities are:

a) Planned deforestation (e.g. to build project infrastructure);

b) Planned degradation (e.g. timber logging, fuel-wood collection or charcoal production);

c) Protection without harvesting leading to carbon sequestration in forest classes that at project start are below their carbon stock potential at maturity *in situ*.

If the project activity generates a significant decrease in carbon stocks during the fixed baseline period, the carbon stock change must be estimated *ex ante* and measured *ex post*. If the decrease is not significant, it must not be accounted, and *ex post* monitoring will not be required.

If the project activity generates an increase in carbon stocks, ignoring the carbon stock change is conservative. However, if the project proponent wishes to be credited for carbon stock increases on areas projected to be deforested in the baseline case, *ex post* monitoring of the carbon stock increase is mandatory[42].

Changes in carbon stocks that are not attributable to the project activity cannot be accounted.

Mandatory accounting of significant carbon stock decreases:

Where the AUD project activity includes planned deforestation, harvesting of timber[43], fuel-wood collection or charcoal production above the baseline case do the following:

a) Identify the forest areas (polygons) within the project area that will be subject to planned deforestation and planned degradation activities (logging, fuel-wood collection or charcoal production) during the project crediting period.

b) Prepare maps showing the annual locations of the planned activities.

c) Identify the forest classes that are located within these polygons.

d) Define activity data (annual areas) for each forest class, according to the planned interventions and types of intervention.

e) Estimate the impact of the planned activities on carbon stocks as follows:

- Planned deforestation: Conservatively assume that 100% of the carbon stocks will be lost at the year of the planned deforestation.
- Areas subject to planned logging, fuel-wood collection or charcoal production above the baseline case: Conservatively assume that the carbon stock of these areas will be the lowest of the production cycle according to the planned levels of extraction.

f) Summarize the result of the previous assessments and calculations in Tables 25.a – 25.d. Tables 25.b and 25.c can only be filled out *ex post* and do not need to be filled out *ex ante* (i.e. their *ex ante* values are 0). These tables are for unpredictable carbon stock decreases that may have to be measured and reported *ex post* due to uncontrolled forest fires and other catastrophic events that may occur within the project area during project implementation.

[42] If an area is not projected to be deforested, carbon stock increase in the project scenario cannot be accounted in this methodology, as the project category would be IFM and not AUD.

[43] Ignoring the carbon stocks in the long-lived wood products is conservative under the project scenario.

Table 25.a. ***Ex ante*** **estimated actual carbon stock decrease due to planned deforestation in the project area**

Project year *t*	Areas of planned deforestation x Carbon stock change (decrease) in the project area								Total carbon stock decrease due to planned deforestation	
	ID_{cl} = 1		ID_{cl} = 2		ID_{cl} = . . .		ID_{cl} = Icl		annual	cumulative
	$APDPA_{icl,t}$	$Ctot_{icl,t}$	$APDPA_{icl,t}$	$Ctot_{icl,t}$	$APDPA_{icl,t}$	$Ctot_{icl,t}$	$APDPA_{icl,t}$	$Ctot_{icl,t}$	$\Delta CPDdPA_t$	$\Delta CPDdPA$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
0										
1										
2										
. . .										
T										

Table 25.b. ***Ex ante*** **estimated actual carbon stock decrease due to planned logging activities in the project area**

Project year *t*	Areas of planned logging activities x Carbon stock change (decrease) in the project area								Total carbon stock decrease due to planned logging activities	
	ID_{cl} = 1		ID_{cl} = 2		ID_{cl} = . . .		ID_{cl} = Icl		annual	cumulative
	$APLPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APLPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APLPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APLPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$\Delta CPLdPA_t$	$\Delta CPLdPA$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
0										
1										
2										
. . .										
T										

Table 25.c. *Ex ante* estimated actual carbon stock decrease due to planned fuel wood collection and charcoal production in the project area

Project year *t*	Areas of planned fuel-wood & charcoal activities x Carbon stock change (decrease) in the project areas								Total carbon stock decrease due to planned fuel-wood and charcoal activities	
	ID_{cl} = 1		ID_{cl} = 2		ID_{cl} = . . .		ID_{cl} = Icl		annual	cumulative
	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$\Delta CPFdPA_t$	$\Delta CPFdPA$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
0										
1										
2										
. . .										
T										

Table 25.d. Total *ex ante* carbon stock decrease due to planned activities in the project area

Project year *t*	Total carbon stock decrease due to planned deforestation		Total carbon stock decrease due to planned logging activities		Total carbon stock decrease due to planned fuel-wood and charcoal activities		Total carbon stock decrease due to planned activities	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CPDdPA_t$	$\Delta CPDdPA$	$\Delta CPLdPA_t$	$\Delta CPLdPA$	$\Delta CPFdPA_t$	$\Delta CPFdPA$	$\Delta CPAdPA_t$	$\Delta CPAdPA$
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
0								
1								
2								
. . .								
T								

Optional accounting of significant carbon stock increase

Consideration of carbon stock increase due to planned activities in areas that would be deforested in the baseline case is optional in this methodology and can always be omitted.

However, if the project area includes degraded and secondary forests that in the baseline case would be deforested and due to the project activity these areas will recover and sequester additional carbon, credits for the increased carbon stocks can be claimed. In the case, do the following:

a) Identify within the project area the polygons that are at the same time projected to be deforested in the baseline case and that are currently covered by secondary forests or degraded forests that have the potential to grow and accumulate significant carbon stocks;

b) Identify also the polygons representing areas of forests that will be subject to planned logging, fuel-wood collection and charcoal production activities under the project scenario and that have the potential to grow and accumulate significant carbon stocks after the periodical harvest cycle;

c) Prepare maps showing the annual locations of the polygons identified above;

d) Identify the forest classes existing in the polygons identified above;

e) Calculate activity data (annual areas) for each forest class in the polygons identified above;

f) For each forest class within the polygons, develop conservative growth projections using field data (measurements in plots of different ages), literature, existing databases and other credible and verifiable sources of information;

g) Calculate the projected increase in carbon stocks of each class. If the class is subject to periodical harvesting in the project case, assume that the maximum carbon stock is the long term average carbon stock (the average of a production cycle). Once a class reaches this level of carbon stock, do not allow any more carbon stock increase in the projections; and

h) Summarize the result of the previous assessments and calculations in Tables 26.a –26.d. Tables 26.b and 26.c can only be filled out *ex post* and do not need to be filled out *ex ante* (i.e. their *ex ante* values are 0). These tables are for unpredictable carbon stock increases that may have to be measured and reported *ex post* due to forest regeneration on areas affected by forest fires and catastrophic events.

Table 26.a. *Ex ante* estimated carbon stock increase due to planned protection without harvest in the project area

Project year *t*	Area of forest classes growing without harvest in the project case x Carbon stock change (increase)								Total carbon stock increase due to growth without harvest	
	ID_{cl} = 1		ID_{cl} = 2		ID_{cl} = . . .		ID_{cl} = Icl		annual	cumulative
	$APNiPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APNiPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APNiPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APNiPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$\Delta CPNiPA_t$	$\Delta CPNiPA$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
0										
1										
2										
. . .										
T										

Table 26.b. *Ex ante* estimated carbon stock increase following planned logging activities in the project area

Project year *t*	Areas of planned logging activities x Carbon stock change (increase up to maximum long-term average)								Total carbon stock increase due to planned logging activities	
	ID_{cl} = 1		ID_{cl} = 2		ID_{cl} = . . .		ID_{cl} = Icl		annual	cumulative
	$APLPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APLPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APLPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APLPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$\Delta CPLiPA_t$	$\Delta CPLiPA$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
0										
1										
2										
. . .										
T										

Table 26.c. *Ex ante* estimated carbon stock increase following planned fuel-wood and charcoal activities in the project area

Project year *t*	Areas of planned fuel-wood and charcoal activities x Carbon stock change (increase up to maximum long-term average)								Total carbon stock increase due to planned fuel-wood and charcoal activities	
	ID_{cl} = 1		ID_{cl} = 2		ID_{cl} = . . .		ID_{cl} = Icl		annual	cumulative
	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$APFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$\Delta CPFiPA_t$	$\Delta CPFiPA$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
0										
1										
2										
. . .										
T										

Table 26.d. Total *ex ante* estimated carbon stock increase due to planned activities in the project area

Project year t	Total carbon stock increase due to growth without harvest		Total carbon stock increase due to planned logging activities		Total carbon stock increase due to planned fuel-wood and charcoal activities		Total carbon stock increase due to planned activities	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CPNiPA_t$	$\Delta CPNiPA$	$\Delta CPLiPA_t$	$\Delta CPLiPA$	$\Delta CPFiPA_t$	$\Delta CPFiPA$	$\Delta CPAiPA_t$	$\Delta CPAiPA$
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
0								
1								
2								
. . .								
T								

7.1.2 *Ex ante* estimation of carbon stock changes due to unavoidable unplanned deforestation within the project area

Some unplanned deforestation may happen in the project area despite the AUD project activity. The level at which deforestation will actually be reduced in the project case depends on the effectiveness of the proposed activities, which cannot be measured *ex ante*. *Ex post* measurements of the project results will be important to determine actual emission reductions.

To allow *ex ante* projections to be made, the project proponent shall make a conservative assumption about the effectiveness of the proposed project activities and estimate an Effectiveness Index (EI) between 0 (no effectiveness) and 1 (maximum effectiveness). The estimated value of EI is used to multiply the baseline projections by the factor (1 - EI) and the result shall be considered the *ex ante* estimated emissions from unplanned deforestation in the project case.

$$\Delta CUDdPA_t = \Delta CBSL_t * (1 - EI) \qquad (16)$$

Where:

$\Delta CUDdPA_t$	Total *ex ante* actual carbon stock change due to unavoided unplanned deforestation at year t in the project area; tCO_2-e
$\Delta CBSL_t$	Total baseline carbon stock change at year t in the project area; tCO_2-e
EI	*Ex ante* estimated Effectiveness Index; %
t	1, 2, 3 … T, a year of the proposed project crediting period; dimensionless

7.1.3 *Ex ante* estimated net actual carbon stock changes in the project area

Summarize the result of the previous assessments in table 27.

Table 27. *Ex ante* estimated net carbon stock change in the project area under the project scenario

Project year *t*	Total carbon stock decrease due to planned activities		Total carbon stock increase due to planned activities		Total carbon stock decrease due to unavoided unplanned deforestation		Total carbon stock change in the project case	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CPAdPA_t$	$\Delta CPAdPA$	$\Delta CPAiPA_t$	$\Delta CPAiPA$	$\Delta CUDdPA_t$	$\Delta CUDdPA$	$\Delta CPSPA_t$	$\Delta CPSPA$
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
0								
1								
2								
. . .								
T								

7.2 *Ex ante* estimation of actual non-CO_2 emissions from forest fires

Where forest fires have been included in the baseline scenario, non-CO_2 emissions from biomass burning must be included in the project scenario. This is done by multiplying the baseline emissions by the factor (1 – *EI*). The results are presented in table 28.

$$EBBPSPA_t = EBBBSPA_t * (1 - EI) \tag{17}$$

Where:

$EBBPSPA_t$	Total *ex ante* actual non-CO_2 emissions from forest fire due to unavoided unplanned deforestation at year *t* in the project area; tCO_2-e
$EBBBSPA_t$	Total non-CO_2 emissions from forest fire at year *t* in the project area; tCO_2-e
EI	*Ex ante* estimated Effectiveness Index; %
t	1, 2, 3 … *T,* a year of the proposed project crediting period; dimensionless

Table 28. Total *ex ante* estimated actual emissions of non-CO_2 gasses due to forest fires in the project area

Project year *t*	Total *ex ante* estimated actual non-CO_2 emissions from forest fires in the Project area	
	$EBBPSPA_t$ annual tCO_2-e	***EBBPSPA*** cumulative tCO_2-e
0		
1		
2		
. . .		
T		

7.3 Total *ex ante* estimations for the project area

Table 29. Total *ex ante* estimated actual net carbon stock changes and emissions of non-CO_2 gasses in the project area

Project year *t*	Total *ex ante* carbon stock decrease due to planned activities		Total *ex ante* carbon stock increase due to planned activities		Total *ex ante* carbon stock decrease due to unavoided unplanned deforestation		Total *ex ante* net carbon stock change		Total *ex ante* estimated actual non-CO_2 emissions from forest fires in the project area	
	annual $\Delta CPAdPA_t$ tCO_2-e	cumulative $\Delta CPAdPA$ tCO_2-e	annual $\Delta CPAiPA_t$ tCO_2-e	cumulative $\Delta CPAiPA$ tCO_2-e	annual $\Delta CUDdPA_t$ tCO_2-e	cumulative $\Delta CUDdPA$ tCO_2-e	annual $\Delta CPSPA_t$ tCO_2-e	cumulative $\Delta CPSPA$ tCO_2-e	annual $EBBPSPA_t$ tCO_2-e	cumulative $EBBPSPA$ tCO_2-e
0										
1										
2										
. . .										
T										

8 STEP 8: *EX ANTE* ESTIMATION OF LEAKAGE

The goal of this step is to provide an *ex ante* estimate of the possible decrease in carbon stock and increase in GHG emissions (other than carbon stock change) due to leakage. The rationale for estimating leakage *ex ante* is to assist in guiding the design of optimal leakage prevention measures, identify sources of leakage that are potentially significant, and therefore subject to MRV, and to allow making reasonable projections of carbon and other project revenues.

Two sources of leakage are considered in this methodology and must be addressed:

8.1 Decrease in carbon stocks and increase in GHG emissions associated with leakage prevention measures;

8.2 Decrease in carbon stocks and increase in GHG emissions associated with activity displacement leakage.

8.1 *Ex ante* estimation of the decrease in carbon stocks and increase in GHG emissions due to leakage prevention measures

To reduce the risk of activity displacement leakage, baseline deforestation agents should be given the opportunity to participate in activities within the project area and in specially designated leakage management areas (outside the project area) that together will replace baseline income, product generation and livelihood of the agents as much as possible, so that deforestation will be reduced and the risk of displacement minimized.

If leakage prevention measures include tree planting, agricultural intensification, fertilization, fodder production and/or other measures to enhance cropland and grazing land areas, a reduction in carbon stocks and/or an increase in GHG emissions may occur compared to the baseline case. If such decrease in carbon stock or increase in GHG emission is significant, it must be accounted and monitoring will be required. If it is not significant, it must not be accounted and *ex post* monitoring will not be necessary.

If leakage prevention activities are associated to other VCS or UNFCCC registered (and VCS endorsed) project activities, changes in carbon stocks and GHG emissions that are already subject to MRV in such other registered project activities must not be estimated and accounted to avoid double-counting.

The following activities in leakage management areas could occasion a decrease in carbon stocks or an increase in GHG emissions:

8.1.1 Carbon stock changes due to activities implemented in leakage management areas;

8.1.2 Methane (CH_4) and nitrous oxide (N_2O) emissions from livestock intensification (involving a change in the animal diet and/or animal numbers).

Note that nitrous oxide (N_2O) emissions from nitrogen fertilization are considered always insignificant according to the most recent version of the VCS Standard.

Consumption of fossil fuels is considered always insignificant in AUD project activities and must not be considered.

8.1.1 Carbon stock changes due to activities implemented in leakage management areas

Leakage prevention activities generating a decrease in carbon stocks should be avoided, but if such activities are necessary the decrease in carbon stock associated to the leakage prevention activity must be estimated *ex ante* and accounted, if significant.

To estimate carbon stock changes in leakage management areas do the following:

a) Prepare a list of the planned leakage prevention activities and briefly describe each of them in the PD;

b) Prepare a map of the planned leakage prevention activities showing annual areas of intervention and type of intervention;

c) Identify the areas where leakage prevention activities will impact on carbon stocks;

d) Identify the non-forest classes[44] existing within these areas in the baseline case;

e) Measure the carbon stocks in the identified classes or use conservative literature estimates for each of the identified classes. If some classes have changing carbon stocks in the baseline, do carbon stock projections using growths data and other relevant and verifiable sources of information;

f) Report in table 30.a the projected baseline carbon stock changes in the leakage management areas;

g) According to the planned interventions, estimate the projected carbon stocks in the leakage management areas under the project scenario. Use conservative growth projections. Report the result in table 30.b; and

h) Calculate the net carbon stock changes that the planned leakage prevention measures are expected to occasion during the fixed baseline period and, optionally, the project crediting period. Report the results of the calculations in table 30.c

- If the net sum of carbon stock changes within a monitoring period is more than zero, leakage prevention measures are not causing any carbon stock decrease. The net increase shall conservatively be ignored in the calculation of net GHG emission reductions of the project activity.

- If the net sum is negative, determine the significance using the most recent version of the EB-CDM approved "Tool for testing significance of GHG emissions in A/R CDM project activities". If the decrease is significant, it must be accounted in the *ex ante* estimation of leakage and carbon stock changes in the land units where leakage prevention measures are implemented will be subject to MRV. If the decrease is not significant, it must not be accounted and carbon stock changes will not be subject to MRV.

[44] Forest classes cannot be present in leakage management areas at the project start date (see section 1.1.4).

Table 30.a. ***Ex ante*** **estimated carbon stock change in leakage management areas in the baseline case**

Project year *t*	Carbon stock changes in leakage management areas in the baseline case								Total carbon stock change in the baseline case	
	ID_{icl} = 1		ID_{icl} = 2		ID_{icl} = . . .		ID_{icl} = Icl		annual	cumulative
	$ABSLLKicl,t$	$Ctot_{icl,t}$	$ABSLLKicl,t$	$Ctot_{icl,t}$	$ABSLLKicl,t$	$Ctot_{icl,t}$	$ABSLLKicl,t$	$Ctot_{icl,t}$	$\Delta CBSLLKt$	$\Delta CBSLLK$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
0										
1										
2										
. . .										
T										

Table 30.b. ***Ex ante*** **estimated carbon stock change in leakage management areas in the project case**

Project year *t*	Carbon stock changes in leakage management areas in the project case								Total carbon stock change in the project case	
	ID_{fcl} = 1		ID_{fcl} = 2		ID_{fcl} = . . .		ID_{fcl} = Fcl		annual	cumulative
	$APSLKfcl,t$	$Ctot_{fcl,t}$	$APSLKfcl,t$	$Ctot_{fcl,t}$	$APSLKfcl,t$	$Ctot_{fcl,t}$	$APSLKfcl,t$	$Ctot_{fcl,t}$	$\Delta CPSLKt$	$\Delta CPSLK$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
0										
1										
2										
. . .										
T										

Table 30.c. *Ex ante* estimated net carbon stock change in leakage management areas

Project year *t*	Total carbon stock change in the baseline case		Total carbon stock change in the project case		Net carbon stock change due to leakage prevention measures	
	annual	cumulative	annual	cumulative	annual	cumulative
	ΔCBSLLKt	*ΔCBSLLK*	*ΔCPSLKt*	*ΔCPSLK*	*ΔCLPMLKt*	*ΔCLPMLK*
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
0						
1						
2						
. . .						
T						

8.1.2 *Ex ante* estimation of CH_4 and N_2O emissions from grazing animals

To estimate the increase in emissions of methane (CH_4) and nitrous oxide (N_2O) from grazing animals in leakage management areas do the following:

a) Specify the annual areas that will have grazing activities in the leakage management areas;

b) Briefly describe the types of animal, forage and manure management. Use table 31 to report the key parameters required to perform the calculation of GHG emissions;

c) Determine the number of animals in the baseline case and under the project scenario based on available areas and forage. The difference must be considered for the calculation of the increase in GHG emissions; and

d) Methods to estimate emissions from enteric fermentation and manure management are given in appendix 4. Perform the final calculations using equation 18 and report the results in table 32.

The GHG emissions are estimated as follows:

$$EgLK_t = ECH4ferm_t + ECH4man_t + EN2Oman_t \qquad (18)$$

Where:

$EgLK_t$	Emissions from grazing animals in leakage management areas at year *t;* tCO_2-e yr^{-1}
$ECH4ferm_t$	CH_4 emissions from enteric fermentation in leakage management areas at year *t*; tCO_2-e yr^{-1}
$ECH4man_t$	CH_4 emissions from manure management in leakage management areas year *t*; tCO_2-e yr^{-1}
$EN2Oman_t$	N_2O emissions from manure management in leakage management areas at year *t*; tCO_2-e yr^{-1}
t	1, 2, 3, … *T* years of the project crediting period; dimensionless

Table 31. Parameters used for the *ex ante* estimation of GHG emissions from grazing activities

Parameter	Value used for calculations	Unit	Description
EF1		kg CH_4 head^{-1} yr^{-1}	Enteric CH_4 emission factor for the livestock group
EF2		kg CH4 head^{-1} yr^{-1}	Manure management CH_4 emission factor for the livestock group
EF3		kg N_2O-N (kg N^{-1}) head^{-1} yr^{-1}	Emission factor for N_2O emissions from manure management for the livestock group
EF4		kg N_2O-N (kg NH_3-N and NO_x-N emitted)$^{-1}$ head^{-1} yr^{-1}	Emission factor for N_2O emissions from atmospheric deposition of forage-sourced nitrogen on soils and water surfaces
DBI		kg d.m. head^{-1} day^{-1}	Daily biomass intake
Nex		kg N head^{-1} yr^{-1}	Annual average N excretion per livestock head
Fracgas		kg NH_3-N and NO_x-N emitted (Kg N)$^{-1}$	Fraction of managed livestock manure nitrogen that volatilizes as NH_3 and NO_x in the manure management phase

Table 32. *Ex ante* estimation of leakage emissions above the baseline from grazing animals in leakage management areas

Project year *t*									annual	cumulative
	$Aforage_t$	$Pforage_t$	$Population_t$	$ECH4ferm_t$	$ECH4man_t$	$EdirN20man_t$	$EidN20man_t$	$EN2Oman_{,t}$	$EgLK_t$	$EgLK$
	ha	kg d. m. yr^{-1}	Nr heads	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
0										
1										
2										
…										
T										

8.1.3 Total *ex ante* estimated carbon stock changes and increases in GHG emissions due to leakage prevention measures

Summarize the results of the previous estimations in table 33, where only significant sources must be reported.

Table 33. *Ex ante* estimated total emissions above the baseline from leakage prevention activities

Project year *t*	Carbon stock decrease due to leakage prevention measures		Total *ex ante* GHG emissions from increased grazing activities		Total *ex ante* increase in GHG emissions due to leakage prevention measures	
	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CLPMLKt$	$\Delta CLPMLK$	$EgLK_t$	$EgLK$	$ELPMLK_t$	$ELPMLK$
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
0						
1						
2						
…						
T						

8.2 *Ex ante* estimation of the decrease in carbon stocks and increase in GHG emissions due to activity displacement leakage

Activities that will cause deforestation within the project area in the baseline case could be displaced outside the project boundary due to the implementation of the AUD project activity. If carbon stocks in the leakage belt area will decrease more during project implementation than projected in the baseline case, this will be an indication that leakage due to displacement of baseline activities has occurred. Leakage due to activity displacement can thus be estimated by *ex post* monitoring of deforestation in the leakage belt and comparing *ex post* observed deforestation with *ex ante* projected baseline deforestation. A baseline for the leakage belt is therefore necessary and methods to establish this baseline were described in section 6.1.2 and 6.1.3.

Do the *ex ante* baseline assessment of the leakage belt and report the result in tables 21.c (if Method 1 is used) or 22.c (if Method 2 is used):

However, *ex ante*, activity displacement leakage can only be guessed based on the anticipated combined effectiveness of the proposed leakage prevention measures and project activities.

This shall be done by multiplying the estimated baseline carbon stock changes for the project area by a "Displacement Leakage Factor" (*DLF*) representing the percent of deforestation expected to be displaced outside the project boundary[45].

If emissions from forest fires have been included in the baseline, the *ex ante* emissions from forest fires due to activity displacement leakage will be calculated by multiplying baseline forest fire emissions in the project area by the same *DLF* used to estimate the decrease in carbon stocks.

Report the *ex ante* estimated leakage due to activity displacement in table 34.

Table 34. *Ex ante* estimated leakage due to activity displacement

Project year *t*	Total *ex ante estimated* decrease in carbon stocks due to displaced deforestation		Total *ex ante estimated* increase in GHG emissions due to displaced forest fires	
	annual	cumulative	annual	cumulative
	$\Delta CADLK_t$	$\Delta CADLK$	$EADLK_t$	$EADLK$
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
0				
1				
2				
. . .				
T				

[45] If deforestation agents do not participate in leakage prevention activities and project activities, the Displacement Factor shall be 100%. Where leakage prevention activities are implemented the factor shall be equal to the proportion of the baseline agents estimated to be given the opportunity to participate in leakage prevention activities and project activities.

8.3 *Ex ante* estimation of total leakage

Summarize the result all sources of leakage in table 35.

Table 35. *Ex ante* estimated total leakage

Project year *t*	Total *ex ante* GHG emissions from increased grazing activities		Total *ex ante* increase in GHG emissions due to displaced forest fires		Total *ex ante* decrease in carbon stocks due to displaced deforestation		Carbon stock decrease due to leakage prevention measures		Total net carbon stock change due to leakage		Total net increase in emissions due to leakage	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$EgLK_t$	$EgLK$	$EADLK_t$	$EADLK$	$\Delta CADLK_t$	$\Delta CADLK$	$\Delta CLPMLK_t$	$\Delta CLPMLK$	ΔCLK_t	ΔCLK	ELK_t	ELK
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
0												
1												
2												
. . .												
T												

9 STEP 9: *EX ANTE* TOTAL NET ANTHROPOGENIC GHG EMISSION REDUCTIONS

9.1 Significance assessment

All carbon pools and sources of GHG emissions considered in this methodology must be calculated to assess their significance. Use the latest EB-CDM approved “Tool for testing significance of GHG emissions in A/R CDM project activities” to determine the significance of each of the *ex ante* calculated carbon stock changes and GHG emissions. Report the result of the analysis in the PD.

Only significant sources and pools need to be accounted in the calculation of net anthropogenic GHG emission reductions (step 9.2) and only significant sources and pools must be considered in the monitoring plan.

9.2 Calculation of *ex-ante* estimation of total net GHG emissions reductions

The net anthropogenic GHG emission reduction of the proposed AUD project activity is calculated as follows:

$$\Delta REDD_t = (\Delta CBSLPA_t + EBBBSLPA_t) - (\Delta CPSPA_t + EBBPSPA_t) - (\Delta CLK_t + ELK_t) \quad (19)$$

Where:

$\Delta REDD_t$ — *Ex ante* estimated net anthropogenic greenhouse gas emission reduction attributable to the AUD project activity at year t; tCO_2e

$\Delta CBSLPA_t$ — Sum of baseline carbon stock changes in the project area at year t; tCO_2e

Note: The absolute values of $\Delta CBSLPA_t$ shall be used in equation 19.

$EBBBSLPA_t$ — Sum of baseline emissions from biomass burning in the project area at year t; tCO_2e

$\Delta CPSPA_t$ — Sum of *ex ante* estimated actual carbon stock changes in the project area at year t; tCO_2e

Note: If $\Delta CPSPA_t$ represents a net increase in carbon stocks, a negative sign before the absolute value of $\Delta CPSPA_t$ shall be used. If $\Delta CPSPA_t$ represents a net decrease, the positive sign shall be used.

$EBBPSPA_t$ — Sum of (*ex ante* estimated) actual emissions from biomass burning in the project area at year t; tCO_2e

ΔCLK_t — Sum of *ex ante* estimated leakage net carbon stock changes at year t; tCO_2e

Note: If the cumulative sum of ΔCLK_t within a fixed baseline period is > 0, ΔCLK_t shall be set to zero.

ELK_t — Sum of *ex ante* estimated leakage emissions at year t; tCO_2e

t — 1, 2, 3 … T, a year of the proposed project crediting period; dimensionless

9.3 Calculation of *ex-ante* Verified Carbon Units (VCUs)

The number of Verified Carbon Units (VCUs) to be generated through the proposed AUD project activity at year t is calculated as follows:

$VCU_t = \Delta REDD_t - VBC_t$ (20)

$VBC_t = (\Delta CBSLPA_t - \Delta CPSPA_t) * RF_t$ (21)

Where:

VCU_t Number of Verified Carbon Units that can be traded at time *t*; t CO_2-e

Note: If $VCU_t < 0$ no credits (VCUs) will be awarded to the proponents of the AUD project activity. VCUs can only be granted if the following condition is met:

$\sum_{t=0}^{t} \Delta REDD_t > 0$ (22)

$\Delta REDD_t$ *Ex ante* estimated net anthropogenic greenhouse gas emission reduction attributable to the AUD project activity at year *t*; tCO_2-e ha^{-1}

VBC_t Number of Buffer Credits deposited in the VCS Buffer at time *t*; t CO_2-e

$\Delta CBSLPA_t$ Sum of baseline carbon stock changes in the project area at year *t*; tCO_2e

$\Delta CPSPA_t$ Sum of *ex ante* estimated actual carbon stock changes in the project area at year *t*; tCO_2-e ha^{-1}

RF_t Risk factor used to calculate VCS buffer credits; %

Note: RF_t is a risk factor to be determined using the latest version of the VCS-approved AFOLU Non-Permanence Risk Tool.

t 1, 2, 3 … *T,* a year of the proposed project crediting period; dimensionless

See also the latest version of the Registration and Issuance Process document for information on this subject matter[46].

Present the result of the calculations in table 36.

[46] Available at: http://www.v-c-s.org

Table 36. *Ex ante* estimated net anthropogenic GHG emission reductions ($\Delta REDD_t$) and Verified Carbon Units (VCU_t)

Project year *t*	Baseline carbon stock changes		Baseline GHG emissions		*Ex ante* project carbon stock changes		*Ex ante* project GHG emissions		*Ex ante* leakage carbon stock changes		*Ex ante* leakage GHG emissions		*Ex ante* net anthropogenic GHG emission reductions		*Ex ante* VCUs tradable		*Ex ante* buffer credits	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CBSLPA_t$	$\Delta CBSLPA$	$EBBBSLPA_t$	$EBBBSLPA$	$\Delta CPSPA_t$	$\Delta CPSPA$	$EBBPSPA_t$	$EBBPSPA$	ΔCLK_t	ΔCLK	ELK_t	ELK	$\Delta REDD_t$	$\Delta REDD$	VCU_t	VCU	VBC_t	VBC
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
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PART 3 – METHODOLOGY FOR MONITORING AND RE-VALIDATION OF THE BASELINE

The *ex post* methodology (to be implemented immediately after project start) includes two main tasks:

1) Monitoring of carbon stock changes and GHG emissions for periodical verifications within the fixed baseline period; and
2) Monitoring of key baseline parameters for revisiting the baseline at the end of the fixed baseline period.

Appendix 6 provides an overview of the tables that should be prepared to report monitoring results.

1 TASK 1: MONITORING OF CARBON STOCK CHANGES AND GHG EMISSIONS FOR PERIODICAL VERIFICATIONS

There are three main monitoring tasks:

1.1 Monitoring of actual carbon stock changes and GHG emissions within the project area;

1.2 Monitoring of leakage; and

1.3 *Ex post* calculation of net anthropogenic GHG emission reduction.

Prepare a Monitoring Plan describing how these tasks will be implemented. For each task the monitoring plan must include the following sections:

a) Technical description of the monitoring tasks.
b) Data to be collected (see appendix 5).
c) Overview of data collection procedures.
d) Quality control and quality assurance procedures.
e) Data archiving.
f) Organization and responsibilities of the parties involved in all the above.

To allow a transparent comparison between *ex ante* and *ex post* estimates, use the same formats and tables presented in Part 2 of the methodology to report the results of monitoring.

1.1 Monitoring of actual carbon stock changes and GHG emissions within the project area

This task involves:

1.1.1 Monitoring of project implementation;

1.1.2 Monitoring of land-use and land-cover change;

1.1.3 Monitoring of carbon stocks and non-CO_2 emissions; and

1.1.4 Monitoring of impacts of natural disturbances and other catastrophic events.

1.1.1 Monitoring of project implementation

Project activities implemented within the project area should be consistent with the management plans of the project area and the PD. All maps and records generated during project implementation should be conserved and made available to VCS verifiers at verification for inspection to demonstrate that the AUD project activity has actually been implemented.

1.1.2 Monitoring of land-use and land-cover change within the project area

The categories of changes that may be subject to MRV are summarized in table 37.

Table 37. Categories subject to MRV

ID	Type	Conditions under which monitoring is mandatory	Explanations
I	Area of forest land converted to non-forest land.	Mandatory in all AUD project activities	
II	Area of forest land undergoing carbon stock decrease.	Mandatory only for AUD project activities having planned logging, fuel-wood collection and charcoal production activities above the baseline.	Change in carbon stock must be significant according to *ex ante* assessment, otherwise monitoring is not required.
III	Area of forest land undergoing carbon stock increase.	Mandatory only for AUD project activities wishing to claim carbon credits for carbon stock increase.	Increase must be significant according to *ex ante* assessment and can only be accounted on areas that will be deforested in the baseline case.

If the project area is located within a region subject to MRV by a jurisdictional program, the MRV data generated by this program must be used.

Similarly, if the project area is located within a region that is subject to a monitoring program that is approved or sanctioned by the national or sub-national government, the data generated by such program must be used, unless they are not applicable according to the criteria listed below:

a) Monitoring occurs in the entire project area and, if the project must monitor a leakage belt, in the leakage belt.

b) If data from the existing monitoring program are used to periodically revisit the baseline, monitoring must occur in the entire reference region at least at the beginning, middle and end of the fixed baseline period.

c) At least category I (table 37) is subject to monitoring (conversion of forest land to non-forest land).

d) It the project must do a monitoring of other categories (II and/or III) and these are not included in the existing program, the existing program can only be used for monitoring category I, and the project proponent must implement a separate monitoring program for category II and/or III.

e) Monitoring will occur during the entire fixed baseline period.

f) Monitoring methods are transparently documented and are similar to those used to determine the baseline of the AUD project activity.

g) Monitoring protocols and data must be accessible for inspection by VCS accredited verifier.

If no existing monitoring program exist or can be used, monitoring must be done by the project proponent or outsourced to a third party having sufficient capacities to perform the monitoring tasks. Methods used to monitor LU/LC change categories and to assess accuracy must be similar to those explained in part 2, step 2.4 and part 2, step 2.5, respectively.

The results of monitoring shall be reported by creating *ex post* tables of activity data per stratum (Tables 9.a, 9.b and 9.c); per initial forest class *icl* (Tables 11.a, 11.b and 11.c); per post-deforestation zone *z* (Tables 13.a, 13.b and 13.c) and, where applicable, per category of land-use change *ct* (Tables 14.a, 14.b and 14.c).or *ctz* (Tables 19.a, 19.b and 19.c).

1.1.3 Monitoring of carbon stock changes and non-CO_2 emissions from forest fires

Monitoring of carbon stock changes

In most cases, the *ex ante* estimated average carbon stocks per LU/LC class (or carbon stock change factors per LU/LC change category) will not change during a fixed baseline period and monitoring of carbon stocks will not be necessary.

However, monitoring of carbon stocks is mandatory in the following cases:

Within the project area:

a) Areas subject to significant carbon stock decrease in the project scenario according to the *ex ante* assessment. These will be areas subject to controlled deforestation and planned harvest activities, such as logging, fuel wood collection and charcoal production. In these areas, carbon stock changes must be estimated at least once after each harvest event.

b) Areas subject to unplanned and significant carbon stock decrease, e.g. due to uncontrolled forest fires and other catastrophic events. In these areas, carbon stock losses must be estimated as soon as possible after the catastrophic event. See section 1.1.4 below for more detailed guidance.

Within leakage management areas:

a) Areas subject to planned and significant carbon stock decrease in the project scenario according to the *ex ante* assessment. In these areas, carbon stocks must be estimated at least once after the planned event that caused the carbon stock decrease.

Monitoring of carbon stocks is optional in the following cases:

Within the project area:

a) Areas subject to carbon stock increase after planned harvest activities, such as logging, fuel wood collection and charcoal production. In these areas, the carbon stock increase occurring after the harvest event can be measured and accounted, when significant.

b) Areas recovering after disturbances, such unplanned forest fires and other catastrophic events. In these areas, the carbon stock increase occurring after the catastrophic event can be measured and accounted, when significant. See section 1.1.4 below for more detailed guidance.

Within leakage management areas:

a) Areas subject to carbon stock increase due to leakage prevention measures. In these areas, the carbon stock increase can be measured and accounted only up to the amount necessary to offset any carbon stock decrease caused by leakage prevention measures in other leakage management areas or in previous years.

Within the leakage belt:

a) Areas undergoing significant changes in carbon stock may be measured at the end of each fixed baseline period in order to update carbon stock information for the subsequent period.

Where carbon stocks are monitored, the methods on sampling and measuring carbon stocks described in appendix 3 must be used.

Some project proponents may wish to do additional carbon stock measurements during project implementation to gain accuracy and credits. If new and more accurate carbon stock data become available, these can be used to estimate the net anthropogenic GHG emission reduction of the subsequent fixed baseline period. For the current fixed baseline period, new data on carbon stocks can only be used if they are validated by an accredited VCS verifier. If new data are used in the current fixed baseline period, the baseline must be recalculated using the new data.

The results of monitoring activity data and carbon stocks must be reported using the same formats and tables used for the *ex ante* assessment:

Table 15	*Ex post* carbon stock per hectare of initial forest classes *icl* existing in the project area and leakage belt
Table 16	*Ex post* carbon stock per hectare of initial final classes *fcl* existing in the project area and leakage belt
Table 25.a	*Ex post* carbon stock decrease due to planned and unplanned deforestation in the project area.
Table 25.b	*Ex post* carbon stock decrease due to planned logging activities.
Table 25.c	*Ex post* carbon stock decrease due to planned fuel-wood and charcoal activities.
Table 25.d	Total *ex post* carbon stock decrease due to planned activities in the project area.
Table 25.e	*Ex post* carbon stock decrease due to forest fires (see below).
Table 25.f	*Ex post* carbon stock decrease due to catastrophic events (see below and section 1.1.4).
Table 25.g	Total *ex post* carbon stock decrease due to forest fires and catastrophic events (see below)
Table 26.a	*Ex post* carbon stock increase due to growth without harvest.
Table 26.b	*Ex post* carbon stock increase following planned logging activities.
Table 26.c	*Ex post* carbon stock increase following planned fuel-wood and charcoal activities.
Table 26.d	Total *ex post* carbon stock increase due to planned activities in the project area.
Table 26.e	*Ex post* carbon stock increase on areas affected by forest fires (see below).
Table 26.f	*Ex post* carbon stock increase on areas affected by catastrophic events (see below and section 1.1.4).

Table 26.g *Ex post* carbon stock increase on areas recovering after forest fires and catastrophic events (see below).

Table 27 *Ex post* total net carbon stock change in the project area (see below).

Table 25.e *Ex post* actual carbon stock decrease due to forest fires in the project area

Project year *t*	Areas affected by forest fires x Carbon stock change (decrease)								Total carbon stock decrease due to forest fires	
	ID_{cl} = 1		ID_{cl} = 2		ID_{cl} = . . .		ID_{cl} = Icl		annual	cumulative
	$AUFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$AUFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$AUFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$AUFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$\Delta CUFdPA_t$	$\Delta CUFdFA$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
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Table 25.f *Ex post* carbon stock decrease due to catastrophic events in the project area

Project year *t*	Areas affected by catastrophic events x Carbon stock change (decrease)								Total carbon stock decrease due to catastrophic events	
	ID_{cl} = 1		ID_{cl} = 2		ID_{cl} = . . .		ID_{cl} = Icl		annual	cumulative
	$ACPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$ACPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$ACPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$ACPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$\Delta CUCdPA_t$	$\Delta CUCdPA$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
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Table 25.g Total *ex post* carbon stock decrease due to forest fires and catastrophic events

Project year t	Total carbon stock decrease due to forest fires		Total carbon stock decrease due to catastrophic events		Total carbon stock decrease due to forest fires and catastrophic events	
	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CUFdPA_t$	$\Delta CUFdPA$	$\Delta CUCdPA_t$	$\Delta CUCdPA$	$\Delta CFCdPA_t$	$\Delta CFCdPA$
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
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Table 26.e *Ex post* actual carbon stock increase on areas affected by forest fires in the project area

Project year t	Areas affected by forest fires x Carbon stock change (increase)								Total carbon stock increase due to forest fires	
	ID_{cl} = 1		ID_{cl} = 2		ID_{cl} = . . .		ID_{cl} = Icl		annual	cumulative
	$AUFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$AUFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$AUFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$AUFPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$\Delta CUFiPA_t$	$\Delta CUFiPA$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
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Table 26.f *Ex post* carbon stock increase on areas affected by catastrophic events

Project year *t*	Areas affected by catastrophic events x Carbon stock change (increase) in the project area								Total carbon stock increase due to catastrophic events	
	ID_{cl} = 1		ID_{cl} = 2		ID_{cl} = . . .		ID_{cl} = Icl		annual	cumulative
	$ACPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$ACPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$ACPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$ACPA_{icl,t}$	$\Delta Ctot_{icl,t}$	$\Delta CUCiPA_t$	$\Delta CUCiPA$
	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	ha	tCO_2-e ha^{-1}	tCO_2-e	tCO_2-e
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Table 26.g Total *ex post* carbon stock increase on areas affected by forest fires and catastrophic events

Project year *t*	Total carbon stock increase due to forest fires		Total carbon stock increase due to catastrophic events		Total carbon stock increase due to forest fires and catastrophic events	
	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CUFiPA_t$	$\Delta CUFiPA$	$\Delta CUCiPA_t$	$\Delta CUCiPA$	$\Delta CFCiPA_t$	$\Delta CFCiPA$
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
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Table 27. *Ex post* estimated net carbon stock change in the project area under the project scenario

Project year *t*	Total carbon stock decrease due to planned activities		Total carbon stock increase due to planned activities		Total carbon stock decrease due to fires and catastrophic events		Total carbon stock increase due to fires and catastrophic events		Total *ex post* carbon stock change in the project case	
	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CPAdPA_t$	$\Delta CPAdPA$	$\Delta CPAiPA_t$	$\Delta CPAiPA$	$\Delta CFCdPA_t$	$\Delta CFCdPA$	$\Delta CFCiPA_t$	$\Delta CFCiPA$	$\Delta CPSPA_t$	$\Delta CPSPA$
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
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Monitoring of non-CO_2 emissions from forest fires

These are subject to monitoring and accounting, when significant. In this case, under the project scenario it will be necessary to monitor the variables of table 23 within the project area and to report the results in table 24.

1.1.4 Monitoring of impacts of natural disturbances and other catastrophic events

Decreases in carbon stocks and increases in GHG emissions (e.g. in case of forest fires) due to natural disturbances (such as hurricanes, earthquakes, volcanic eruptions, tsunamis, flooding, drought[47], fires, tornados or winter storms) or man-made events, including those over which the project proponent has no control (such as acts of terrorism or war), are subject to monitoring and must be accounted under the project scenario, when significant. Use tables 25.e, 25.f and 25.g to report carbon stock decreases and, optionally, tables 26.e, 26.f and 26.g to report carbon stock increases that may happen on the disturbed lands after the occurrence of an event. Use tables 23 and 24 to report emissions from forest fires.

If the area (or a sub-set of it) affected by natural disturbances or man-made events generated VCUs in past verifications, the total net change in carbon stocks and GHG emissions in the area(s) that generated VCUs must be estimated, and an equivalent amount of VCUs must be cancelled from the VCS buffer.

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[47] When the 1997-1998 El Niño episode provoked severe droughts in the Amazon and Indonesia, large areas of tropical forest burned, releasing 0.2 to 0.,4 Gt of carbon to the atmosphere (de Mendonça *et al.*, 2004; Siegert *et al.*, 2001; Page *et al*., 2002). If droughts become more severe in the future through more frequent and severe el Niño episodes (Trenberth and Hoar, 1997; Timmermann *et al*., 1999), or the dry season becomes lengthier due to deforestation-induced rainfall inhibition (Nobre *et al*., 1991; Silva-Dias *et al*., 2002) or there are rainfall reductions due to climate change (White *et al*., 1999; Cox *et al*., 2000), then substantial portions of the 200 Gt of carbon stored globally on tropical forest trees could be transferred to the atmosphere in the coming decades (Santilli *et al*., 2005).

No VCUs can be issued to the project until all carbon stock losses and increases in GHG emissions have been offset, i.e. until the following condition is satisfied:

$$\sum_{t=0}^{t} REDD_t > 0 \quad (23)$$

Where:

$\Delta REDD_t$ — *Ex post* estimated net anthropogenic greenhouse gas emission reduction attributable to the AUD project activity at year *t*; tCO_2e

t — 1, 2, 3 … *T,* a year of the proposed project crediting period; dimensionless

1.1.5 Total *ex post* estimated actual net carbon stock changes and GHG emissions in the project area

Summarize the results of all *ex post* estimations in the project area using the same table format used for the *ex ante* assessment:

Table 29: Total *ex post* estimated actual net changes in carbon stocks and emissions of GHG gases in the project area.

1.2 Monitoring of leakage

Monitoring of leakage may not be required if the project area is located within a jurisdiction that is monitoring, reporting, verifying and accounting GHG emissions from deforestation under a VCS or UNFCCC registered (and VCS endorsed) program. In such cases, the most recent VCS JNR Requirements shall be applied.

In all other circumstances, the sources of leakage identified as significant in the *ex ante* assessment are subject to monitoring. Two sources of leakage are potentially subject to monitoring:

1.2.1 Decrease in carbon stocks and increase in GHG emissions associated with leakage prevention activities;

1.2.2 Decrease in carbon stocks and increase in GHG emissions in due to activity displacement leakage.

1.2.1 Monitoring of carbon stock changes and GHG emissions associated to leakage prevention activities

Monitoring of the sources of emissions associated with leakage prevention activities must follow the methods and tools described in part 2, step 8.1 of the methodology.

Results must be reported using the same formats and tables used in the *ex ante* assessment:

Table 30.b *Ex post* carbon stock change in leakage management areas.

Table 30.c *Ex post* net carbon stock change in leakage management areas[48].

[48] Calculations of total net carbon stock changes in Leakage Management Areas use the ex ante estimated baseline carbon stock changes in the Leakage Management Area and the measured ex post carbon stock changes. If the cumulative value of the carbon stock change within a Fixed Baseline Period is > 0, $\Delta CLPMLK_t$ shall be set to zero.

Table 31 *Ex post* parameters for estimating GHG emissions from grazing activities

Table 32 *Ex post* estimation of emissions from grazing animals in leakage management areas.

Table 33 *Ex post* estimation of net carbon stock changes and GHG emissions from leakage prevention activities.

1.2.2 Monitoring of carbon stock decrease and increases in GHG emissions due to activity displacement leakage

Monitoring of carbon stock changes

Deforestation above the baseline in the leakage belt area will be considered activity displacement leakage.

Activity data for the leakage belt area must be determined using the same methods applied to monitoring deforestation activity data (category I, table 37) in the project area. Monitoring of the categories II and III outside the project area is not required because no credits are claimed for avoided degradation under this methodology.

The result of the *ex post* estimations of carbon stock changes must be reported using the same table formats used in the *ex ante* assessment of baseline carbon stock changes in the leakage belt.

Table 21.c *Ex post* total net carbon stock changes in the leakage belt (when using method 1 based on activity data per class).

or

Table 22.c *Ex post* total net carbon stock changes in the leakage belt (when using method 2 based on activity data per category).

Leakage will be calculated as the difference between the *ex ante* and the *ex post* assessment. Report the results in table 21.d

Table 21.d. Total net baseline carbon stock change in the leakage belt
(Calculated with Method 1: Activity data per class)

Project year *t*	Total *ex ante* net baseline carbon stock change		Total *ex post* net actual carbon stock change		Total *ex post* leakage	
	annual	cumulative	annual	cumulative	annual	cumulative
	$\Delta CBSLLK_t$	$\Delta CBSLLK$	$\Delta CBSLLK_t$	$\Delta CBSLLK$	$\Delta CBSLLK_t$	$\Delta CBSLLK$
	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e	tCO_2-e
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Where strong evidence can be collected that deforestation in the leakage belt is attributable to deforestation agents that are not linked to the project area, the detected deforestation may not be attributed to the project activity and considered leakage. The operational entity verifying the monitoring data shall determine whether the documentation provided by the project proponent represents sufficient evidence to consider the detected deforestation as not attributable to the project activity and therefore not leakage.

Monitoring of increases in GHG emissions

These must only be estimated and accounted if emissions from forest fires are included in the baseline.

To estimate the increased GHG emissions due to forest fires in the leakage belt area the assumption is made that forest clearing is done by burning the forest. The parameter values used to estimate emissions shall be the same used for estimating forest fires in the baseline (table 23), except for the initial carbon stocks (*Cab*, *Cdw*) which shall be those of the initial forest classes burned in the leakage belt area.

Report the result of the estimations using the same table formats used in the *ex ante* assessment of baseline GHG emissions from forest fires in the project area:

Table 23: Parameters used to calculate emissions from forest fires in the leakage belt area

Table 24: *Ex post* estimated non-CO_2 emissions from forest fires in the leakage belt area

1.2.3 Total *ex post* estimated leakage

Summarize the results of all *ex post* estimations of leakage using the same table format used for the *ex ante* assessment:

Table 35. Total *ex post* estimated leakage.

<u>Note:</u> Monitoring of leakage may become obsolete at the date when a VCS or UNFCCC registered (and VCS endorsed) program is monitoring, reporting, verifying and accounting GHG emissions from deforestation in a broader region encompassing the project area. In such cases, the most recent VCS guidelines on this subject matter shall be applied.

1.3 *Ex post* net anthropogenic GHG emission reductions

The calculation of *ex post* net anthropogenic GHG emission reductions is similar to the e*x ante* calculation with the only difference that *ex post* estimated carbon stock changes and GHG emissions must be used in the case of the project scenario and leakage.

Report the *ex post* estimated net anthropogenic GHG emissions and calculation of Verified Carbon Units (VCU_t, and VBC_t) using the same table format used for the *ex ante* assessment:

Table 36: *Ex post* estimated net anthropogenic GHG emission reductions and VCUs**.**

Note: A map showing Cumulative Areas Credited within the project area shall be updated and presented to VCS verifiers at each verification event. The cumulative area cannot generate additional VCUs in future periods.

2 TASK 2: REVISITING THE BASELINE PROJECTIONS FOR FUTURE FIXED BASELINE PERIOD

Baselines, independently from the approach chosen to establish them, must be revisited over time because agents, drivers and underlying causes of deforestation change dynamically. Frequent and unpredicted updating of the baseline can create serious market uncertainties. Therefore, the baseline must be revisited only every 10 years. Where an applicable sub-national or national jurisdictional baseline becomes available, baselines may be reassessed earlier in accordance with section 2.2 below. Tasks involved in revisiting the baseline are:

2.1 Update information on agents, drivers and underlying causes of deforestation.

2.2 Adjust the land-use and land-cover change component of the baseline.

2.3 Adjust, as needed, the carbon component of the baseline.

2.1 Update information on agents, drivers and underlying causes of deforestation

Information on agents, drivers and underlying causes of deforestation in the reference region must be collected periodically, as these are essential for improving future deforestation projections and the design of the project activity.

- Collect information that is relevant to understand deforestation agents, drivers and underlying causes.
- Redo step 3 of the *ex ante* methodology at the beginning of each fixed baseline period.
- Where a spatial model was used to locate future deforestation, new data on the spatial driver variables used to model the deforestation risk must be collected as they become available. These must be used to create updated spatial datasets and new “Factor Maps” for the subsequent fixed baseline period.

2.2 Adjustment of the land-use and land-cover change component of the baseline

If an applicable sub-national or national baseline becomes available during the fixed baseline period, it must be used for the subsequent period. Use the criteria of table 2 to assess the applicability of sub-national or national baselines. If VCS requirements on regional baselines are available, use the most recent version of these guidelines instead of table 2.

If an applicable sub-national or national baseline is not available, the baseline projections must be revisited and adjusted as necessary.

The two components of the baseline projections that must be reassessed are:

2.2.1 The annual areas of baseline deforestation; and

2.2.2 The location of baseline deforestation.

2.2.1 Adjustment of the annual areas of baseline deforestation

At the end of each fixed baseline period, the projected annual areas of baseline deforestation for the reference region need to be revisited and eventually adjusted for the subsequent fixed baseline period. The adjusted baseline rates must be submitted to an independent validation.

Adjustments must be made using the methods described in part 2 of the methodology and using the data obtained from monitoring LU/LC changes in the reference region during the past fixed baseline period, updated information on deforestation agents, drivers and underlying cases of deforestation and, where applicable, any updated information on the variables included in the estimation of the projected areas of baseline deforestation.

2.2.2 Adjustment of the location of the projected baseline deforestation

Using the adjusted projections for annual areas of baseline deforestation and any improved spatial data for the creation of the factor maps included in the spatial model, the location of the projected baseline deforestation must be reassessed using the methods explained in part 2 of the methodology.

All areas credited for avoided deforestation in past fixed baseline periods must be excluded from the revisited baseline projections as these areas cannot be credited again. To perform this exclusion use the map of "cumulative areas credited" that was updated in all previous verification events.

Note: If the boundary of the leakage belt area was assessed using equation (1) or any other spatial model, the boundary of the leakage belt will have to be reassessed at the end of each fixed baseline period using the same methodological approaches used in the first period. This will be required until monitoring of leakage will become unnecessary[49].

2.3 Adjustment of the carbon component of the baseline

Adjusting the carbon component of the baseline will not be necessary in most cases (see section 1.1.3 in Part 3 for more detailed guidance). However, improved carbon stock data are likely to become available over time and if this is the case, they must be used when revisiting the baseline projections. Methods to measure and estimate carbon stocks are described in appendix 3.

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[49] Monitoring of leakage will become obsolete at the date when a VCS or UNFCCC registered (and VCS endorsed) program is monitoring, reporting, verifying and accounting emissions from deforestation in a broader area encompassing the project area.

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APPENDIX 1: DEFINITION OF TERMS FREQUENTLY USED IN THE METHODOLOGY

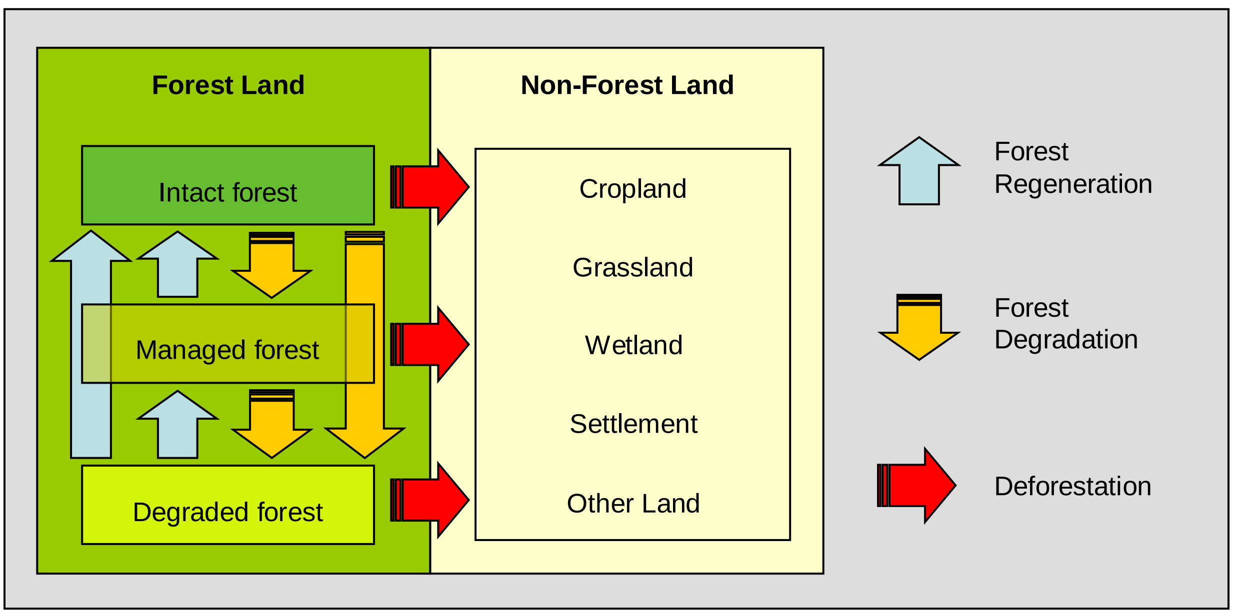
Activity Data is the annual area (ha yr^{-1}) lost or acquired by a *LU/LC class cl* at a given year *t* or the annual area of a *category of LU/LC change ct* for a given year *t*.

Baseline Scenario is the expected change in land use and land cover (LU/LC) in the absence of any *project activity* designed to reduce emissions from *deforestation, forest degradation*, or enhance *carbon stocks*.

Baseline is the sum of *carbon stock* changes and GHG emissions that would occur in the absence of the proposed REDD *project activity*.

Broad Category is the term used in this methodology to identify three main *categories* of LU/LC-change: *deforestation*, *forest degradation* (with carbon stock decrease) and *forest regeneration*(with carbon stock increase) (see figure A1-1):

Figure A1-1. *Broad categories* of land-use and land-cover change



Carbon Density (or *carbon stock* per hectare) is the amount of carbon (as CO_2-e) per hectare (ha^{-1}) estimated to be present in the accounted carbon pools of a *LU/LC Class* at year *t*.

Carbon Stock is the *carbon density* of an area times the number of hectares in the area.

Carbon Stock Change Factor: see "*Emission Factor*".

Category of LU/LC-Change (or simply "*category*") is the change from one *LU/LC class* to another that occurs during a given period of time.

Category is the term used in IPCC reports to refer to specific sources of emissions or removals of greenhouse gases. Under the AFOLU sector, "categories" are land-use / land-cover (LU/LC) transitions. REDD methodologies deal with the following categories:

(a) *Forest* Land to *Forest* Land (degradation and regeneration of *forest* land remaining *forest* land)

(b) *Forest* Land to Crop Land (*deforestation* followed by agriculture)

(c) *Forest* Land to Grass Land (*deforestation* followed by pasture)

(d) *Forest* Land to Settlements (*deforestation* followed by settlements)

(e) *Forest* Land to Wetlands (*deforestation* followed by wetlands)

(f) *Forest* Land to Other Land (*deforestation* followed by other land)

Activities that convert non *forest* land back to *forest* (Crop Land to *Forest* Land, Grass Land to *Forest* Land, etc.) are considered afforestation and reforestation and are excluded from this REDD methodology."

***Class*.** See *LU/LC Class*.

Deforestation is the direct, human-induced and long-term (or permanent) conversion of *forest* land to non-*forest* land[50]. It occurs when at least one of the parameter values used to define "*forest* land" is reduced from above the threshold for defining "*forest*" to below this threshold for a period of time that is longer than the period of time used to define "*temporarily un-stocked*"[51]. For example, if a country defines a *forest* as having a crown cover greater than 30% and "*temporarily un-stocked*" as a maximum period of 3 years, then *deforestation* would not be recorded until the crown cover is reduced below 30% for at least three consecutive years[52]. Country should develop and report criteria by which temporary removal or loss of tree cover can be distinguished from *deforestation*.

Eligible Land. To avoid double counting of emission reductions, land areas registered under the CDM or the VCS or any other carbon trading scheme (both voluntary and compliance-oriented) should be transparently reported and excluded from the *project area*.

Emission Factor (or *Carbon Stock Change Factor*) is the difference between the *carbon density* of the two *LU/LC classes* describing a *category of LU/LC change*.

Fixed baseline period is the period of time for which the validated *baseline* is fixed, which under the VCS can be up to 10 years. After this period of time, the baseline must be reassessed using a VCS approved methodology.

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[50] Forest area and carbon stock losses due to natural disturbances (landslides, consequences of volcanic eruptions, and see level rise, among other) are not considered "deforestation".

[51] According to IPCC (GPG LUUCF, 2003, Chapter 4.2.6.2.) "The identification of units of land subject to deforestation activities requires the delineation of units of land that:

(a) Meet or exceed the size of the country's minimum forest area (i.e., 0.05 to 1 ha); and

(b) Have met the definition of forest on 31 December 1989; and

(c) Have ceased to meet the definition of forest at some time after 1 January 1990 as the result of direct human-induced deforestation."

[52] Deforestation can be the result of an abrupt event (deforestation = forest → non-forest), in which case the change in land-cover and land-use occurs immediately and simultaneously; or of a process of progressive degradation (deforestation = forest → degraded forest → non-forest), in which case the change in land-cover occurs when one of the parameters used for defining "forest land" falls below its minimum threshold, but the change in land-use may have already occurred or will occur later (e.g. use of the land for the production of crops or grazing animals). Land-use is thus not a reliable indicator for identifying a forest class or for defining a category of change. .

Forest is a land with woody vegetation consistent with the thresholds used to define "*forest* land" in the country where the REDD *project activity* will be implemented. Where the country has adopted a *forest* definition for the Kyoto Protocol, the minimum thresholds of the vegetation indicators (minimum area, tree crown cover and height)[53] used for defining "*forests*", as communicated by the DNA[54]consistent with decision 11/CP.7 and 19/CP.9, should be used. Otherwise, the definition used to define "*Forest* Land" in national GHG inventory should be used.

Land defined as "*forest* land" can include areas that do not, but at maturity *in situ* could potentially reach, the thresholds used to define "*forest* land". To distinguish between "non-*forest*" (and hence "deforested") and "*temporarily un-stocked*" areas in managed *forests*, the definition of "*forest*" should include the maximum period of time that the woody vegetation can remain below the thresholds used to define "*forest* land". This maximum period can be specific for each *category of land-use / land-cover change (LU/LC-change)*. For instance, it could be zero years for conversion from "*forest* land to crop land", but up to 5 or more years for transitions between *forest* classes (e.g. age classes)[55].

Areas covered with planted *forests* as well as with any other anthropogenic vegetation type that meet the definition of "*forest*" since the earliest date of the *historical reference period* used to assess *deforestation* can be considered "*forest* land". Hence, "*forests*" can be natural, semi-natural, or anthropogenic and they may include primary or old-growth *forests* (intact or logged), secondary *forests*, planted *forests*, agro-forestry and silvo-pastoral systems.

Forest degradation is "*forest* land remaining *forest* land" but gradually losing *carbon stocks* as a consequence of direct-human intervention (e.g. logging, fuel-wood collection, fire, grazing, etc.)[56]. Units of *forest* land subject to degradation are allocated to different *forest classes* over time, with each successive *class* having a lower *carbon density* than the previous one. The difference in average *carbon density* between two contiguous *forest classes* should be at least 10%. The difference refers to the upper and lower levels of the confidence intervals of the two contiguous *forest classes* in the degradation sequence (figure A1-2).

Forest management. Areas subject to sustainable *forest management* (with logging activities) represent a particular *class* of "degraded *forest*". An undisturbed natural *forest* that will be subject to

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[53] "Forest is a minimum area of land of 0.05 – 1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10 – 30 per cent with trees with the potential to reach a minimum height of 2 – 5 meters at maturity *in situ*. A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high portion of the ground or open forest. Young natural stands and all plantations which have yet to reach a crown density of 10 – 30 per cent or tree height of 2 – 5 meters are included under forest, as are areas normally forming part of the forest area which are temporarily un-stocked as a result of human intervention such as harvesting or natural causes but which are expected to revert to forest".

[54] DNA = Designated National Authority of the Clean Development Mechanism

[55] Project proponents should report on how they distinguish between deforestation and areas that remain forests but where tree cover has been removed temporarily, notably areas that have been harvested or have been subject to other human or natural disturbance but for which it is expected that forest will be replanted or regenerate naturally. See IPCC GPG LULUCF, 2003, Chapter. 4.2.6.2.1 for further guidance on this issue.

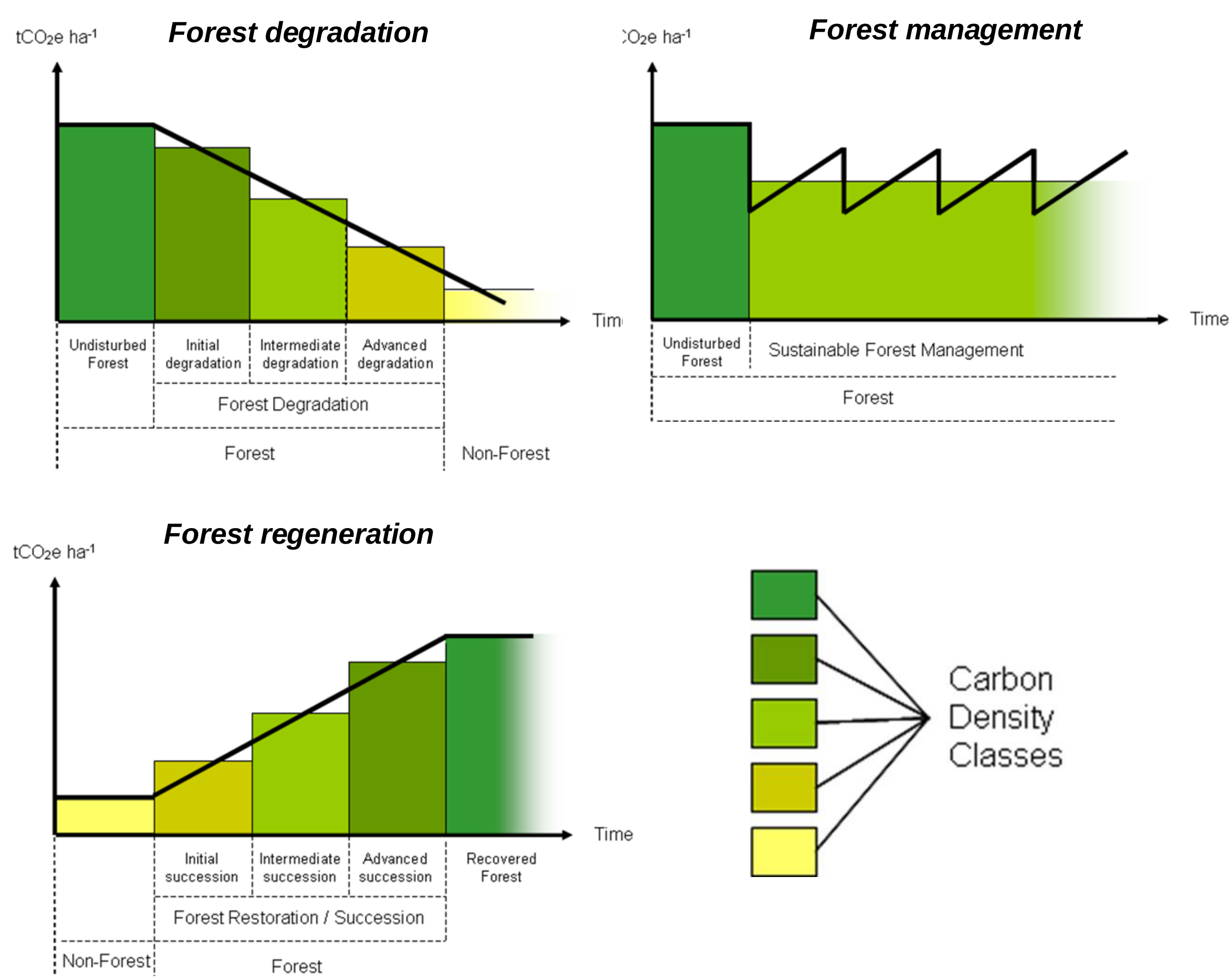
[56] According to IPCC GPG LLUCF "forest degradation" is "a direct, human-induced, long-term (persisting for *X* years or more) or at least *Y%* of forest carbon stock [and forest values] since time *T* and not qualifying as deforestation". Note that *X*, *Y%* and *T* are not quantified. See IPCC 2003 (Report on Definitions and Methodological Options to Inventory Emissions from Direct Human-induced Degradation of Forests and Devegetation of Other Vegetation Types, Chapter 2.2) for a discussion on the definition of "forest degradation", in particular table 2.1 for alternative definitions of direct human-induced forest degradation.

sustainable *forest management* will lose part of its carbon, but the loss will partially recover over time. In the long-term, a sustainable harvesting and re-growth cycle will maintain a constant average *carbon density* in the *forest*. Since this average *carbon density* is lower than in the original *forest*, sustainably managed *forests* can be considered a degraded *forest class*.

Depending on the magnitude and timeframe of the *carbon stock* changes, managed *forests* could be classified into one single "managed *forest*" *class* (with a *carbon density* equivalent to the average of the entire management cycle) or to different sub-*classes* representing different average carbon densities (figure A1-2).

Forest Regeneration is "*forest* land remaining *forest* land" but gradually enhancing its carbon stock as a consequence of direct-human intervention. Units of *forest* land subject to regeneration are allocated to different *forest classes* over time, with each successive *forest* class having a higher *carbon density* than the previous one. The difference in average *carbon density* between two contiguous *forest classes* should be at least 10%. The difference refers to the upper and lower levels of the confidence intervals of the two *forest classes*.

A1-2. *Carbon density* in "*forest* land remaining *forest* land" (living tree biomass)



Frontier Deforestation is the conversion of *forest* land to non-*forest* land occurring when the agricultural frontier expands as a result of improved access to *forest* into areas with relatively little human activity.

Historical Reference Period is a time period preceding the starting date of the proposed REDD project activity. It is analyzed to determine the magnitude of *deforestation* and *forest degradation* in the *reference region* and to identify agents and drivers of DD and the chain of events leading to land-use / land-cover change. In order to be useful for understanding recent and likely future DD trends, the starting date of the *historical reference period* should be selected between 10 and 15 years in the past, and the end date as close as possible to present.

Leakage is the decrease in *carbon stocks* and the increase in GHG emissions attributable to the implementation of the REDD *project activity* that occurs outside the boundary of the *Project area*.

Leakage Belt is the geographical area surrounding or adjacent to the *project area* which activity displacement *leakage* could occur.

Leakage Management Area(s) are areas outside the *project area* in which activities are implemented to avoid *leakage.* At the project start date, leakage management areas must be non-forest land

LU/LC Class (or simply "*class*") is a unique combination of land use and land cover having a specific *carbon density* at time *t*.

LU/LC Polygon is a discrete area falling into a single *LU/LC class*.

Monitoring period is the period of time (in years) between two monitoring and verification events. Typically it is a fraction of the *fixed baseline period*. The minimum duration is one year and the maximum is the duration of the *fixed baseline period*.

Mosaic Deforestation is the conversion of *forest* land to non-*forest* land occurring in a patchy pattern where human population and associated agricultural activities and infrastructure (roads, towns, etc.) are spread out across the landscape and most areas of *forest* within such a configured region or country are practically already accessible.

Planned Deforestation is the legally authorized conversion of *forest* land to non-*forest* land occurring in a discrete area of land. *Deforestation* within an area can be planned (designated and sanctioned) or unplanned (unsanctioned). *Planned deforestation* can include a wide variety of activities such as national resettlement programs from non-forested to forested regions; a component of a national land plan to reduce the *forest* estate and convert it to other industrial-scale production of goods such as soybeans, pulpwood plantations, and oil palm plantations; or plans to convert well-managed community-owned *forests* to other non-*forest* uses. Other forms of *planned deforestation* could also include decisions by individual land owners, whose land is legally zoned for agriculture, to convert their say selectively logged *forest* to crop production. These *planned deforestation* activities would be a component of some land planning or management document and could be readily verified.

Project Activity is the series of planned steps and activities by which the proponent intends to reduce *deforestation* and *forest degradation* and/or enhance forest regeneration.

Project area is the area or areas of land on which the proponent will undertake the *project activities.* No lands on which the *project activity* will not be undertaken can be included in the *project area*.

Project crediting period. Please see current VCS definition.

Project Scenario is the expected change in land use and land cover within the boundary of the *project area* resulting from the undertaking of the *project activity*.

Project Term is the projected lifetime of the REDD *project activity*, which under the VCS is equivalent to the project *crediting period*.

Reference region is the spatial delimitation of the analytic domain from which information about *deforestation* and degradation agents, drivers and LU/LC-change is obtained, projected into the future and monitored. The *reference region* includes the *Project area*[57] and is defined by the project proponent using transparent criteria. It must contain *LU/LC classes* and *deforestation* agents and drivers similar to those found in the *project area* under the *baseline* and *project scenarios*.

Zone is a stratum of the reference region containing a distinctive mix of final post-deforestation classes *fcl*

[57] The methodology thus adopts a so called "Stratified Regional Baseline" (SRB) approach, which has been recommended in recent literature (Sataye and Andrasko, 2007; Brown *et al.*, 2007)

APPENDIX 2: INDICATIVE TABLES

Table 1. Guidance on carbon pool selection depending on the land-use / land-cover change *category* considered[58]

Type of land-use / land-cover transition	Living biomass (trees)		Dead organic matter			Soil
	Above-ground	Below-ground	Wood products	Dead wood	Litter	Organic matter
Forest to cropland	+++	++	+	+	+	+
Forest to pasture	+++	++	+	+	+	
Forest to shifting cultivation	+++	++		+		
Forest to degraded *forest*	+++	++	+			
+++ = include always; ++ = inclusion recommended; + = inclusion possible						

Table 2. Present availability of optical mid-resolution (10-60m) sensors (GOFC-GOLD, 2008)

Nation	Satellite & sensor	Resolution & coverage	Cost (archive[59])	Feature
U.S.A.	Landsat-5 TM	30 m 180×180 km^2	600 US$/scene 0.02 US$/km^2	Images every 16 days to any satellite receiving station. Operating beyond expected lifetime.
U.S.A.	Landsat-7 ETM+	30 m 60×180 km^2	600 US$/scene 0.06 US$/km^2	On April 2003 the failure of the scan line corrector resulted in data gaps outside of the central portion of images, seriously compromising data quality
U.S.A./Japan	Terra ASTER	15 m 60×60 km^2	60 US$/scene 0.02 US$/km^2	Data is acquired on request and is not routinely collected for all areas
India	IRS-P2 LISS-III & AWIFS	23.5 & 56 m		Experimental craft shows promise, although images are hard to acquire
China/Brazil	CBERS-2 HRCCD	20 m		Experimental; Brazil uses on-demand images to bolster their coverage.
Algeria/China/ Nigeria/Turkey/ U.K.	DMC	32 m 160×660 km^2	3000 €/scene 0.03 €/km^2	Commercial; Brazil uses alongside Landsat data
France	SPOT-5 HRVIR	5-20 m 60×60 km^2	2000 €/scene 0.5 €/km^2	Commercial Indonesia & Thailand used alongside Landsat data

[58] Modified from GOFC-GOLD, 2008. See the most recent version of the GOFC-GOLD sourcebook for REDD, as new remote sensing platforms are becoming available.

[59] Some acquisitions can be programmed (e.g., DMC, SPOT). The cost of programmed data is generally at least twice the cost of archived data.

Table 3. Example of a potential land use-change matrix

Final \ Initial		Forest land: *Class 1*	*Class 2*	*Class 3*	*Class 4*	*Class 5*
Forest Land	*Class 1*	*Category 1/1*	*Category 2/1*	*Category 3/1*	*Category 4/1*	*Category 5/1*
	Class 2	*Category 1/2*	*Category 2/2*	*Category 3/2*	*Category 4/2*	*Category 5/2*
	Class 3	*Category 1/3*	*Category 2/3*	*Category 3/3*	*Category 4/3*	*Category 5/3*
	Class 4	*Category 1/4*	*Category 2/4*	*Category 3/4*	*Category 4/4*	*Category 5/4*
	Class 5	*Category 1/5*	*Category 2/5*	*Category 3/5*	*Category 4/5*	*Category 5/5*
Grassland	*Class 6*	*Category 1/6*	*Category 2/6*	*Category 3/6*	*Category 4/6*	*Category 5/6*
Cropland	*Class 7*	*Category 1/7*	*Category 2/7*	*Category 3/7*	*Category 4/7*	*Category 5/7*
Wetland	*Class 8*	*Category 1/8*	*Category 2/8*	*Category 3/8*	*Category 4/8*	*Category 5/8*
Settlement	*Class 9*	*Category 1/9*	*Category 2/9*	*Category 3/9*	*Category 4/9*	*Category 5/9*
Other Land	*Class 10*	*Category 1/10*	*Category 2/10*	*Category 3/10*	*Category 4/10*	*Category 5/10*

Table 4. Example of a land-use / land-cover change matrix

Final \ **Initial**			Forest land: Old growth forests		Degraded old growth forest			Secondary forest			Plantations			**Final area**
			intact	managed	initial	intermediate	advanced	initial	intermediate	advanced	young	mid	mature	
Forest Land	Old-growth	intact	100											**100**
		managed	1	5										**6**
	Degraded	initial	1		2									**3**
		intermediate			2	1								**3**
		advanced				2	3							**5**
	Secondary	initial						2						**2**
		intermediate						1	3					**4**
		advanced							1	1				**2**
	Plantations	young					1	1	1		1		1	**5**
		mid									1	2		**3**
		mature											1	**1**
Grassland		unimproved	1	1	1	2		1	1	1				**8**
		improved				1	1							**2**
Cropland				1		1		2	3	3				**10**
Wetland														**0**
Settlement														**0**
Other Land														**0**
Initial Area			**103**	**7**	**5**	**7**	**5**	**7**	**9**	**5**	**2**	**2**	**2**	**154**
Net Change			-3	-1	-2	-4	0	-5	-5	-3	3	1	-1	0

Notes:

- Numbers represent hectares or *activity data* (in this case numbers are for illustrative purposes only, they do not represent any real case).

- Column and rows totals show net conversion of each LU/LC-class.
- "Initial" indicates the area of the LU/LC-class at the starting date of the period assessed, and "Final" the area of the class at the end date of the assessment period.
- Net changes (bottom rows) are the final area minus the initial area for each of the LU/LC-classes shown at the head of the corresponding column.
- Blank entries indicate no LU/LC-change the period assessed.

Table 5. Approximate values of daily biomass intake (d. m. – dry mass) for different type of animals[60]

Animal Type		Daily Feed Intake (MJ head^{-1} day^{-1})	Daily Biomass Intake (kg d. m. head^{-1} day^{-1})
Sheep	Developed Countries	20	2.0
	Developing Countries	9	1.3
Goats	Developed Countries	14	1.4
	Developing Countries	14	1.4
Mules/Asses	Developed Countries	60	6.0
	Developing Countries	60	6.0
Sources: Feed intake from Crutzen *et al.* (1986).			

[60] Taken form AR-AM0003 version 2

Box 1: Geomod

Geomod is a land-use land-cover change simulation model implemented in Idrisi, a GIS software developed by Clark University (Pontius *et al.*, 2001; Brown *et al.*, 2007). Geomod has been used frequently to analyze baseline scenarios of deforestation at continental scale for Africa, Asia and Latin America; at the country scale for Costa Rica and India; and at local scale within India, Egypt, Unites States and several countries in Latin America (Pontius and Chen, 2006).

Geomod is a grid-based model that predicts the transition from one *LU/LC class* to another *LU/LC class*, i.e. the location of grid cells that change over time from *class* 1 to *class* 2. Hence, Geomod can be used to predict areas likely to change from *forest class* 1 to non-forest *class* 2 (*deforestation*) over a given time.

Geomod creates the LU/LC-change risk map empirically, by using several driver images and the land-cover map from the beginning time. For example, Geomod's *deforestation* risk maps have relatively high values at location that have biogeophysical attributes similar to those of the deforested land (= "developed land" in Geomod's jargon) of the beginning time, and has relatively low values at locations that have biogeophysical attributes similar to those of forested land ("non-developed" land) of the beginning time.

APPENDIX 3: METHODS TO ESTIMATE CARBON STOCKS

Sampling framework

The sampling framework, including sample size, plot size, plot shape and plot location should be specified in the PD.

Areas to be sampled in forest classes should be at locations expected to be deforested according to the baseline projections.

The sampling areas for non-forest classes should be selected within the reference region at locations that represent a chrono-sequence of 10 to 30 years since the deforestation date.

Temporary or permanent plots

Plots can be temporary or permanent depending on the specific project circumstances, interests and needs, but in general temporary plots should be sufficient.

Where changes in carbon stocks are to be monitored, permanent sampling plots are recommended. Permanent sample plots are generally regarded as statistically efficient in estimating changes in forest carbon stocks because typically there is high covariance between observations at successive sampling events. However, it should be ensured that the plots are treated in the same way as other lands within the project boundary, e.g., during logging operations, and should not be destroyed over the monitoring interval. Ideally, staff involved in forest management activities should not be aware of the location of monitoring plots. Where local markers are used, these should not be visible. If trees markers are required (e.g. if plots are also used for ecological or structural monitoring), these should be as unconspicous as possible and no bias in the treatment of plots compared to the surrounding forest must be granted.

Permanent plots may also be considered to reduce the uncertainty of the average carbon density of a forest class undergoing carbon stock changes due to management and to detect changes in carbon stocks induced by climate change or large-scale natural disturbances.

Definition of the sample size and allocation among LU/LC-classes

The number of sample plots is estimated as dependent on accuracy, variability of the parameter to estimate in each class and costs. The sample size calculation also corresponds to the method of samples drawn without replacement. Where at the beginning of a REDD project activity accurate data for sample size estimation and allocation are not available, the sampling size can initially be estimated by using a desired level of accuracy (10% of sampling error at 90% confidence level), and by allocating the estimated sample size proportionally to the area of each class[61], using respectively equations 1, and 2. Then, once data on carbon stock variability within each class become available, the sample size and allocation is recalculated using the methodology described by Wenger (1984)[62], which also accounts for the cost of sampling (see equations 3 and 4).

Equation 1 was chosen because it works with percentages rather than absolute units (biomass, carbon, or CO_2), and coefficient variation data could be more easy to find in the literature at the beginning of a project activity. The initial allocation of the sample plots shall be proportional to the area of the LU/LC-

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[61] Loetsch, F. and Haller, K. 1964. Forest Inventory. Volume 1. BLV-VERLAGS GESE LLSCHAFT, München.

[62] Wenger, K.F. (ed). 1984. Forestry handbook (2nd edition). New York: John Wiley and Sons.

classes, but with minimum of 5 plots per class. The t-student for a 95% confidence level is approximately equal to 2 when the number of sample plot is over 30. As the first step, use 2 as the t –student value, and if the resulting "*n*" is less than 30, use the new "*n*" to get a new t-student value and conduct the new estimation of the sample size. This process can be repeated until the calculated *n* is stabilized.

$$n = \frac{t_{st}^2 \cdot (CV\%)^2}{(E\%)^2 + \frac{t_{st}^2 \cdot (CV\%)^2}{N}} \quad \text{(A3-1)}$$

$$n_{cl} = n \cdot \frac{N_{cl}}{N} \quad \text{(A3-2)}$$

Where:

cl	=	1, 2, 3, …. *Cl* LU/LC classes
Cl	=	Total number of LU/LC classes
t_{st}	=	t-student value for a 90% confidence level (initial value t = 2)
n	=	total number of sample units to be measured (in all LU/LC classes)
E%	=	allowable sample error in percentage (±10%)
CV%	=	the highest coefficient of variation (%) reported in the literature from different volume or biomass forest inventories in forest plantations, natural forests, agro-forestry and/or silvo-pastoral systems.
n_i	=	number of samples units to be measured in LU/LC class *cl* that is allocated proportional to the size of the class. If estimated $n_{cl} < 3$, set $n_{cl} = 3$.
N_i	=	maximum number of possible sample units for LU/LC class *cl*, calculated by dividing the area of *class cl* by the measurement plot area.
N	=	population size or maximum number of possible sample units (all LU/LC classes), $N = \sum_{cl=1}^{Cl} N_{cl}$

In equation A3-2 the standard deviation of each LU/LC class (S_{cl}) shall be determined using the actual data from the latest field measurement. The allowable error is an absolute value, and can be estimated as ±10% of the observed overall average carbon stock per hectare. It is possible to reasonably modify the LU/LC class limits and the sample size after each monitoring event based on the actual variation of the carbon stock changes determined from taking "*n*" sample plots. Where costs for selecting and measuring plots are not a significant consideration then the calculation and allocation of the sample size can be simplified by setting C_{cl} equal to 1 across all LU/LC classes.

$$n = \left(\frac{t_{st}}{E}\right)^2 \left[\sum_{cl=1}^{Cl} W_{cl} \cdot S_{cl} \cdot \sqrt{C_{cl}}\right] \cdot \left[\sum_{cl=1}^{Cl} W_{cl} \cdot S_{cl} \big/ \sqrt{C_{cl}} \cdot\right] \quad \text{(A3-3)}$$

$$n_{cl} = n \cdot \frac{W_{cl} \cdot S_{cl} \Big/ \sqrt{C_{cl}}}{\sum_{cl=1}^{Cl} W_{cl} \cdot S_{cl} \Big/ \sqrt{C_{cl}}} \qquad \text{(A3-4)}$$

Where:

cl	=	1, 2, 3, … *Cl* LU/LC classes
Cl	=	total number of LU/LC classes
t_{st}	=	t-student value for a 95% confidence level, with n-2 degrees of freedom
E	=	allowable error (±10% of the mean)
S_{cl}	=	standard deviation of LU/LC class *cl*
n_{cl}	=	number of samples units to be measured in LU/LC class *cl* that is allocated proportional to $W_{cl} \cdot S_{cl} \Big/ \sqrt{C_{cl}}$. If $n_{cl} < 3$, set $n_{cl} = 3$.
W_{cl}	=	N_{cl}/N
n	=	total number of sample units to be measured (in all LU/LC classes)
N_{cl}	=	maximum number of possible sample units for LU/LC class *cl*, calculated by dividing the area of LU/LC class *cl* by the measurement plot area
N	=	population size or maximum number of possible sample units (all strata), $N = \sum_{cl=1}^{Cl} N_{cl}$
C_i	=	cost to select and measure a plot of the LU/LC class *cl*

Sample plot size

The plot area *a* has major influence on the sampling intensity, time and resources spent in the field measurements. The area of a plot depends on the stand density. Therefore, increasing the plot area decreases the variability between two samples. According to Freese (1962)[63], the relationship between coefficient of variation and plot area can be denoted as follows:

$$CV_2^{\ 2} = \quad CV_1^{\ 2} \sqrt{(a_1 / a_2)} \qquad \text{(A3-5)}$$

Where a_1 and a_2 represent different sample plot areas and their corresponding coefficient of variation (*CV*). Thus, by increasing the sample plot area, variation among plots can be reduced permitting the use of small sample size at the same precision level. Usually, the size of plots is between 100 m^2 for dense

63 Freese, F. 1962. Elementary Forest Sampling. USDA Handbook 232. GPO Washington, DC. 91 pp

stands and 1000 m^2 for open stands[64].

Plot location

To avoid subjective choice of plot locations (plot centers, plot reference points, movement of plot centers to more "convenient" positions), the permanent sample plots shall be located either systematically with a random start (which is considered good practice in IPCC GPG-LULUCF) or completely randomly inside each defined stratum. This can be accomplished with the help of the project GIS platform and a GPS in the field. The geographical position (GPS coordinate), administrative location, stratum and stand, series number of each plot, as well as the procedure used for locating them shall be recorded and archived.

Also, it is recommended that the sampling plots are as evenly distributed as possible. For example, if one stratum consists of three geographically separated sites, then it is proposed to

- Divide the total stratum area by the number of plots, resulting in the average area represented by each plot;
- Divide the area of each site by this average area per plot, and assign the integer part of the result to this site. e.g., if the division results in 6.3 plots, then 6 plots are assigned to this site, and 0.3 plots are carried over to the next site, and so on.

However, remote areas and areas with poor accessibility (either because of physical or social barriers such as unsafe areas) may be excluded for the location of sampling plots, using a transparent and conservative procedure, such as creating a buffer zone along roads, paths or navigable rivers that may be used for reaching the sampling plots. In this case, the representativeness of the plots for the corresponding stratum must be ensured.

The exact total number of plots is unknown at the beginning of the field sampling and thus a perfectly even distribution of sampling plots is not possible. This is also the case if pre existing inventory data is used. In any case, the uneven distribution of sampling plots will be accepted provided that statistical representativeness and the use of standard sampling techniques are granted, clearly reported and archived.

Estimation of carbon stocks

The total average carbon stock per hectare (= carbon density) in a LU/LC class is estimated by the following equation:

$$Ctot_{cl} = Cab_{cl} + Cbb_{cl} + Cdw_{cl} + Cl_{cl} + Csoc_{cl} - Cwp_{cl} \qquad \text{(A3-6)}$$

Where:

$Ctot_{cl}$ = Average carbon stock per hectare in all accounted carbon pools of the LU/LC-class *cl*; tCO_2-e ha^{-1}

Note: *Cwp_{cl}* is subtracted if *cl* is an initial pre-deforestation forest class in the baseline case. It is added if *cl* is a final post-deforestation class or a forest class not deforested in the project scenario.

[64] It is recommended to use sample plots of equal area for the strata. This methodology cannot be used if sample plots area varies within the same stratum. The density of trees to be considered is the one at maturity of the trees.

Cab_{cl}	=	Average *carbon stock* per hectare in the above-ground biomass carbon pool of the LU/LC class *cl*; tCO_2.e ha^{-1}
Cbb_{cl}	=	Average carbon stock per hectare in the below-ground biomass carbon pool of the *LU/LC class cl*; tCO_2.e ha^{-1}
Cdw_{cl}	=	Average carbon stock per hectare in the dead wood carbon pool of the LU/LC class *cl*; tCO_2.e ha^{-1}
Cl_{cl}	=	Average carbon stock per hectare in the litter carbon pool of the LU/LC class *cl*; tCO_2.e ha^{-1}
$Csoc_{cl}$	=	Average carbon stock per hectare in the soil organic carbon pool of the LU/LC class *cl*; tCO_2.e ha^{-1}
Cwp_{cl}	=	Average carbon stock per hectare in the wood products carbon pool of the LU/LC class *cl*;

Note: See methodology Part 2 on mandatory carbon pools.

Estimation of carbon stocks in the living biomass carbon pools (Cab_{cl} and Cbb_{cl})

In a forest most of the carbon is stored in the tree component of the living biomass. Hence, for a majority of forest classes it is sufficient to estimate the carbon stock in the tree component and to ignore the carbon stock in the non-tree vegetation component.

However, there might be situations where carbon stocks in the non-tree vegetation component are significantly increased in the LU/LC-classes adopted after deforestation (e.g. coffee plantations). Under such circumstances, carbon stocks in the non-tree vegetation component should be estimated[65].

The living biomass components that are measured and the minimum diameter at breast height (DBH) above which trees are measured should be specified in the PD.

Carbon stocks in the living biomass are given by the following equations:

$$Cab_{cl} = Cabt_{cl} + Cabnt_{cl} \tag{A3-7}$$

$$Cbb_{cl} = Cbbt_{cl} + Cbbnt_{cl} \tag{A3-8}$$

Where:

Cab_{cl}	=	Average *carbon stock* per hectare in the above-ground biomass carbon pool of the LU/LC class *cl*; tCO_2.e ha^{-1}
$Cabt_{cl}$	=	Average *carbon stock* per hectare in the above-ground tree biomass carbon pool of the LU/LC class *cl*; tCO_2.e ha^{-1}
$Cabnt_{cl}$	=	Average *carbon stock* per hectare in the above-ground non-tree biomass carbon pool of the LU/LC class *cl*; tCO_2.e ha^{-1}
Cbb_{cl}	=	Average *carbon stock* per hectare in the below-ground biomass carbon pool of the LU/LC class *cl*; tCO_2.e ha^{-1}

65 The same carbon pools are to be estimated for the two classes of a LU/LC-change category

$Cbbt_{cl}$	=	Average *carbon stock* per hectare in the below-ground tree biomass carbon pool of the LU/LC class *cl*; tCO_{2}-e ha^{-1}
$Cbbnt_{cl}$	=	Average carbon stock per hectare in the below-ground non-tree biomass carbon pool of the LU/LC class *cl*; tCO_{2}-e ha^{-1}

Tree component ($Cabt_{cl}$ and Cbb_{cl})

The carbon stock of trees can be estimated using: (a) Existing forest inventory data; or (b) Direct field measurements.

(a) Estimations using *forest* inventory data

(See the most recent version of the GOFC-GOLD sourcebook for REDD for more details)

Forest inventory data typically comes in two different forms: (1) Stand tables and (2) Stock tables.

(a.1) Stand tables provide the number of trees in diameter (DBH) classes. The method basically involves estimating the biomass per average tree of each diameter class of the stand table, multiplying by the number of trees in the class, and summing across all classes. The mid-point diameter of a diameter class should be used in combination with an allometric biomass regression equation (explained later).

Stand tables often include trees with a minimum diameter of 30 cm or more, which essentially ignores a significant amount of carbon particularly for younger *forests* or heavily logged. To overcome this problem Gillespie *et al.* (1992) developed a technique that can be used to estimate the number of trees in lower diameter classes (see Box 1).

Box 1. Adding diameter classes to truncated stand tables

DBH-Class cm	Midpoint Diameter cm	Number of Stems per ha Nr
10-19	15	-
20-29	25	-
30-39	35	35.1
40-49	45	11.8
50-59	55	4.7
…	…	…

DBH class 1 = 30-39 cm, DBH class 2 =40-49 cm

Ratio = 35.1/11.8 = = 2.97

(a.2) Stock tables indicate the volume of merchantable timber by diameter class or total per hectare. If volume data are just for commercial species do not use them for estimating *carbon stock*s, because a large and unknown proportion of the total volume is excluded.

The biomass density can be calculated from Volume Over Bark (*VOB*) by multiplying this value with the Biomass Conversion and Expansion Factor (*BCEF*). When using this approach and default values of the *BCEF* provided in the IPCC GL AFOLU, it is important that the definitions of *VOB* match. The values of *BCEF* for tropical *forests* in the AFOLU report are based on a definition of *VOB* as follows:

> *"Inventoried volume over bark of free bole, i.e. from stump or buttress to crown point or first main branch. Inventoried volume must include all trees, whether presently commercial or not, with a minimum diameter of 10 cm at breast height or above buttress if this is higher"*.

Values of the *BCEF* are given in table 4.5 of the IPCC GL AFOLU guidelines, and those relevant to tropical humid broadleaf and pine *forests* are shown in the table 1.

Table 1. Values of *BCEF* for application to volume data

(Modified by GOFC-GOLD (2008) from table 4.5 in IPCC GL AFOLU)

	Growing stock volume –*average* and range (*VOB*, m^3/ha)						
Forest type	<20	21-40	41-60	61-80	80-120	120-200	>200
Natural broadleaf	4.0 2.5-12.0	2.8 1.8-304	2.1 1.2-2.5	1.7 1.2-2.2	1.5 1.0-1.8	1.3 0.9-1.6	1.0 0.7-1.1
Conifer	1.8 1.4-2.4	1.3 1.0-1.5	1.0 0.8-1.2	0.8 0.7-1.2	0.8 0.6-1.0	0.7 1.6-0.9	0.7 0.6-0.9

In cases where the definition of *VOB* does not match exactly the definition given above, GOFC-GOLD (2008) recommend the following:

- If the definition of *VOB* also includes stem tops and large branches then the lower bound of the range for a given growing stock should be used;
- If the definition of *VOB* has a large minimum top diameter or the *VOB* is comprised of trees with particularly high basic wood density then the upper bound of the range should be used.

Forest inventories often report volumes for trees above a minimum *DBH*. To include the volume of *DBH* classes below the minimum *DBH*, GOFC-GOLD (2008) proposes Volume Expansion Factors (*VEF*). However, due to large uncertainties in the volume of smaller *DBH* classes, inventories with a minimum diameter that is higher than 30 cm should not be used. Volume expansion factors range from about 1.1 to 2.5, and are related to the *VOB*30 as follows to allow conversion of *VOB*30 to a *VOB*10 equivalent:

- For *VOB*30 < 250 m^3/ha use the following equation:

$$VEF = Exp(1.300 - 0.209 * \ln(VOB30)) \quad \text{(A3-9)}$$

- For *VOB*30 > 250 m^3/ha use *VEF* = 1.9

See Box 2 for a demonstration of the use of the *VEF* correction factor and *BCEF* to estimate biomass density.

Box 2. Use of volume expansion factor (*VEF*) and biomass conversion and expansion factor (*BCEF*)

Tropical broadleaf *forest* with a VOB30 = 100 m^3/ha

(1) Calculate the *VEF*:
VEF = Exp(1.300 - 0.209*Ln(100)) = 1.40

(2) Calculate *VOB*10:
*VOB*10 = 100 m^3/ha x 1.40 = 140 m^3/ha

(3) Take the *BCEF* from the table 1 above:
BCEF for tropical hardwood with growing stock of 140 m^3/ha = 1.3

(4) Calculate above-ground biomass density:
= 1.3 x 140 = 182 t/ha

Below-ground tree biomass (roots) is almost never measured, but instead is included through a relationship to above-ground biomass (usually a root-to-shoot ratio). If the vegetation strata correspond with tropical or subtropical types listed in table 2 (modified by GOFC-GOLD, 2008 from table 4.4 in IPCC GL AFOLU to exclude non-*forest* or non-tropical values and to account for incorrect values) then it makes sense to include roots.

Table 2. Root to shoot ratios

(Modified[66] by GOFC-GOLD, 2008) from table 4.4 in IPCC GL AFOLU)

Domain	Ecological Zone	Above-ground biomass	Root-to-shoot ratio	Range
Tropical	Tropical rain*forest*	<125 $t.ha^{-1}$	0.20	0.09-0.25
		>125 $t.ha^{-1}$	0.24	0.22-0.33
	Tropical dry *forest*	<20 $t.ha^{-1}$	0.56	0.28-0.68
		>20 $t.ha^{-1}$	0.28	0.27-0.28
Subtropical	Subtropical humid *forest*	<125 $t.ha^{-1}$	0.20	0.09-0.25
		>125 $t.ha^{-1}$	0.24	0.22-0.33
	Subtropical dry *forest*	<20 $t.ha^{-1}$	0.56	0.28-0.68
		>20 $t.ha^{-1}$	0.28	0.27-0.28

(b) Estimations using direct field measurements

Two methods are available to estimate the carbon stock of trees: (1) Allometric Equations method, and (2) Biomass Expansion Factors (*BEF*). The Allometric Equations method should be favored over the *BEF* method. However, if no biomass equations are available for a given species or *forest* type, the *BEF* method shall be used.

(b.1) <u>Allometric method</u>

1. In the sample plots, identify the plot unique identification number and record the measurement date. Then identify the tree species and identification numbers and measure the diameter at breast height (*DBH*, at 1.3 m above ground), and possibly, depending on the form of the allometric equation, the height of all the trees above a minimum *DBH*.

2. Choose or establish the appropriate allometric equations for each species or species group *j*.

$$TBab_j = f_j(DBH, H)_{ab} \quad \text{(A3-10)}$$

Where:

$TBab_j$ = above-ground biomass of a tree of species, or species group, or forest type *j*, kg $tree^{-1}$

[66] The modification corrects an error in the table based on communications with Karel Mulroney, the lead author of the peer reviewed paper from which the data were extracted.

Note: the unit (Kg $tree^{-1}$) could also be t $tree^{-1}$ or t ha^{-1}, depending on the type of allometric equation

$f_j(DBH,H)_{ab}$ = an allometric equation for species, or group of species, or forest type *j*, linking above-ground tree biomass (in kg $tree^{-1}$ – see the note above) to diameter at breast height (*DBH*) and possibly tree height (*H*).

The allometric equations are preferably local-derived and forest type-specific. When allometric equations developed from a biome-wide database, such as those in Annex 4A.2, Tables 4.A.1 and 4.A.2 of GPG LULUCF, are used, it is necessary to verify by destructively harvesting, within the project area (or within the forest class), but outside the sample plots, a few trees of different species and sizes and estimate their biomass and then compare against the selected equation. The number of trees to be felled will depend on the number of species and the range of size of trees the model(s) will represent. As a general rule, there should be two trees sampled for each 5 cm *DBH* width class. In case of mixed species natural forests, the sample should represent all strata existing in the forest. If the biomass estimated from the harvested trees is within about ±10% of that predicted by the equation, then it can be assumed that the selected equation is suitable for the project; otherwise, it will be required to develop full allometric models valid for the project. In this case, the sample must be increased until obtaining an appropriated statistical fit (all model variables should be statistically significant and the squared r of equation should be at least 0.7). If resources permit, the carbon content can be determined in the laboratory. Finally, allometric equations are constructed relating the biomass with values from easily measured variables, such as basal area or tree diameter and total height (see Chapter 4.3 in GPG LULUCF). Also generic allometric equations can be used, as long as it can be proven that they are conservative.

3. Estimate the carbon stock in the above-ground biomass of all trees measured in the permanent sample plots using the allometric equations selected or established for each species, group of species or forest type.

$$TCab_{tr} = TBab_{tr} \cdot CF_j \qquad \text{(A3-11)}$$

Where:

$TCab_{,tr}$ = *Carbon stock* in above-ground biomass of tree *tr*; kg C $tree^{-1}$(or t C tree-^{1})

$TBab_{tr}$ = Above-ground biomass of tree *tr*; kg $tree^{-1}$(or t tree-^{1})

CF_j = Carbon fraction for tree *tr,* of species, group of species or forest type *j*; t C (t d. m.)$^{-1}$

4. Calculate the carbon stock in above-ground biomass per plot on a per area basis. Calculate by summing the carbon stock in above-ground biomass of all trees within each plot and multiplying by a plot expansion factor that is proportional to the area of the measurement plot. If carbon stock is calculated in kilograms, it is divided by 1,000 to convert from kg to tonnes.

$$PCab_{pl} = \frac{\left(\sum_{tr=1}^{TR_{pl}} TCab_{tr} \cdot XF \right)}{1000} \qquad \text{(A3-12)}$$

$$XF = \frac{10{,}000}{AP} \quad \text{(A3-13)}$$

Where:

$PCab_{pl}$	=	Carbon stock in above-ground biomass in plot *pl*; t C ha^{-1}
$TCab_{tr}$	=	Above-ground biomass of tree *tr*; kg $tree^{-1}$(or t tree-^{1})
XF	=	Plot expansion factor from per plot values to per hectare values; dimensionless
AP	=	Plot area; m^2
tr	=	1, 2, 3, … TR_{pl} number of trees in plot *pl*; dimensionless

5. Calculate the average carbon stock by averaging across all plots within a LU/LC class.

$$Cab_{cl} = 44/12 * \frac{\sum_{pl=1}^{PL_{cl}} PCab_{pl}}{PL_{cl}} \quad \text{(A3-14)}$$

Where:

Ca_{cl}	=	Average carbon stock per hectare in above-ground biomass in LU/LC class *cl*; tCO_2-eha^{-1}.
$PCab_{pl}$	=	Carbon stock in above-ground biomass in plot *pl*; t C ha^{-1}
44/12	=	Ratio converting C to CO_2-e
pl	=	1, 2, 3, … PL_{cl} plots in LU/LC class c*l*; dimensionless
PL_{cl}	=	Total number of plots in LU/LC class c*l*; dimensionless

6. Estimate the carbon stock in the below-ground biomass of tree *tr* using root-shoot ratios and above-ground carbon stock and apply steps 4 and 5 to below-ground biomass.

$$TCbb_{tr} = TCab_{tr} \cdot R_j \quad \text{(A3-15)}$$

$$PCbb_{pl} = \frac{\left(\sum_{tr=1}^{TR} TCbb_{tr} \cdot XF \right)}{1000} \quad \text{(A3-16)}$$

$$Cbb_{cl} = 44/12 * \frac{\sum_{pl=1}^{PL_l} PCbb_{pl}}{PL_l} \quad \text{(A3-17)}$$

Where:

$TCbb_{tr}$	=	Carbon stock in below-ground biomass of tree *tr*; kg C $tree^{-1}$(or t C tree-^{1})
$TCab_{tr}$	=	Carbon stock in above-ground biomass of tree *tr*; kg C $tree^{-1}$(or t C tree-^{1})

R_j	=	Root-shoot ratio appropriate for species, group of species or forest type *j*; dimensionless
$PCbb_{pl}$	=	Carbon stock in below-ground biomass in plot *pl*; t C ha^{-1}
XF	=	Plot expansion factor from per plot values to per hectare values
tr	=	1, 2, 3, … TR_{pl} number of trees in plot *pl*; dimensionless
Cbb_{cl}	=	Average carbon stock per hectare in below-ground biomass in *LU/LC class cl*; tCO_2-eha^{-1}
44/12	=	Ratio converting C to CO_2-e
pl	=	1, 2, 3, … PL_l plots in LU/LC class *cl*; dimensionless
PL_{cl}	=	total number of plots in LU/LC class *cl*; dimensionless

(b.2) Biomass Expansion Factor (*BEF*) Method

1. In the sample plots, identify the plot unique identification number and record the measurement date. Then identify the tree species and identification numbers and measure the diameter at breast height (*DBH*, at 1.3 m above ground), and possibly, depending on the form of the volume equation, the height of all the trees above a minimum *DBH*.
2. Estimate the volume of the commercial component per each tree based on locally derived equations by species, species group or forest type. Then, sum for all trees within a plot, and express it as commercial volume per unit of area (m^3 ha^{-1}). It is also possible to combine step b.1 and step b.2 if there are available field instruments that measure volume per hectare directly (e.g. a Bitterlich relascope). The volume per plot is an ancillary variable, and it may be needed in some cases to estimate the proper biomass expansion factor or the root-shoot ratio.[67]

$$V_{tr} = f_j(DBH, H)_V \tag{A3-18}$$

$$V_{pl} = \sum_{tr=1}^{TR} V_{tr} \cdot XF \tag{A3-19}$$

$$XF = \frac{10{,}000}{AP} \tag{A3-20}$$

Where:

V_{tr}	=	Commercial volume of tree *tr*; m^3 $tree^{-1}$
V_{pl}	=	Commercial volume of plot *pl*; m^3 $plot^{-1}$

[67] See for example: Brown, S. 1997. Estimating Biomass and Biomass Change of Tropical Forests: A primer. FAO Forestry Paper 134, UN FAO, Rome.

$f_j(DBH,H)_V$	=	a commercial volume equation for species or species group *j*, linking commercial volume to diameter at breast height (*DBH*) and possibly tree height (*H*).
tr	=	1, 2, 3, … TR_p number of trees in plot *p*; dimensionless
XF	=	Plot expansion factor from per plot values to per hectare values
AP	=	plot area; m^2

3. Choose a biomass expansion factor (*BEF*) and a root-shoot ratio (*R*). The *BEF* and root-shoot ratio vary with local environmental conditions, forest type, species and age of trees, and the volume of the commercial component of trees, therefore, they should be calculated for each plot in a given *LU/LC class*. Use the result from ‘2’ to choose them.

   These parameters can be determined by either developing a local regression equation or selecting from national inventory, annex 3A.1 table 3A.1.10 of GPG LULUCF, or from published sources.

   If a significant amount of effort is required to develop local *BEFs* and root-shoot ratio, involving, for instance, harvest of trees, then it is recommended not to use this method but rather to use the resources to develop local allometric equations as described in the allometric method above (refers to Chapter 4.3 in GPG LULUCF). If that is not possible either, national species specific defaults for *BEF* and *R* can be used. Since both *BEF* and the root-shoot ratio (*R*) are age or stand density dependent, it is desirable to use age-dependent or stand density-dependent equations (for example, volume per hectare). Stem wood volume can be very small in young stands and *BEF* can be very large, while for old stands *BEF* is usually significantly smaller. Therefore using average *BEF* value may result in significant errors for both young stands and old stands. It is preferable to use allometric equations, if the equations are available, and as a second best solution, to use age-dependent or stand density-dependent *BEFs* (but for very young trees, multiplying a small number for stem wood with a large number for the *BEF* can result in significant error).

4. Convert the volume of the commercial component of each tree in a plot into carbon stock in above-ground biomass and below-ground biomass per tree via basic wood density, BEF, root-shoot ratio and carbon fraction (applicable to the species):

$$TCab_{tr} = V_{tr} \cdot D_j \cdot BEF_{pl} \cdot CF_j \quad \text{(A3-21)}$$

$$TCbb_{tr} = TCab_{tr} \cdot R_{j,pl,tr} \quad \text{(A3-22)}$$

Where:

$TCab_{tr}$	=	Carbon stock in above-ground biomass of tree *tr*; kg C $tree^{-1}$
$TCbb_{tr}$	=	Carbon stock in below-ground biomass of tree *tr*; kg C $tree^{-1}$
V_{tr}	=	Commercial volume of tree *tr*; m^3 $tree^{-1}$
D_j	=	Wood density for species *j*; tonnes d. m. m^{-3} (See IPCC GPG-LULUCF, 2003 table 3A.1.9 or USDA wood density table[68])

68 Reyes *et al.*, 1992. Wood densities of tropical tree species. USDA

BEF_{pl}	=	Biomass expansion factor for converting volumes of extracted round wood to total above-ground biomass (including bark), applicable to tree *tr,* in plot *p*; dimensionless.
CF_j	=	Carbon fraction applicable to tree *tr* of species *j*; tonnes C (tonne d. m.)$^{-1}$.
$R_{j,pl,tr}$	=	Root-shoot ratio, applicable to tree *tr* of species *j* in plot *p*; dimensionless

5. Continue with step a.4 of the allometric equation method to calculate the *carbon stock* in above-ground and below-ground biomass by aggregating successively at the tree, plot, and *LU/LC class* levels.

Non-tree component (*$Cabnt_{cl}$* and *$Cbbnt_{cl}$*)

In tropical forests non-tree vegetation includes palms, shrubs, herbaceous plants, lianas and other epiphytes. These types of plants are difficult to measure. Unless they form a significant component of the ecosystem, they should not be measured, which is conservative as their biomass is usually much reduced in the LU/LC classes adopted after deforestation.

Carbon stock estimations for the non-tree vegetation components are usually based on destructive harvesting, drying and weighting. These methods are described in the Sourcebook for LULUCF projects (Pearson *et al*., 2005) from which most of the following explanations are taken.

For herbaceous plants, a square frame of 1m^2 made from PVC pipe or another appropriated material is sufficient for sampling. For shrubs and other large non-tree vegetation, similar or larger frames should be used (about 1-2 m^2, depending on the size, distribution and frequency of this vegetation). For specific *forest* species (e.g. bamboo) or crop types (e.g. coffee) it is also possible to develop allometric equations. When using destructive sampling, apply the following steps:

a. Place the clip frame at the sampling site. If necessary, open the frame and place around the vegetation.

b. Clip all vegetation within the frame to ground level. Cut everything growing within the quadrate (ground surface not three-dimensional column) and sample this.

c. Weigh the sample and remove a well-mixed sub-sample for determination of dry-to-wet mass ratio. Weight the sub-sample in the field, then oven-dry to constant mass (usually at ~ 70 ^{o}C).

d. Calculate the dry mass of each sample. Where a sub-sample was taken for determination of moisture content use the following equation:

$$Dry\ mass = \left(\frac{subsample\ dry\ mass}{subsample\ fresh\ mass} \right) * fresh\ mass\ of\ whole\ sample \qquad \text{(A3-23)}$$

e. The *carbon stock* in the above-ground non-tree biomass per hectare is calculated by multiplying the dry mass by an expansion factor calculated from the sample-frame or plot size and then by multiplying by the carbon fraction and CO_2/C ratio. For calculating the average *carbon stock* per *LU/LC class*, average over all samples:

$$Cabnt_{cl} = \frac{\sum_{pl=1}^{PLcl} DM_{pl} * XF * CF_{pl} * 44/12}{PL_{cl}} \quad \text{(A3-24)}$$

Where:

$Cabnt_{cl}$	=	Average carbon stock per hectare in the above-ground non-tree biomass carbon pool of the LU/LC class *cl*; tCO_2-e ha^{-1}
DM_{pl}	=	Dry mass of sample *pl*; tonnes of d.m.
XF	=	Plot expansion factor = [10.000 / Plot Area (m^2)]; dimensionless
CF_{pl}	=	Carbon fraction of sample *pl*; tonnes C (tonne d. m.)$^{-1}$
44/12	=	Ratio converting C to CO_2-e
pl	=	1, 2, 3, … PL_{pl} plots in LU/LC class *cl*; dimensionless
PL_{cl}	=	Total number of plots in LU/LC class *cl*; dimensionless

f. The carbon stock per hectare of the below-ground non-tree biomass is calculated by multiplying the estimated above-ground estimate by and appropriate root to shoot ratio.

Estimation of carbon stocks in the dead wood carbon pool (Cdw_{cl})

Carbon stocks in the dead wood carbon pool can be significant in forest classes although is usually insignificant or zero in most agricultural and pastoral LU/LC classes. However, if burning is used to clear slash, dead wood maybe a significant component of carbon stocks in agricultural/pasture, especially in the short term. Therefore, in most cases it will be conservative to ignore the dead wood carbon pool.

Deadwood comprises two types: standing dead wood and lying dead wood. Different sampling and estimation procedures are used to estimate the carbon stocks of the two components.

$$Cdw_{cl} = Csdw_{cl} + Cldw_{cl} \quad \text{(A3-25)}$$

Where:

Cdw_{cl}	=	Average carbon stock per hectare in the dead wood carbon pool of the LU/LC class *cl*; tCO_2-e ha^{-1}
$Csdw_{cl}$	=	Average carbon stock per hectare in the standing dead wood carbon pool of the LU/LC class *cl*; tCO_2-e ha^{-1}
$Cñdw_{cl}$	=	Average carbon stock per hectare in the lying dead wood carbon pool of the LU/LC class *cl*; tCO_2-e ha^{-1}

Standing dead wood shall be measured using the sampling criteria and monitoring frequency used for measuring live trees. Lying deadwood shall be measured using the transect method as explained below. The description of the method to measure lying deadwood is taken from Harmon and Sexton (1996).

Standing dead wood (*$Csdw_{cl}$*)

a. Within the plots delineated for live trees, the diameter at breast height (*DBH*) of standing dead trees can also be measured. In addition, the standing dead wood is categorized under the following four decomposition classes:

1. Tree with branches and twigs that resemble a live tree (except for leaves);
2. Tree with no twig, but with persistent small and large branches;
3. Tree with large branches only;
4. Bole (trunk) only, no branches.

b. For classes 2, 3 and 4, the height of the tree (*H*) and the diameter at ground level should be measured and the diameter at the top should be estimated. Height can be measured using a clinometer.

c. Top diameter can be estimated using a relascope or through the use of a transparent measuring ruler. Hold the ruler approximately 10-20 cm from your eye and record the apparent diameter of the top of the tree. The true diameter is the equal to:

$$True\ \ diameter - (m) = \frac{Dis\tan ce\ eye\ to\ tree\ (m)}{Dis\tan ce\ eye\ to\ ruler\ (m)} * Ruler\ \ measurment\,(m) \quad \text{(A3-26)}$$

Distance can also be measured with a laser range finder.

d. For decomposition class 1 the carbon content of each dead tree is estimated using the allometric or *BEF* methods applied for live trees and by subtracting out the biomass of leaves (about 2-3% of the above-ground biomass for hardwood/broadleaf species and 5-6% for softwood/conifer species).

e. For classes 2, 3 and 4, where it is not clear what proportion of the original biomass has been lost, it is conservative to estimate the biomass of just the bole (trunk) of the tree.
The volume is calculated using *DBH* and height measurements and the estimate of the top diameter. It is then estimated as the volume of a truncated cone:

$$Volume\ (m3) = 1/3 * \pi * H * \left(r_1^2 + r_2^2 + r_1 * r_2\right) \quad \text{(A3-27)}$$

Where:

H	=	Height of the tree; meters
r_1	=	Radius at the base of the tree; meters
r_2	=	Radius at the top of the tree; meters

The volume is converted to dry biomass using the appropriate wood density D_j and then to carbon dioxide equivalents using the carbon fraction Cu_{ff} and CO_2/C ratio (44/12), as in the *BEF* method, but ignoring the Biomass Expansion Factor.

f. To aggregate the carbon stock of each standing dead tree at the plot level and then at the LU/LC class level, continue with step a.4 of the allometric equation method.

Lying dead wood (*$Cldw_{cl}$*)

Lying dead wood is most efficiently measured using the line-intersect method. Only coarse dead wood above a predefined minimum diameter (e.g. > 10 cm) is measured with this method – dead wood with smaller diameter can be measured with litter.

a. At each plot location, lay out two lines of 50 meters either in a single line or at right angles. The lines should be outside the boundaries of the plot to avoid damage to seedlings in the plots during measurement, and also to biasing the dead wood pool by damaging during tree measurement. Alternatively, separate and independent sampling of lying deadwood may be used, in which case deadwood transects must be randomly located (to avoid subjective choice of plots locations), without sample replacement, using the same procedure used for live trees[69]. Their location must also be permanently marked and their coordinates reported.

b. Along the length of the lines, measure the diameter of each intersecting piece of coarse dead wood above a predefined minimum diameter (e.g. > 10 cm). Calipers work best for measuring the diameter. A piece of dead wood should only be measured if: (a) more than 50% of the log is above-ground and (b) the sampling line crosses through at least 50% of the diameter of the piece. If the log is hollow at the intersection point, measure the diameter of the hollow: the hollow portion in the volume estimates should be excluded.

c. Assign each piece of dead wood to one of the three following density classes:

   1. Sound
   2. Intermediate
   3. Rotten

   To determine what density class a piece of dead wood fits into, each piece should be struck with a machete. If the blade does not sink into the piece (that is, it bounces off), it is classified as sound. If it sinks partly into the piece and there has been some wood loss, it is classified as intermediate. If the blade sinks into the piece, there is more extensive wood loss and the piece is crumbly, it is classified as rotten.

d. At least 10 random dead wood samples of each three density classes, representing a range of species present, should be collected for density determination. This determination can be accomplished using the maximum moisture content method (Smith 1954), which does not require sample volume determination. Using a chainsaw or a handsaw, cut a compete disc or a piece of reasonable size from the selected piece of dead wood and bring to the laboratory for wood density determination.

e. Submerge wood samples in water until saturation is reached. Weight saturated samples. Then, dry samples at 105°C for 26 hours. Extract and weight samples again. Do this last weight quickly, withdrawing samples from oven immediately before weighting them, so that no moisture is absorbed by dried samples before obtaining weights.

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[69] Using this alternate approach, transects may be located in places distant to live trees plots, increasing sampling costs. Even if lying deadwood stocks are very homogeneous in all the strata, implying that fewer samples will be required, the cost of additional displacements and work won't probably compensate for the decrease in samples number.

f. Calculate the wood density for each density class (sound, intermediate, rotten) from the pieces of dead wood collected. Density is calculated by the following equation:

$$Dm = \frac{1}{\frac{ps - po}{po} + \frac{1}{1.53}} \quad \text{(A3-28)}$$

Where:

Dm	= Deadwood density; g cm^{-3}
Ps	= Saturated weight of sample; g
Po	= Anhydrous weight of sample, g
1.53	= Wood density constant

Average the densities to get a single density value for each class.

g. For each density class, the volume is calculated separately as follows:

$$Volume\ (m^3/ha) = \pi^2 * \left(\frac{d_1^2 + d_2^2 + ...d_n^2}{8 * L} \right) \quad \text{(A3-29)}$$

Where:

$d_1, d_2, ..., d_n$	=	Diameters of intersecting pieces of dead wood; cm
L	=	Length of the line; meters

h. The per hectare carbon stock in the lying dead wood carbon pool of each LU/LC class is calculated as follows:

$$Cldw_{cl} = \frac{\sum_{pl=1}^{PL_{cl}} \left(\sum_{dc=1}^{DC} Volume_{dc} * D_{dc} * CF_{dc} * 44/12 \right)_{pl}}{PL_{cl}} \quad \text{(A3-30)}$$

Where:

$Cldw_{cl}$	=	Average carbon stock per hectare in the lying dead wood carbon pool of the LU/LC class *cl*; tCO_2-e ha^{-1}
$Volume_{dc}$	=	Volume of lying dead wood in the density class *dc*; m^3
D_{dc}	=	Dead wood density of class *dc*; tonnes d. m. m^{-3}
CF_{dc}	=	Carbon fraction of the density class *dc*; tonnes C (tonne d. m.)$^{-1}$
44/12	=	Ratio converting C to CO_2-e
pl	=	1, 2, 3, … PL_{cl} plots in LU/LC class *cl*; dimensionless
PL_{cl}	=	Total number of plots in LU/LC class *cl*; dimensionless
dc	=	1, 2, 3 dead wood density classes; dimensionless
DC	=	Total number of density classes (3); dimensionless

Estimation of carbon stocks in the litter carbon pool (CL_{cl})

In some forest ecosystem litter carbon stocks in the litter carbon pool can be a significant component of the total carbon stock while in anthropogenic ecosystem, particularly in agricultural or pastoral systems, litter is almost absent.

Litter is defined as all dead organic surface material on top of the mineral soil not considered in the lying dead wood pool. Some of this material is recognizable (for example dead leaves, twigs, dead grasses and small branches) and some is unidentifiable (decomposed fragments of different components of originally live biomass. To differentiate small woody debris from the lying dead wood it is necessary to define a diameter (i.e. 10 cm) below which small dead wood pieces are classified as litter and above which they are considered dead wood.

If litter is measured, it should be sampled at the same time of the year at each monitoring event in order to eliminate seasonal effects. The sampling technique is similar to the one used for non-tree vegetation: a square frame of 1.0 m^2 made from PVC pipe or another suitable material can be used. The following description of the sampling and data analysis techniques is taken from the sourcebook for LULUCF projects (Pearson *et al.*, 2005).

a. Place the sampling frame at the sample site.

b. Collect all the litter inside the frame. Pieces of twigs or wood that cross the border of the frame should be cut using a knife or pruning scissors. Place all the litter on a tarpaulin beside the frame or inside a weighting bag. Weigh the sample on-site, then oven-dry to a constant weight.

c. Where sample bulk is excessive, the fresh weight of the total sample should be recorded in the field and a sub-sample of manageable size (approximately 80-100 g) taken for moisture content determination, from which the total dry mass can be calculated.

d. Calculate the dry mass of the sample. Where a sub-sample was taken for determination of the moisture content use equation 23 to estimate the dry mass of the whole sample.

e. The carbon stock per hectare in the litter carbon pool is calculated by multiplying the dry mass by an expansion factor calculated from the sample-frame or plot size and then by multiplying by the carbon fraction and CO_2/C ratio. For calculating the average carbon stock per LU/LC class, average over all samples (see equation 24).

Estimation of carbon stocks in soil organic carbon pool ($Csoc_{cl}$)

Methods to estimate *carbon stocks* in the soil organic carbon pool are described in the sourcebook for LULUCF projects (Pearson *et al.*, 2006) from which the following explanations have been taken.

Three types of variables must be measured to estimate soil organic carbon stocks: (1) depth, (2) bulk density (calculated from the oven-dried weight of soil from a known volume of sampled material), and (3) the concentrations of organic carbon within the sample.

The sample depth should be constant, 30 cm is usually a sufficient sampling depth.

a. Steadily insert the soil probe to a 30 cm depth. If the soil is compacted, use a rubber mallet to fully insert. If the probe will not penetrate to the full depth, do not force it as it is likely a stone or root that is blocking its route and, if forced, the probe will be damaged. Instead, withdraw the probe, clean out any collected soil and insert in a new location.

b. Carefully extract the probe and place the sample into a bag. Because the carbon concentration of organic materials is much higher than that of the mineral soil, including even a small amount of surface material can result in a serious overestimation of soil *carbon stocks*.

c. To reduce variability, aggregate four samples from each collection point for carbon concentration analysis.

d. At each sampling point, take two additional aggregated cores for determination of bulk density. When taking the cores for measurements of bulk density, care should be taken to avoid any excess or loss of soil from the cores.

e. Soil samples can be sent to a professional laboratory for analysis. Commercial laboratories exist throughout the world and routinely analyze plant and soil samples using standard techniques. It is recommended the selected laboratory be checked to ensure they follow commonly accepted standard procedures with respect to sample preparation (for example, mixing and sieving), drying temperatures and carbon analysis methods.

For bulk density determination, ensure the laboratory dries the samples in an oven at 105 ^{o}C for a minimum of 48 hours. If the soil contains coarse, rocky fragments, the coarse fragments must be retained and weighted. For soil carbon determination, the material is sieved through a 2 mm sieve, and then thoroughly mixed. The well-mixed sample should not be oven-dried for the carbon analysis, but only air-dried; however, the carbon concentration does need to be expressed on an oven dry basis at 105 ^{o}C. The dry combustions method using o controlled temperature furnace (for example, a LECO CHN-2000 or equivalent) is the recommended method for determining total soil carbon, but the Walkley-Black method is also commonly used.

f. Calculate the bulk density of the mineral soil core:

$$Bulk\ density\ (g/cm^3) = \frac{oven\, dry\, mass\,(g/cm^3)}{core\, volume\,(cm^3) - \dfrac{mass\, of\ coarse\ fragments\,(cg)}{density\ of\ rock\ fragments\,(cg/m^3)}} \quad \text{(A3-31)}$$

Where the bulk density is for the < 2 mm fraction, coarse fragments are > 2 mm. The density of rock fragments is often given as 2.65 g/cm^3.

g. Using the carbon concentration data obtained from the laboratory, the amount of carbon per unit area is given by:

$$Csoc_{cl}\,(t/ha) = [(soil\ bulk\ density\ (g/cm^3) * soil\ depth\ (cm) * C)] * 100 \qquad \text{(A3-32)}$$

In the above equation, C must be expressed as a decimal fraction. For example, 2.2% carbon is expressed as 0.022 in the equation.

h. The *carbon stock* per hectare in the soil organic carbon pool is calculated by averaging the *carbon stock* estimates per each *LU/LC class*:

$$Csoc_{cl} = \frac{\sum_{pl=1}^{PL_{pl}} Csoc_{pl}}{PL_{pl}} \qquad \text{(A3-33)}$$

Where:

$Csoc_{cl}$	=	Average carbon stock per hectare in the soil organic carbon pool of the LU/LC class *cl*; tCO_2-e ha^{-1}
$Csoc_{pl}$	=	***Carbon stock*** per hectare in the soil organic carbon pool estimated for the plot *pl*; tCO_2-e ha^{-1}
pl	=	1, 2, 3, … PL_{pl} plots in LU/LC class *cl*; dimensionless
PL_{pl}	=	Total number of plots in LU/LC class *cl*; dimensionless

Estimation of *carbon stocks* in the harvested wood products carbon pool (Cwp_{cl})

The wood products carbon pool must be included where there is timber harvest in the baseline scenario prior to or in the process of deforestation and where project activities may significantly reduce the pool. The wood products carbon pool may (optionally) be included where baseline activities may significantly reduce the pool. In this case, Cwp_{cl} must be subtracted in the calculation of $Ctot_{cl}$ in the baseline case and can be added in the calculation of $Ctot_{cl}$ in the project case.

Carbon stocks in wood products are those stocks that become wood products pool at the time of deforestation. They are divided in three fractions, as follows:

- Short-term wood products: wood products and waste that would decay within 3 years; all carbon shall be assumed to be lost immediately;
- Medium-term wood products: wood products that are retired between 3 and 100 years; for this group of wood products, a 20-year linear decay function shall be applied;
- Long-term wood products: wood products that are considered permanent (i.e. carbon is stored for 100 years or more); it may be assumed that no carbon is released.

Accounting for carbon stocks in wood products in the baseline case should only take place at the time of deforestation (year *t*). In the project case, Cwp_{cl} can be accounted at the years of planned timber harvest, in which case monitoring is mandatory.

The proportion of carbon stock stored in each fraction of the wood products carbon pool must be obtained from specific studies applicable to the local conditions or from country-specific data about the volume of timber harvested per forest classes. If data on the proportion of carbon stocks in each fraction of the wood product carbon pool are unavailable, it is conservative to assume that 100% of the carbon is stored in the long-term fraction in the baseline case (in which case no carbon is released into the atmosphere in the baseline case), and that 100% of the carbon is stored in short-term fraction in the project case (in which case all carbon is emitted immediately in the project case).

If data on carbon stocks in each fraction of wood products are available and if timber harvest plans, specifying harvest intensity per forest class in terms of volume extracted per ha, are available for the Project area use Method 1. If approved harvest plans are not available use Method 2.

Method 1: Direct Volume Extraction Estimation

Step 1: Calculate the biomass carbon of the commercial volume extracted since the project start date and in the process of deforestation as follows:

$$CXB_{w,icl,t} = \frac{1}{ABSLPA_{icl,t}} * (\sum_{t=1}^{t*}\sum_{j=1}^{J}(VEX_{w,j,icl,t} * D_j * CF_j * \frac{44}{12}) \quad \text{(A3-34)}$$

Where:

$CXB_{w,icl,t}$	=	Mean carbon stock per hectare of extracted biomass carbon by class of wood product *w* from forest class *icl* at time *t*; tCO_2-e ha^{-1}
icl	=	1, 2, 3, …*Icl* initial pre-deforestation forest classes; dimensionless
w	=	1, 2, 3 … *W* Wood product class (sawn-wood, wood-based panels, other industrial round-wood, paper and paper board, and other); dimensionless
t	=	1, 2, 3… *T* years, a year of the project crediting period; dimensionless
*t**	=	the year at which the area A$BSLPA_{icl,t}$ is deforested in the baseline case; dimensionless
j	=	1, 2, 3 … *J* tree species; dimensionless
$ABSLPA_{icl,t}$	=	Area of forest class *icl* deforested at year *t**; ha
$VEX_{,w,j,fcl,t}$	=	Volume of timber for product class *w*, of species *j*, extracted from within forest class *fcl* at time *t*; m^3
D_j	=	Mean wood density of species *j*; t d.m.m^{-3}
CF_j	=	Carbon fraction of biomass for tree species *j*; t C t^{-1}d.m.
44/12	=	Ratio of molecular weight of CO_2 to carbon; dimensionless

Step 2: Calculate the carbon stock in the wood products carbon pool extracted from the biomass at time *t* (year of deforestation).

$$Cwp_{icl,t} = \sum_{w=1}^{W} CXB_{w,icl,t} * (1 - STF_w) \quad \text{(A3-35)}$$

Where:

$Cwp_{icl,t}$	=	Carbon stock in the wood products carbon pool in initial forest class *icl* at time *t*; tCO_2-e ha^{-1}
icl	=	1, 2, 3, …*Icl* forest classes; dimensionless
w	=	1, 2, 3 … *W* Wood product class (sawn-wood, wood-based panels, other industrial round-wood, paper and paper board, and other); dimensionless
t	=	1, 2, 3… *T* years, a year of the project crediting period; dimensionless
$CXB_{w,icl,t}$	=	Mean stock of extracted biomass carbon by class of wood product *w* from forest class *icl* at time *t*; tCO_2-e ha^{-1}
STF_w	=	Fraction of wood products and waste that will be emitted to the atmosphere within 3 years; all carbon shall be assumed to be lost immediately; dimensionless

Step 3: Calculate the biomass carbon extacted at time *t* that becomes the medium-term wood products at the time of deforestation.

$$Cwp_{mt,icl,t} = Cwp_{icl,t} - (Cwp_{icl,t} * (1 - STF_w) * (1 - LTF_w)) \quad \text{(A3-36)}$$

Where:

$Cwp_{mt,icl,t}$ = Carbon stock in the medium-term wood products carbon pool at the time of deforestation *t* of the initial forest class *icl*; tCO_2-e ha^{-1}

$Cwp_{icl,t}$ = Carbon stock in the wood products carbon pool at the time of deforestation *t* of the initial forest class *icl*; tCO_2-e ha^{-1}

STFw = Fraction of wood products and waste that will be emitted to the atmosphere within 3 years; all carbon shall be assumed to be lost immediately; dimensionless

LTFw = Fraction of wood products that are considered permanent (i.e. carbon is stored for 100 years or more); it may be assumed no carbon is released

Step 4: Calculate the biomass carbon extacted at time *t* that becomes the long-term wood products at the time of deforestation.

$$Cwp_{lt,icl,t} = Cwp_{icl,t} - (Cwp_{icl,t} * (1 - STF_w) * (1 - MTF_w)) \quad \text{(A3-37)}$$

Where:

$Cwp_{lt,icl,t}$ = Carbon stock in the long-term wood products carbon pool at the time of deforestation *t* of the initial forest class *icl*; tCO_2-e ha^{-1}

$Cwp_{icl,t}$ = Carbon stock in the wood products carbon pool at the time of deforestation *t* of the initial forest class *icl*; tCO_2-e ha^{-1}

STFw = Fraction of wood products and waste that will be emitted to the atmosphere within 3 years; all carbon shall be assumed to be lost immediately; dimensionless

MTFw = Fraction of wood products that are retired between 3 and 100 years; for this group of wood products, a 20-year linear decay function shall be applied

Method 2: Commercial inventory estimation

Step 1: Calculate the biomass carbon of the commercial volume extracted prior to or in the process of deforestation:

$$CXB_{icl,t} = Cab_{icl,t} * \frac{1}{BCEF} * Pcom_{icl} \quad \text{(A3-38)}$$

Where:

$CXB_{icl,t}$ = Mean stock of extracted biomass carbon from initial forest class *icl* at time *t*; tCO_2-e ha^{-1}

$Cab_{icl,t}$ = Mean above-ground biomass carbon stock in initial forest class *icl* at time *t*; tCO_2-e ha^{-1}

BCEF	=	Biomass conversion and expansion factor for conversion of merchantable volume to total aboveground tree biomass; dimensionless
$Pcom_{icl}$	=	Commercial volume as a percent of total aboveground volume in initial forest class *icl*; dimensionless
t	=	1, 2, 3… *T* years, a year of the project crediting period; dimensionless
icl	=	1, 2, 3, …*Icl* forest classes; dimensionless

Step 2: Identify the wood product class(es) (*w,* defined here as sawn-wood, wood-based panels, other industrial round-wood, paper and paper board, and other) that are the anticipated end use of the extracted carbon calculated in step 1. It is acceptable practice to assign gross percentages of volume extracted to wood product classes on the basis of local expert knowledge of harvest activities and markets.

Step 3: Calculate the biomass carbon extracted at time *t* that becomes the wood products at the time of deforestation.

$$Cwp_{icl,t} = \sum_{w=1}^{W} CXB_{w,icl,t} * (1 - STF_w) \qquad \text{(A3-39)}$$

Where:

$Cwp_{icl,t}$	=	Carbon stock in wood products pool in initial forest class *icl* at time *t*; tCO_2-e ha^{-1}
icl	=	1, 2, 3, …*Icl* forest classes; dimensionless
w	=	Wood product class (sawn-wood, wood-based panels, other industrial round-wood, paper and paper board, and other); dimensionless
t	=	1, 2, 3 … *T* years, a year of the project crediting period; dimensionless
$CXB_{w,icl,t}$	=	Mean stock of extracted biomass carbon by class of wood product *w* from initial forest class *icl* at time *t*; tCO_2-e ha^{-1}
STF_w	=	Fraction of wood products and waste that will be emitted to the atmosphere within 3 years; all carbon shall be assumed to be lost immediately; dimensionless

Step 4: Calculate the biomass carbon extacted at time *t* that becomes the medium-term wood products at the time of deforestation.

$$Cwp_{mt,icl,t} = Cwp_{icl,t} - (Cwp_{icl,t} * (1 - STF_w) * (1 - LTF_w)) \qquad \text{(A3-40)}$$

Where:

$Cwp_{mt,icl,t}$	=	Carbon stock in the medium-term wood products carbon pool at the time of deforestation *t* of the initial forest class *icl*; tCO_2-e ha^{-1}
$Cwp_{icl,t}$	=	Carbon stock in the wood products carbon pool at the time of deforestation *t* of the initial forest class *icl*; tCO_2-e ha^{-1}
STFw	=	Fraction of wood products and waste that will be emitted to the atmosphere within 3 years; all carbon shall be assumed to be lost immediately; dimensionless
LTFw	=	Fraction of wood products that are considered permanent (i.e. carbon is stored for 100 years or more); it may be assumed no carbon is released

Step 5: Calculate the biomass carbon extacted at time *t* that becomes the long-term wood products at the time of deforestation.

$$Cwp_{lt,icl,t} = Cwp_{icl,t} - (Cwp_{icl,t} * (1 - STF_w) * (1 - MTF_w)) \quad \text{(A3-41)}$$

Where:

$Cwp_{lt,icl,t}$	=	Carbon stock in the long-term wood products carbon pool at the time of deforestation *t* of the initial forest class *icl*; tCO_2-e ha^{-1}
$Cwp_{icl,t}$	=	Carbon stock in the wood products carbon pool at the time of deforestation *t* of the initial forest class *icl*; tCO_2-e ha^{-1}
STFw	=	Fraction of wood products and waste that will be emitted to the atmosphere within 3 years; all carbon shall be assumed to be lost immediately; dimensionless
MTFw	=	Fraction of wood products that are retired between 3 and 100 years; for this group of wood products, a 20-year linear decay function shall be applied

APPENDIX 4: METHODS TO ESTIMATE EMISSIONS FROM ENTERIC FERMENTATION AND MANURE MANAGEMENT

Estimation of CH_4 emissions from enteric fermentation ($ECH4ferm_{,t,t}$)

The amount of methane[70] emitted by a population of animals is calculated by multiplying the emission rate per animal by the number of animals above the baseline case. To reflect the variation in emission rates among animal types, the population of animals is divided into subgroups, and an *emission factor* per animal is estimated for each subgroup. As per IPCC GPG 2000 and IPCC 2006 Guidelines for AFOLU, use the following equation[71]:

$$ECH4ferm_t = EF_1 * Population_t * 0{,}001 * GWP_{CH4} \quad \text{(A4-1)}$$

$$Population_t = Pforage_t / (DBI * 365) \quad \text{(A4-2)}$$

Where:

$ECH4ferm_t$	=	CH_4 emissions from enteric fermentation at year *t*; tCO_2e
EF_1	=	Enteric CH_4 emission factor for the livestock group; kg CH_4 head^{-1} yr^{-1}
$Population_t$	=	Equivalent number of forage-fed livestock at year *t*; heads
$Pforage_t$	=	Production of forage at year *t*; kg d.m. yr^{-1}
DBI	=	Daily biomass intake; kg d.m. head^{-1} day^{-1}
GWP_{CH4}	=	Global warming potential for CH_4 (with a value of 21 for the first commitment period); dimensionless
0.001	=	Conversion factor of kilograms into tonnes; dimensionless
365	=	Number of day per year; dimensionless
t	=	1, 2, 3, … *T* years of the project crediting period

The production of forage can be estimated by collecting production rates from the literature that represents the shrub species, climate, soil conditions and other features of the areas in which forage will be produced. Sampling surveys is also a good option.

Country-specific emission factors for enteric CH_4 emissions are documented in peer reviewed literature or can be obtained from national GHG inventories. Default values are given in table 10.10 and 10.11 in the

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[70] Methane is produced in herbivores as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream. Both ruminant animals (e.g., cattle, sheep) and some non-ruminant animals (e.g., pigs, horses) produce CH_4, although ruminants are the largest source since they are able to digest cellulose, due to the presence of specific micro organisms in their digestive tracts. The amount of CH_4 that is released depends on the type, age, and weight of the animal, the quality and quantity of the feed, and the energy expenditure of the animal.

[71] Refer to equation 10.19 and equation 10.20 in IPCC 2006 GL AFOLU or equation 4.12 and equation 4.13 in GPG 2000 for agriculture.

IPCC 2006 Guidelines for AFOLU. When selecting emission factors it is important to select those from a region that is similar to the Project area. The tables in Annex 10A.1 of the IPCC 2006 Guidelines for AFOLU specify the animal characteristic such as weight, growth rate and milk production used to estimate the emission factors. These tables should be consulted in order to ensure that the local conditions are similar. In particular, data on average milk production by dairy livestock should be analyzed when selecting an emission factor for dairy livestock. To estimate the emission factor, the data in table 10A.1 can interpolated using the data on the local average milk production.

For data on daily biomass intake use local data or data that are applicable to the local conditions according to peer-reviewed literature or the national GHG inventory. When selecting a value for daily biomass intake, ensure that the chosen data are applicable to both the forage types to be produced and the livestock group (see also table 5 in appendix 2).

Estimation of CH_4 emissions from manure management (*$ECH4man_t$*) [72]

The storage and treatment of manure under anaerobic conditions produces CH_4. These conditions occur most readily when large numbers of animals are managed in confined area (e.g. dairy farms, beef feedlots, and swine and poultry farms), and where manure is disposed of in liquid based systems. The main factors affecting CH_4 emissions are the amount of manure produced and the portion of manure that decomposes anaerobically. The former depends on the rate of waste production per animal and the number of animals, and the latter on how the manure is managed. When manure is stored or treated as a liquid (e.g. in lagoons, ponds, tanks, or pits), it decomposes anaerobically and can produce a significant quantity of CH_4. The temperature and the retention time of storage greatly affect the amount on methane produced. When manure is handled as a solid (e.g. in stacks or piles), or when it is deposited on pastures and rangelands, it tends to decompose under more aerobic conditions and less CH_4 is produced.

CH_4 emissions from manure management for the forage-fed livestock can be estimated using IPCC methods[73].

$$ECH4man_t = EF_2 * Population_t * 0{,}001 * GWP_{CH4} \qquad \text{(A4-3)}$$

Where:

$ECH4man_{t,t}$	=	CH_4 emissions from manure management at year *t*; tCO_2e
EF_2	=	Manure management CH_4 emission factor for the livestock group; kg CH_4 $head^{-1}$ yr^{-1}
$Population_t$	=	Equivalent number of forage-fed livestock at year *t*; heads
GWP_{CH4}	=	Global warming potential for CH_4 (with a value of 21 for the first commitment period); dimensionless
0.001	=	Conversion factor of kilograms into tonnes; dimensionless
t	=	1, 2, 3, … *T* years of the project crediting period

[72] Taken from AR-AM0006 version 1

[73] Refer to equation 10.22 in AFOLU volume of the IPCC 2066 Guidelines or equation 4.15 in GPG 2000 for agriculture.

The best estimate of emissions will usually be obtained using country-specific emission factors that have been published in peer-reviewed literature or in the national GHG inventory. It is recommended that country-specific emission factors be used that reflect the actual duration of storage and type of treatment of animal manure in the management system used. If appropriate country-specific emission factors are unavailable, default emission factors presented in table 10.14-10.16 of IPCC 2006 Guidelines for AFOLU may be used. These emission factors represent those for a range of livestock types and associated management systems, by regional management practices and temperature. When selecting a default factor, be sure to consult the supporting tables in Annex 10A.2 of IPCC 2006 Guidelines for AFOLU, for the distribution of manure management systems and animal waste characteristics used to estimate emissions. Select an emission factor for a region that most closely matches the circumstances of the livestock that are fed forage from the project area.

Estimation of N_2O emissions from manure management (*$EN2Oman_t$*) [74]

Nitrous oxide emissions from manure management vary significantly between the type of management system used, and can also result in indirect emissions due to other forms of nitrogen loss from the system. The N_2O emissions from manure management can be estimated using method provided in the IPCC 2006 Guidelines for AFOLU, or in IPCC GPG 2000[75]

$$EN2Oman_t = EdirN2Oman_t + EindN2Oman_t \quad \text{(A4}$$

$$EdirN2Oman_t = Population_t * Nex * EF_3 \cdot 0{,}001 * 44/28 * GWP_{N20} \quad \text{(A4-5)}$$

$$EindN2Oman_t = Population_t * Nex * Frac_{gas} * EF_4 * 0{,}001 * 44/28 * GWP_{N2O} \quad \text{(A4-6)}$$

Where:

$EN2Oman_{fcl,t}$	=	N_2O emissions from manure management at year *t*; tCO_2e[1]
$EdirN_2Oman_t$	=	Direct N_2O emissions from manure management at year *t*; tCO_2e
$EindNOman_t$	=	Indirect N_2O emissions from manure management at year *t*; tCO_2e
$Population_t$	=	Equivalent number of forage-fed livestock at year *t*; heads
Nex	=	Annual average N excretion per livestock head; kg N $head^{-1}$ yr^{-1}
EF_3	=	Emission factor for N_2O emissions from manure management for the livestock group; kg N_2O-N (kg N^{-1}) $head^{-1}$ yr^{-1}
EF_4	=	Emission factor for N_2O emissions from atmospheric deposition of forage-sourced nitrogen on soils and water surfaces; kg N_2O-N (kg NH_3-N and NO_x-N emitted)$^{-1}$ $head^{-1}$ yr^{-1} **<u>Note:</u>** The use of the IPCC default factor 0.01 is recommended.

74 Taken from AR-AM0006 version 1

75 Refer to equations 10.25, 10.26 and 10.27 in AFOLU volume of the IPCC 2006 Guidelines and/or equation 4.18 in GPG 2000 for agriculture.

$Frac_{gas}$	=	Fraction of managed livestock manure nitrogen that volatilizes as NH3 and NOx in the manure management phase; kg NH_3-N and NO_x-N emitted (Kg N)$^{-1}$
GWP_{N2O}	=	Global warming potential for N_2O (310 for the first commitment period); dimensionless
44/28	=	Conversion of N_20-N emissions to N_2O emissions
0.001	=	Conversion factor of kilograms into tonnes; dimensionless

The best estimate of the annual nitrogen excretion rates for each livestock group will usually be obtained using country-specific rates from published peer reviewed literature or from the national GHG inventory. If country-specific data cannot be collected or derived, or appropriate data are not available from another country with similar conditions, default nitrogen excretion rates can be obtained from table 10.19 of IPCC 2006 Guidelines for AFOLU.

The possible data sources for emission factors are similar. Default emission factors are given in table 10.21 and 11.3 of the IPCC 2006 Guidelines for AFOLU and default values for volatilization of NH_3 and NO_x ($Frac_{gas}$) in the manure management system are presented in table 10.22 of the same IPCC 2006 Guidelines. For $EF_4$the IPCC default value 0.01 is recommended (equation 10.27, IPCC 2006 Guidelines for AFOLU).

APPENDIX 5: DATA AND PARAMETERS USED IN THIS METHODOLOGY

Notation	Description	Unit	Equation	Observation	Source	Monitoring
±90%CI	90% Confidence Interval					
A	Area of error due to observed change predicted as persistence	ha	9		calculated	each renewal of fixed baseline period
a	Estimated intercept of the regression line	ha yr^{-1}	4a,		calculated	each renewal of fixed baseline period
a_1 and a_2	sample plot areas	ha	A3-5		calculated	each renewal of fixed baseline period
$Aaverage_i$	Area of "average" forest land suitable for conversion to non-forest land within stratum	ha	6		calculated	each renewal of fixed baseline period
ABSLLK	Cumulative area of baseline deforestation within the leakage belt at year *t*	ha	Table 9c, Table 11c, Table 13c, Table 14c, Table 19c		calculated	each renewal of fixed baseline period
$ABSLLK_{ct,t}$	Area of category *ct* deforested at time *t* within the leakage belt in the baseline case	ha			measured or estimated from literature	each renewal of fixed baseline period
$ABSLLK_{fcl,t}$	Area of final (post-deforestation) forest class *fcl* deforested at time *t* within the leakage belt in the baseline case	ha			calculated	each renewal of fixed baseline period

Notation	Description	Unit	Equation	Observation	Source	Monitoring
$ABSLLK_{i,t}$	Annual area of baseline deforestation in stratum *i* within the leakage belt at year *t*;	ha	Table 9.c		calculated	each renewal of fixed baseline period
$ABSLLK_{icl,t}$	Area of initial (pre-deforestation) forest class *icl* deforested at time *t* within the leakage belt in the baseline case	ha	Table 30a		calculated	each renewal of fixed baseline period
$ABSLLK_t$	Annual area of baseline deforestation within the leakage belt at year *t*;	ha	Table 9c, Table 11c, Table 13c, Table 14c, Table 19c		calculated	each renewal of fixed baseline period
$ABSLPA$	Cumulative area of baseline deforestation in the project area at year *t*	ha	Table 9b, Table 11b, Table 13b, Table 14b, Table 19b		calculated	each renewal of fixed baseline period
$ABSLPA_{ct,t}$	Area of category *ct* deforested at time *t* within the project area in the baseline case	ha	Table 22b1		measured or estimated from literature	each renewal of fixed baseline period
$ABSLPA_{i,t}$	Annual area of baseline deforestation in stratum *i* within the project area at year *t*;	ha	Table 9b		calculated	each renewal of fixed baseline period
$ABSLPA_{icl,t}$	Area of initial (pre-deforestation) forest class *icl* deforested at time *t* within the project area in the baseline	ha	10		calculated	each renewal of fixed baseline period

Notation	Description	Unit	Equation	Observation	Source	Monitoring
	case					
$ABSLPA_t$	Annual area of baseline deforestation in the project area at year *t*	ha	Table 9b, Table 11b, Table 13b, Table 14b, Table 19b		calculated	each renewal of fixed baseline period
ABSLPAz,t	Area of the zone *z* "deforested" at time *t* within the project area in the baseline case; ha	ha	10		calculated	each renewal of fixed baseline period
ABSLRR	cumulative area of baseline deforestation in the reference region at year t	ha	Table 9.a, Table 11a, Table 13a, Table 14a, Table 19a		calculated	each renewal of fixed baseline period
$ABSLRR_{ct,t}$	Area of category *ct* deforested at time *t* within the reference region in the baseline case	ha	Table 22.a.1		measured or estimated from literature	each renewal of fixed baseline period
$ABSLRR_{i,t}$	Annual area of baseline deforestation in stratum *i* within the reference region at year *t*	ha	3, 4a, 4b, 4c, 5, 6, 7, 8a, 8b, 8c,		calculated	each renewal of fixed baseline period
ABSLRRtaverage,i	Annual area of baseline deforestation in stratum *i* within the Reference region at a year $taverage_i$	ha	7		calculated	each renewal of Fixed Baseline Period

Notation	Description	Unit	Equation	Observation	Source	Monitoring
$ABSLRR_t$	Annual area of baseline deforestation in the reference region at year t	ha	Table 9.a, Table 11a, Table 13a, Table 14a, Table 19a		calculated	each renewal of fixed baseline period
$ACPA_{icl,t}$	Annal area within the Project Area affected by catastrophic evens in class *icl* at year *t*	ha	Table 25f, Table 26f		measured *ex post*	each time a catastrophic event occurs
$Aforage_t$	Area under forege above the baseline in leakage management areas	ha	Table 32		calculated *ex ante*, measured *ex post*	annually
$Aoptimal_i$	Area of "optimal" forest land suitable for conversion to non-forest land within stratum *i*	ha	5		calculated	each renewal of fixed baseline period
AP	Plot area	m^2	A3-13		measured or estimated from literature	only once at project start and when mandatory
$APDPA_{icl,t}$	Areas of planned deforestation in forest class *icl* at year *t* in the project area	ha	Table 25a	*ex ante* and *ex post*	measured or estimated from literature	annually
$APFPA_{icl,t}$	Annual area of planned fuel-wood and charcoal activities in forest class *icl* at year *t* in the project area	ha	Table 25, Table 26c	*ex ante* and *ex post*	calculated *ex ante*, measured *ex post*	annually
$APLPA_{icl,t}$	Areas of planned logging activities in forest class *icl* at year *t* in the project area	ha	Table 25b, Table 26b	*ex ante* and *ex post*	calculated ex *ante*, measured *ex post*	annually

Notation	Description	Unit	Equation	Observation	Source	Monitoring
$APNiPA_{icl,t}$	Annual area of forest class *icl* with increasing carbon stock without harvest at year *t* in the project area	ha	Table 26a	*ex ante* and *ex post*	calculated ex *ante*, measured *ex post*	annually
$APSLK_{fcl,t}$	Annual area of class *fcl* with decreasing carbon stock in leakage management areas in the project case at year *t*	ha	Table 30b		measured *ex post*	annually
ARR_i	Total forest area in stratum *i* within the reference region at the project start date	ha	4.b, 8.c		measured or estimated from literature	each renewal of fixed baseline period
$ARR_{i,t-1}$	Area with forest cover in stratum *i* within the reference region a year *t-1*	ha	3		calculated	each renewal of fixed baseline period
$AUFPA_{icl,t}$	Areas affected by forest fires in class *icl* in which carbon stock recovery occurs at year *t*	ha	Table 25e, Table 26e		measured *ex post*	annually
B	Area correct due to observed change predicted as change	ha	9		measured or estimated from literature	each renewal of fixed baseline period
b	Estimated coefficient of the time variable (or slope of the linear regression)	dimensionless	4.a, 7, 8.a, 8.b		calculated	each renewal of fixed baseline period
BCEF	Biomass conversion and expansion factor for conversion of merchantable volume to total aboveground tree biomass	dimensionless	A3-9, A3-36		measured or estimated from literature	only once at project start

Notation	Description	Unit	Equation	Observation	Source	Monitoring
BEFpl	Biomass expansion factor for converting volumes of extracted round wood to total above-ground biomass (including bark), applicable to tree tr, in plot pl	dimensionless	A3-21		measured or estimated from literature	only once at project start
BLDA, BLDB, … BLDN	Total area of projected baseline deforestation during the fixed baseline period of Project A	ha	2.a, 2.b, 2.n		PD of project A; PD of project B, … PD of Project N;	each renewal of fixed baseline period
C	Area of error due to observed persistence predicted as change	ha	9		calculated	
Cab_{fcl}	Average carbon stock per hectare in the above-ground biomass carbon pool of final post-deforestation class *fcl*	t CO_2e ha^{-1}	Table 16, Table 17		measured or estimated from literature	
Cab_{cl}	Average carbon stock per hectare in the above-ground biomass carbon pool of LU/LC class *cl*	t CO_2e ha^{-1}	A3-6, A3-14,A3-36		measured or estimated from literature	only once at project start and when mandatory
Cab_{icl}	Average carbon stock per hectare in the above-ground biomass carbon pool of initial forest class *icl*	t CO_2e ha^{-1}	Table 15a, A3-38		measured or estimated from literature	Cab_{icl}
$Cabnt_{cl}$	Average carbon stock per hectare in the above-ground non-tree biomass carbon pool of LU/LC class *cl*	t CO_2-e ha^{-1}	A3-7, A3-24		measured or estimated from literature	only once at project start and when mandatory

Notation	Description	Unit	Equation	Observation	Source	Monitoring
$Cabt_{cl}$	Average carbon stock per hectare in the above-ground tree biomass carbon pool of LU/LC class *cl*	t CO_2-e ha^{-1}	A3-7		measured or estimated from literature	only once at project start and when mandatory
Cabz	Average carbon stock per hectare in the above-ground biomass carbon pool per zone z	t CO_2-e ha^{-1}	Table 17		measured or estimated from literature	only once at project start and when mandatory
Ca_{cl}	Average carbon stock per hectare in above-ground biomass in LU/LC class *cl*	tCO_2-eha^{-1}	A3-14			
Cbb_{cl}	Average carbon stock per hectare below-ground biomass carbon pool of LU/LC class *cl*	t CO_2-e ha^{-1}	A3-6, A3-17		measured or estimated from literature	only once at project start and when mandatory
Cbb_{fcl}	Average carbon stock per hectare below-ground biomass carbon pool of final post-deforestation class *fcl*	t CO_2-e ha^{-1}	Table 16, Table 17		measured or estimated from literature	
Cbb_{icl}	Average carbon stock per hectare below-ground biomass carbon pool of initial forest class *icl*	t CO_2-e ha^{-1}	Table 15		measured or estimated from literature	
$Cbbnt_{cl}$	Average carbon stock per hectare below-ground non-tree biomass carbon pool of LU/LC class *cl*	t CO_2-e ha^{-1}	A3-8		measured or estimated from literature	only once at project start and when mandatory
Cbb_{fcl}	Average carbon stock per hectare below-ground biomass carbon pool of final post-	t CO_2-e ha^{-1}			measured or estimated from literature	

Notation	Description	Unit	Equation	Observation	Source	Monitoring
	deforestation class *fcl*					
$Cbbt_{cl}$	Average carbon stock per hectare below-ground tree biomass carbon pool of LU/LC class *cl*	t CO_2-e ha^{-1}	A3-8		measured or estimated from literature	only once at project start and when mandatory
Cbbz	Average carbon stock per hectare below-ground tree biomass carbon pool per zone z	t CO_2-e ha^{-1}	Table 17		measured or estimated from literature	only once at project start and when mandatory
Cdw_{fcl}	Average carbon stock per hectare in the in the dead wood biomass carbon pool of final post-deforestation class *fcl*	t CO_2-e ha^{-1}	Table 16, Table 17		measured or estimated from literature	only once at project start and when mandatory
Cdw_{cl}	Average carbon stock per hectare in the in the dead wood biomass carbon pool of LU/LC class *cl*	t CO_2-e ha^{-1}	A3-6, A3-25		measured or estimated from literature	only once at project start and when mandatory
Cdw_{icl}	Average carbon stock per hectare in the in the dead wood biomass carbon pool of initial forest class *icl*	t CO_2-e ha^{-1}	Table 15		measured or estimated from literature	
Cdwz	Average carbon stock per hectare in the in the dead wood biomass carbon pool per zone z	t CO_2-e ha^{-1}	Table 17		measured or estimated from literature	only once at project start and when mandatory
$CE_{p,icl}$	Average combustion efficiency of the carbon pool *p* in the forest class	dimensionless	14		measured or estimated from literature	only once at project start

Notation	Description	Unit	Equation	Observation	Source	Monitoring
CF_{dc}	Carbon fraction of the density class *dc*	tonnes C (tonne d. m.)$^{-1}$	A3-30		measured or estimated from literature	only once at project start and when mandatory
CF_j	Carbon fraction for tree *tr*, of species, group of species or forest type *j*	tonnes C (tonne d. m.)$^{-1}$	A3-11, A3-21, A3-24		measured or estimated from literature	only once at project start
CF_{pl}	Carbon fraction of sample *pl*	tonnes C (tonne d. m.)$^{-1}$	A3-24		calculated	only once at project start and when mandatory
C_i	Cost to select and measure a plot of the LU/LC class *cl*		A3-3; A3-4		estimated	each renewal of fixed baseline period
cl	1, 2, 3 … *Cl* LU/LC classes	dimensionless	A3-3		measured or estimated from literature	each renewal of fixed baseline period
$Cldw_{fcl}$	Average carbon stock per hectare in the lying dead wood carbon pool of final post-deforestation class *fcl*	t CO_2-e			measured or estimated from literature	$Cldw_{fcl}$
Cl_{cl}	Average carbon stock per hectare in the litter carbon pool of LU/LC class *cl*	t CO_2-e ha^{-1}	A3-6		measured or estimated from literature	only once at project start and when mandatory
$Cldw_{cl}$	Average carbon stock per hectare in the lying dead wood carbon pool of the LU/LC class *cl*	t CO_2-e	A3-25, A3-30		measured or estimated from literature	only once at project start and when mandatory
$Cldw_{icl}$	Average carbon stock per hectare in the lying dead wood carbon pool of initial forest	t CO_2-e			measured or estimated from literature	

Notation	Description	Unit	Equation	Observation	Source	Monitoring
	class *icl*					
Clfcl	Average carbon stock per hectare in the litter carbon pool of LU/LC class f*cl*	t CO_2-e ha^{-1}	Table 16, Table 17		measured or estimated from literature	only once at project start and when mandatory
Clicl	Average carbon stock per hectare in the litter carbon pool of LU/LC class i*cl*	t CO_2-e ha^{-1}	Table 15		measured or estimated from literature	only once at project start and when mandatory
Clz	Average carbon stock per hectare in the litter carbon pool per zone z	t CO_2-e ha^{-1}	Table 17		measured or estimated from literature	only once at project start and when mandatory
Cp	Average carbon stock per hectare in the carbon pool *p*	t CO_2-e ha^{-1}	Table 7b		calculated	only once at project start
$Cp_{,icl,t}$	Average carbon stock per hectare in the carbon pool *p* burnt at year *t* in the forest class *icl*;	t CO_2-e ha^{-1}	14		calculated	only once at project start
$Csoc_{fcl}$	Average carbon stock per hectare in the soil organic carbon pool of final post-deforestation class *fcl*	t CO_2-e ha^{-1}	Table 16, table 17		measured or estimated from literature	
Csocz	Average carbon stock per hectare in the soil organic carbon pool per zone z	t CO_2-e ha^{-1}	Table 17		measured or estimated from literature	only once at project start and when mandatory
$Csdw_{cl}$	Average carbon stock per hectare in the standing dead wood carbon pool of the LU/LC class *cl*	t CO_2-e ha^{-1}	A3-25		measured or estimated from literature	only once at project start and when mandatory

Notation	Description	Unit	Equation	Observation	Source	Monitoring
$Csoc_{icl}$	Average carbon stock per hectare in the soil organic carbon pool of initial forest class *icl*	t CO_2-e ha^{-1}	Table 15		measured or estimated from literature	only once at project start and when mandatory
$Csoc_{cl}$	Average carbon stock per hectare in the soil organic carbon pool of LU/LC class *cl*	t CO_2-e ha^{-1}	A3-6, A3-33		measured or estimated from literature	only once at project start and when mandatory
$Csoc_{p}l$	Carbon stock per hectare in the soil organic carbon pool estimated for the plot *pl*;	t CO_2-e ha^{-1}	A3-33		measured or estimated from literature	only once at project start
ct	1, 2, 3 … *Ct* categories of LU/LC change (from initial forest classes *icl* to final post-deforestation classes *fcl*)	dimensionless			calculated	each renewal of fixed baseline period
$Ctot_{cl}$	Average carbon stock per hectare in all accounted carbon pools of LU/LC class *cl*	t CO_2-e ha^{-1}	A3-6		calculated	only once at project start and when mandatory
$Ctot_{fcl,t}$	Average carbon stock of all accounted carbon pools in non-forest class *fcl* at time *t*;	CO_2-e ha^{-1}	Table 30b		calculated	only once at project start
$Ctot_{icl}$	Average carbon stock of all accounted carbon pools in forest class *icl*	t CO_2-e ha^{-1}	Table 15		calculated	only once at project start and when mandatory
$Ctot_{icl,t}$	Average carbon stock of all accounted carbon pools in forest class *icl* at time *t*	t CO_2-e ha^{-1}	Table 25a, Table 30a		calculated	only once at project start and when mandatory
Ctotz	Average carbon stock of all accounted carbon pools per zone z	t CO_2-e ha^{-1}	Table 17		calculated	only once at project start and when mandatory

Notation	Description	Unit	Equation	Observation	Source	Monitoring
ctz	1, 2, 3 … *Ctz* categories of LU/LC change (from initial forest classes *icl* to post deforestation zones *z*)	dimensionless			calculated	each renewal of fixed baseline period
CV%	The highest coefficient of variation (%) reported in the literature from different volume or biomass forest inventories in forest plantations, natural forests, agro-forestry and/or silvo-pastoral systems	%	A3-1, A3-5		literature	only once at project start and when mandatory
Cwp_{fcl}	Average carbon stock per hectare in the harvested wood products carbon pool of final post-deforestation class *fcl*	t CO_2-e ha^{-1}	Table 16, Table 17			only once at project start and when mandatory
Cwp_{cl}	Average carbon stock per hectare in the harvested wood products carbon pool of LU/LC class *cl*	t CO_2-e ha^{-1}	A3-6, A3-35, A3-37		measured or estimated from literature	only once at project start and when mandatory
Cwp_{icl}	Average carbon stock per hectare in the harvested wood products carbon pool of initial forest class *icl*	t CO_2-e ha^{-1}	Table 15, A3-35,A3-36, A3-37, A3-39, A3-40, A3-41			only once at project start and when mandatory
$Cwp_{lt,icl,t}$	Carbon stock in the long-term wood products carbon pool at the time of deforestation *t* of the initial forest class *icl*		A3-37, A3-41			

Notation	Description	Unit	Equation	Observation	Source	Monitoring
Cwpmt,icl,t	Carbon stock in the medium-term wood products carbon pool at the time of deforestation *t* of the initial forest class *icl*		A3-36, A3-40			
Cwpz	Average carbon stock per hectare in the harvested wood products carbon pool per zone z	t CO_2-e ha^{-1}	Table 17		measured or estimated from literature	only once at project start and when mandatory
$CXB_{w,icl,t}$	Mean carbon stock per hectare of extracted biomass carbon by class of wood product *w* from forest class *icl* at time *t*	t CO_2-e ha^{-1}	A3-34, A3-35, A3-39		measured or estimated from literature	only once at project start and when mandatory
d1, d2, ..., dn	Diameters of intersecting pieces of dead wood	cm	A3-29		measured or estimated from literature	only once at project start and when mandatory
DBH	Diameter at Breast Height	cm	A3-18		measured or estimated from literature	only once at project start and when mandatory
DBI	Daily biomass intake	kg d.m. $head^{-1}$ day^{-1}	A4-2, Table 31		measured or estimated from literature	each renewal of fixed baseline period
dc	1, 2, 3 dead wood density classes	dimensionless	A3-30		defined	
DC	Total number of density classes (3)	dimensionless	A3-30		defined	

Notation	Description	Unit	Equation	Observation	Source	Monitoring
ΔCab_{ct}	Average carbon stock change factor in the above-ground biomass carbon pool of category *ct*	t CO_2-e ha^{-1}	Table 22.a.1		calculated	only once at project start and when mandatory
$\Delta CabBSLLK_t$	Total baseline carbon stock changes for the above-ground biomass pool in the leakage belt	t CO_2-e	Table 22.c.1		calculated	each renewal of fixed baseline period
$\Delta CabBSLLK_t$	Cumuativel baseline carbon stock changes for the above-ground biomass pool in the leakage belt	t CO_2-e	Table 22.c.1		calculated	each renewal of fixed baseline period
$\Delta CabBSLPA$	Cumulative baseline carbon stock changes for the above-ground biomass pool in the project area	t CO_2-e	Table 22.b.1		calculated	each renewal of fixed baseline period
$\Delta CabBSLPA_t$	Total baseline carbon stock changes for the above-ground biomass pool in the project area	t CO_2-e	Table 22.b.1		calculated	each renewal of fixed baseline period
$\Delta CabBSLRR$	Cumulative baseline carbon stock changes for the above-ground biomass pool in the reference region	t CO_2-e	Table 22.a.1		calculated	each renewal of fixed baseline period
$\Delta CabBSLRR_t$	Total baseline carbon stock changes for the above-ground biomass pool in the reference region	t CO_2-e	Table 22.a.1		calculated	each renewal of fixed baseline period

Notation	Description	Unit	Equation	Observation	Source	Monitoring
$\Delta CADLK$	Cumulative total decrease in carbon stocks due to displaced deforestation	t CO_2-e	Table 34, Table 35		calculated	annually
$\Delta CADLK_t$	Total decrease in carbon stocks due to displaced deforestation at year *t*	t CO_2-e	Table 34, Table 35		calculated	annually
ΔCbb_{ct}	Average carbon stock change factor in the below-ground biomass carbon pool of category *ct*	t CO_2-e ha^{-1}			calculated	only once at project start and when mandatory
$\Delta CBSLPAf_t$	Total baseline carbon stock change in final classes within the project area at year *t*	t CO_2-e			calculated	each renewal of fixed baseline period
$\Delta CBSLPA$	Total baseline carbon stock changes in the project area	t CO_2-e	Table 36		calculated	each renewal of fixed baseline period
$ABSLPA_{ct,t}$	Area of category *ct* deforested at time *t* within the project area in the baseline case	ha	Table 22.b.1		calculated	each renewal of fixed baseline period
$\Delta CBSLLK$	Cumulative carbon stock changes in leakage management areas in the baseline case	t CO_2-e	Table 21d, Table 30a, Table 30c		calculated	each renewal of fixed baseline period
$\Delta CBSLLK_t$	Annual carbon stock changes in leakage management areas in the baseline case at year *t*	t CO_2-e	Table 21d, Table 30a, Table 30c		calculated	each renewal of fixed baseline period
$\Delta CBSLPAf$	Total cumulative baseline carbon stock change in final classes within the project area	t CO_2-e			calculated	each renewal of fixed baseline period

Notation	Description	Unit	Equation	Observation	Source	Monitoring
	at year *t*					
$\Delta CBSLPAf_t$	Total annual baseline carbon stock change in final classes within the project area at year *t*	t CO_2-e			calculated	each renewal of fixed baseline period
$\Delta CBSLPA$	Total net cumulative baseline carbon stock change in final classes within the project area at year *t*	t CO_2-e	10		calculated	each renewal of fixed baseline period
$\Delta CBSLPAi$	Total cumulative baseline carbon stock change in initial forest classes within the project area at year *t*	t CO_2-e			calculated	each renewal of fixed baseline period
$\Delta CBSLPAi_t$	Total baseline carbon stock change in initial forest classes within the project area at year *t*	t CO_2-e			calculated	each renewal of fixed baseline period
$\Delta CBSLPA_t$	Total baseline carbon stock change within the project area at year *t*	t CO_2-e	19, 21, Table 36		calculated	each renewal of fixed baseline period
$\Delta CBSL_t$	Total baseline carbon stock change at year *t* in the project area	tCO_2-e	16		calculated	each renewal of fixed baseline period
ΔCdw_{ct}	Average carbon stock change factor in the dead wood biomass carbon pool of category *ct*	t CO_2-e ha^{-1}			calculated	only once at project start and when mandatory
$\Delta CFCdPA$	Cumulative decrease in carbon stock due to forest fires	t CO_2-e	Table 25g, Table 27	*ex post*	calculated	$\Delta CFCdPA$

Notation	Description	Unit	Equation	Observation	Source	Monitoring
	and catastrophic events at year *t* in the project area					
$\Delta CFCdPA_t$	Total decrease in carbon stock due to forest fires and catastrophic events at year *t* in the project area	t CO_2-e	Table 25g, Table 27	*ex post*	calculated	annually
$\Delta CFCiPA$	Cumulative increase in carbon stock due to forest fires and catastrophic events at year *t* in the project area	t CO_2-e	Table 26g, Table 27	*ex post*	calculated	annually
$\Delta CFCiPA_t$	Total increase in carbon stock due to forest fires and catastrophic events at year *t* in the project area	t CO_2-e	Table 26g, Table 27	*ex post*	calculated	annually
ΔCl_{ct}	Average carbon stock change factor in the litter carbon pool of category *ct*	t CO_2-e ha^{-1}			calculated	only once at project start and when mandatory
ΔCLK	Total cumulative decrease in carbon stocks within the leakage belt at year *t*	t CO_2-e	Table 35, Table 36		calculated	each renewal of fixed baseline period
ΔCLK_t	Total decrease in carbon stocks within the leakage belt at year *t*	t CO_2-e	19,Table 35, Table 36		calculated	each renewal of fixed baseline period
$\Delta CLPMLK$	Cumulative carbon stock decrease due to leakage prevention measures		Table 30c, Table 33, Table 35	*ex ante* and *ex post*	calculated	annually
$\Delta CLPMLKt$	Carbon stock decrease due to leakage prevention measures		Table 30c, Table 33,	*ex ante* and *ex post*	calculated	annually

Notation	Description	Unit	Equation	Observation	Source	Monitoring
	at year *t*		Table 35			
ΔCp_t	Carbon stock change factor applicable to pool *p* at time *t*	t CO_2-e			calculated	each renewal of fixed baseline period
$\Delta CPAdPA$	Cumulative decrease in carbon stock due to all planned activities at year *t* in the project area	t CO_2-e	Table 25d, Table 27, Table 29	*ex ante* and *ex post*	calculated	annually
$\Delta CPAdPA_t$	Total decrease in carbon stock due to all planned activities at year *t* in the project area	t CO_2-e	Table 25d, Table 27, Table 29	*ex ante* and *ex post*	calculated	annually
$\Delta CPAiPA$	Cumulative increase in carbon stock due to all planned activities at year *t* in the project area	t CO_2-e	Table 26d, Table 27, Table 29	*ex ante* and *ex post*	calculated	annually
$\Delta CPAiPA_t$	Total increase in carbon stock due to all planned activities at year *t* in the project area	t CO_2-e	Table 26d, Table 27, Table 29	*ex ante* and *ex post*	calculated	annually
$\Delta CPDdPA$	Cumulative decrease in carbon stock due to planned deforestation at year *t* in the project area	t CO_2-e	Table 25a	*ex ante* and *ex post*	calculated	annually
$\Delta CPDdPA_t$	Total decrease in carbon stock due to planned deforestation at year *t* in the project area	t CO_2-e	Table 25a	*ex ante* and *ex post*	calculated	annually
$\Delta CPFdPA$	Cumulative decrease in carbon stock due to planned fuel-wood and charcoal	t CO_2-e	Table 25c, Table 25d	*ex ante* and *ex post*	calculated	annually

Notation	Description	Unit	Equation	Observation	Source	Monitoring
	activities at year *t* in the project area					
$\Delta CPFdPA_t$	Total decrease in carbon stock due to planned fuel-wood and charcoal activities at year *t* in the project area	t CO_2-e	Table 25c, Table 25d	*ex ante* and *ex post*	calculated	annually
$\Delta CPFiPA$	Cumulative increase in carbon stock due to planned fuel-wood and charcoal activities at year *t* in the project area	t CO_2-e	Table 26c, Table 26d	*ex ante* and *ex post*	calculated	annually
$\Delta CPFiPA_t$	Total increase in carbon stock due to planned fuel-wood and charcoal activities at year *t* in the project area	t CO_2-e	Table 26c, Table 26d	*ex ante* and *ex post*	calculated	annually
$\Delta\ Cp_{icl,t=t*}$	Average carbon stock change factor for carbon pool *p* in the initial forest class *icl* applicable at time *t*	tCO_2-e ha^{-1}	10			
$\Delta CPLdPA$	Cumulative decrease in carbon stock due to planned logging activities at year *t* in the project area	t CO_2-e	Table 25b, Table 25d	*ex ante* and *ex post*	calculated	annually
$\Delta CPLdPA_t$	Total decrease in carbon stock due to planned logging activities at year *t* in the project area	t CO_2-e	Table 25b, Table 25d	*ex ante* and *ex post*	calculated	annually
$\Delta CPLiPA$	Cumulative increase in carbon stock due to planned logging activities at year *t* in the	t CO_2-e	Table 26b, Table 26d	*ex ante* and *ex post*	calculated	annually

Notation	Description	Unit	Equation	Observation	Source	Monitoring
	project area					
$\Delta CPLiPA_t$	Total increase in carbon stock due to planned logging activities at year *t* in the project area	t CO_2-e	Table 26b, Table 26d	*ex ante* and *ex post*	calculated	annually
$\Delta CPNiPA$	Cumulative increase in carbon stock due to planned protection of growing forest classes in the project area at year *t*	t CO_2-e	Table 26a, Table 26d	*ex ante* and *ex post*	calculated	annually
$\Delta CPNiPA_t$	Total increase in carbon stock due to planned protection of growing forest classes in the project area at year *t*	t CO_2-e	Table 26a, Table 26d	*ex ante* and *ex post*	calculated	annually
$\Delta CPSLK$	Total cumulative carbon stock change in leakage management areas in the project case	t CO_2-e	Table 30b, Table 30c	*ex ante* and *ex post*	calculated	annually
$\Delta CPSLK_t$	Total annual carbon stock change in leakage management areas in the project case	t CO_2-e	Table 30b, Table 30c	*ex ante* and *ex post*	calculated	annually
$\Delta CPSPA$	Cumulative project carbon stock change within the project area at year *t*	t CO_2-e	Table 27, Table 29, Table 36	*ex ante* and *ex post*	calculated	annually
$\Delta CPSPA_t$	Total project carbon stock change within the project area at year *t*	t CO_2-e	19, 21, Table 27, Table 29, Table 36	*ex ante* and *ex post*	calculated	annually

Notation	Description	Unit	Equation	Observation	Source	Monitoring
$\Delta Cp_{z,t=t*}$	Average carbon stock change factor for carbon pool *p* in zone *z* applicable at time *t* = *t**	tCO_2-e ha^{-1}	10		calculated	each renewal of tha baseline
$\Delta Csoc_{ct}$	Average carbon stock change factor in the soil organic carbon pool of category *ct*	t CO_2-e ha^{-1}			calculated	only once at project start and when mandatory
$\Delta Ctot_{ct,t}$	Carbon stock change factor (also called emission factor) for all accounted carbon pools in category *ct* at time *t*	t CO_2-e ha^{-1}			calculated	only once at project start and when mandatory
$\Delta Ctot_{ct}$	Average carbon stock change factor in all accounted carbon pools of category *ct*	t CO_2-e ha^{-1}			calculated	only once at project start and when mandatory
$\Delta Ctot_{icl,t}$	Average carbon stock change of all accounted carbon pools in forest class *icl* at time t	t CO_2-e ha^{-1}	Table 25b, Table 25c, Table 25e, Table 25f, Table 26a, Table 26b, Table 26c, Table 26e, Table 26f		calculated	each renewal of tha baseline
$\Delta CUCdPA$	Cumulative decrease in carbon stock due to catastrophic events at year *t* in the project area	t CO_2-e	Table 25f, Table 25g	*ex post*	calculated	annually
$\Delta CUCdPA_t$	Total decrease in carbon stock due to catastrophic events at year *t* in the project area	t CO_2-e	Table 25f, Table 25g	*ex post*	calculated	annually

Notation	Description	Unit	Equation	Observation	Source	Monitoring
$\Delta CUCiPA$	Cumulative increase in carbon stock in areas affected by catastrophic events (after such events) at year **t** in the project area	t CO_2-e	Table 26f, Table 26g	*ex post*	calculated	annually
$\Delta CUCiPA_t$	Total increase in carbon stock in areas affected by catastrophic events (after such events) at year **t** in the project area	t CO_2-e	Table 26f, Table 26g	*ex post*	calculated	annually
$\Delta CUDdPA$	Cumulative actual carbon stock change due to unavoided unplanned deforestation at year *t* in the project area	t CO_2-e	Table 27, Table 29	*ex ante* and *ex post*	calculated	annually
$\Delta CUDdPA_t$	Total actual carbon stock change due to unavoided unplanned deforestation at year *t* in the project area	t CO_2-e	16,Table 27 Table 29	*ex ante* and *ex post*	calculated	annually
$\Delta CUFdPA$	Cumulative otal decrease in carbon stock due to unplanned (and planned – where applicable) forest fires in the project area	t CO_2-e	Table 25e, Table 25g	*ex post*	calculated	annually
$\Delta CUFdPA_t$	Total decrease in carbon stock due to unplanned (and planned – where applicable) forest fires at year *t* in the project area	t CO_2-e	Table 25e, Table 25g	*ex post*	calculated	annually

Notation	Description	Unit	Equation	Observation	Source	Monitoring
$\Delta CUFiPA$	Cumulative increase in carbon stock in areas affected by forest fires (after such events) in the project area	t CO_2-e	Table 26e, Table 26g	*ex post*	calculated	annually
$\Delta CUFiPA_t$	Total increase in carbon stock in areas affected by forest fires (after such events) at year *t* in the project area	t CO_2-e	Table 26e, Table 26g	*ex post*	calculated	annually
ΔCwp_{ct}	Average carbon stock change factor in the harvested wood products carbon pool of category *ct*	t CO_2-e ha^{-1}			calculated	only once at project start and when mandatory
$\Delta REDD$	Cumulative met anthropogenic greenhouse gas emission reduction attributable to the AUD project activity	t CO_2-e	21	*ex ante* and *ex post*	calculated	annually
$\Delta REDD_t$	Net anthropogenic greenhouse gas emission reduction attributable to the AUD project activity at year *t*	t CO_2-e	19, 20, 23, Table 36	*ex ante* and *ex post*	calculated	annually
D_{dc}	Dead wood density of class *dc*	tonnes d. m. m^{-3}	A3-30		measured or estimated from literature	only once at project start and when mandatory
D_j	Mean wood density of species *j*	t d.m.m^{-3}	A3-34		measured or estimated from literature	only once at project start
DLF	Displacement Leakage Factor	%			defined	each renewal of fixed baseline period

Notation	Description	Unit	Equation	Observation	Source	Monitoring
Dm	Deadwood density	g cm-3	A3-28		measured or estimated from literature	only once at project start and when mandatory
DM_{pl}	Dry mass of sample $_{pl}$;	tonnes of d.m.	A3-24		measured or estimated from literature	only once at project start and when mandatory
e	Euler number (2,71828)	dimensionless	4.b, 8.c			
E%	allowable sample error in percentage (±10%)	%	A3-1			
E	allowable error (±10% of the mean)	%	A3-3			
EADLK	Cumulative total increase in GHG emissions due to displaced forest fires	t CO_2-e	Table 34, Table 35	*ex ante* and *ex post*	calculated	annually
$EADLK_t$	Total *ex ante* increase in GHG emissions due to displaced forest fires at year *t*	t CO_2-e	Table 34, Table 35	*ex ante* and *ex post*	calculated	annually
EBBBSPA	Cumulative baseline non-CO_2 emissions from forest fire at year *t* in the project area	t CO_2-e	17, 19, Table 24, Table 36	*ex ante* and *ex post*	calculated	annually
$EBBBSLPA_t$	Sum of (or total) baseline non-CO_2 emissions from forest fire at year *t* in the project area	t CO_2-e	19, Table 24, Table 36	*ex ante* and *ex post*	calculated	annually
$EBBBSLtot_{icl}$	Sum of (or total) actual non-	t CO_2-e	Table 24	*ex ante* and *ex*	calculated	annually

Notation	Description	Unit	Equation	Observation	Source	Monitoring
	CO_2 emissions from forest fire at year *t* in strata *i* in forest class *icl*			*post*		
$EBBCH4_{icl}$	CH_4 emission from biomass burning in forest class *icl*	t CO_2-e	11, 13	*ex ante* and *ex post*	calculated	annually
$EBBCO2_{icl}$	Per hectare CO_2 emission from biomass burning in slash and burn in forest class *icl*	t CO_2-e ha^{-1}	12, 13, 14		calculated	only once at project start
$EBBN2O_{icl}$	N_2O emission from biomass burning in forest class *icl*	t CO_2-e	11, 12	*ex ante* and *ex post*	calculated	annually
EBBPSPA	Cumulative (or total) actual non-CO_2 emissions from forest fire at year *t* in the project area	t CO_2-e	Table 28, Table 29, Table 36	*ex ante* and *ex post*	calculated	annually
$EBBPSPA_t$	Sum of (or total) actual non-CO_2 emissions from forest fire at year *t* in the project area	t CO_2-e	17,19, Table 28, Table 29, Table 36	*ex ante* and *ex post*	calculated	annually
$EBBtot_{icl}$	Total GHG emission from biomass burning in forest class *icl*	t CO_2-e	11	*ex ante* and *ex post*	calculated	annually
$ECH4ferm_t$	CH_4 emissions from enteric fermentation at year *t*	t CO_2-e	18, A4-1		calculated	annually
$ECH4man_t$	CH_4 emissions from manure management at year *t*	t CO_2-e	18, A4-3		calculated	annually
$EdirN2Oman_t$	Direct N_2O emissions from manure management at year *t*	t CO_2-e	A4-4, A4-5, Table 32		calculated	annually
EF1	Enteric CH_4 emission factor for the livestock group	kg CH_4 $head^{-1}$ yr^{-1}	A4-1, Table 31		calculated	each renewal of fixed baseline period

Notation	Description	Unit	Equation	Observation	Source	Monitoring
EF2	Manure management CH_4 emission factor for the livestock group	kg CH_4 head^{-1} yr^{-1}	A4-3, Table 31		measured or estimated from literature	each renewal of fixed baseline period
EF3	Emission factor for N_2O emissions from manure management for the livestock group	kg N_2O-N (kg N^{-1}) head^{-1} yr^{-1}	A4-5, Table 31		measured or estimated from literature	each renewal of fixed baseline period
EF4	Emission factor for N_2O emissions from atmospheric deposition of forage-sourced nitrogen on soils and water surfaces	kg N_2O-N (kg NH_3-N and NO_x-N emitted)-1 head^{-1} yr^{-1}	A4-6, Table 31		measured or estimated from literature	each renewal of fixed baseline period
EgLK	Cumulative Emissions from grazing animals in leakage management areas at year *t*	t CO_2-e	Table 32, Table 33, Table 35		calculated	annually
$EgLK_t$	Emissions from grazing animals in leakage management areas at year *t*	t CO_2-e	18, Table 32, Table 33, Table 35		calculated	annually
EI	Ex ante estimated Effectiveness Index	%	16		defined	annually
$EindNOman_t$	Indirect N_2O emissions from manure management at year *t*	t CO_2-e	A4-4, A4-5		calculated	annually
ELK	Cumulative sum of ex ante estimated leakage emissions at year *t*	t CO2-e	19, Table 35, Table 36		calculated	annually
ELK_t	Sum of *ex ante* estimated leakage emissions at year *t*	t CO_2-e	19, Table 35, Table 36		calculated	annually

Notation	Description	Unit	Equation	Observation	Source	Monitoring
ELPMLK	Cumulative otal *ex* increase in GHG emissions due to leakage prevention measures	t CO_2-e	Table 33		calculated	annually
$ELPMLK_t$	Annual total increase in GHG emissions due to leakage prevention measures at year *t*	t CO_2-e	Table 33		calculated	annually
$EN2Oman_t$	N_2O emissions from manure management at year *t*	t CO_2-e	18, A4-4, Table 32		calculated	annually
ERCH4	Emission ratio for CH_4 (IPCC default value = 0.012)	dimensionless	13		defined	each renewal of fixed baseline period
ERN2O	Emission ratio for N2O (IPCC default value = 0.007)	dimensionless	12		defined	each renewal of fixed baseline period
$Fburnt_{icl}$	Proportion of forest area burned during the historical reference period in the forest class *icl*	%	14, Table 23		measured or estimated from literature	only once at project start
fcl	1, 2, 3 … *Fcl* final (post-deforestation) non-forest classes	dimensionless			measured or estimated from literature	each renewal of fixed baseline period
$f_j(DBH,H)_{ab}$	an allometric equation for species, or group of species, or forest type *j*, linking above-ground tree biomass (in kg $tree^{-1}$) to diameter at breast height (*DBH*) and possibly tree height (*H*).		A3-10		measured or estimated from literature	only once at project start

Notation	Description	Unit	Equation	Observation	Source	Monitoring
FOM	"Figure of Merit"	dimensionless	9	This is measure of goodness of fit between observed and predicted deforestation	calculated	each renewal of fixed baseline period
Fracgas	Fraction of managed livestock manure nitrogen that volatilizes as NH_3 and NO_x in the manure management phase	kg NH_3-N and NO_x-N emitted $(Kg\ N)^{-1}$	Table 31		calculated	each renewal of fixed baseline period
$f_j(DBH,H)_V$	a commercial volume equation for species or species group j, linking commercial volume to diameter at breast height (DBH) and possibly tree height (H)		A3-20		calculated	each renewal of fixed baseline period
f(t)	A function of time		4.c		calculated	each renewal of fixed baseline period
GWP_{CH4}	Global Warming Potential for CH_4 (IPCC default value = 21 for the first commitment period)	dimensionless	13		defined	each renewal of fixed baseline period
GWP_{N2O}	Global Warming Potential for N_2O (IPCC default value = 310 for the first commitment period)	dimensionless	12		defined	each renewal of fixed baseline period

Notation	Description	Unit	Equation	Observation	Source	Monitoring
H	Height of the tree	meters	A3-27		measured or estimated from literature	only once at project start and when mandatory
i	1, 2, 3 .. I_{RR} A stratum within the reference region	dimensionless	In most equations		defined	each renewal of fixed baseline period
icl	1, 2, 3 … *Icl* initial (pre-deforestation) forest classes	dimensionless	10		measured or estimated from literature	each renewal of fixed baseline period
ID_{cl}	Identifier of a land-use/land-cover class					
ID_{ct}	Identifier of a land-use/ land-cover change category (from initial class *icl* to final class *fcl)*					
ID_{ctz}	Identifier of a land-use/ land-cover change category (from initial class *icl* to zone *z)*					
ID_{fcl}	Identifier of a final post-deforestation class *fcl*					
ID_i	Identifier of a strtum *i* in the reference region					
ID_{icl}	Identifier of an initial forest class *icl*					
ID_z	Identifier of a zone					
j	number of organic fertilizer types	dimensionless			defined	annually
k	Estimated parameter of the logistic regression	dimensionless	4.b, 8.c		calculated	each renewal of fixed baseline period

Notation	Description	Unit	Equation	Observation	Source	Monitoring
L	Length of the line	m	A3-29		measured or estimated from literature	only once at project start and when mandatory
LTFw	Fraction of wood products that are considered permanent (i.e. carbon is stored for 100 years or more); it may be assumed no carbon is released		A3-36, A3-40			
%LKB	Percentage of the overlapping leakage belts area to be assigned to project, A, B…..N	%	2.a,2.b,2.n		calculated	At each verification
MTFw	Fraction of wood products that are retired between 3 and 100 years		A3-37, A3-41			
n	total number of sample units to be measured (in all LU/LC classes)	dimensionless	A3-1, A3-2		calculated	each renewal of fixed baseline period
N	Population size or maximum number of possible sample units (all LU/LC classes)	dimensionless	A3-2		measured	each renewal of fixed baseline period
n_{cl}	number of samples units to be measured in LU/LC class *cl* that is allocated proportional to $W_{cl} \cdot S_{cl} / \sqrt{C_{cl}}$.	dimensionless	A3-2, A3-4			each renewal of fixed baseline period
NCR	Nitrogen/Carbon ratio (IPCC default value = 0.01)	dimensionless	12		defined	each renewal of fixed baseline period
Nex	Annual average N excretion per livestock head	kg N head^{-1} yr^{-1}	A4-6, Table 31		measured or estimated from	each renewal of fixed baseline period

Notation	Description	Unit	Equation	Observation	Source	Monitoring
					literature	
n_i	Number of samples units to be measured in LU/LC class cl that is allocated proportional to the size of the class. If estimated ncl < 3, set *ncl* = 3		A3-2			
N_i	Maximum number of possible sample units for LU/LC class *cl*, calculated by dividing the area of class *cl* by the measurement plot area		A3-2			
OFw	Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years of timber harvest	dimensionless	A3-35, A3-37		measured or estimated from literature	only once at project start
p	Carbon pool that could burn (above-ground biomass, dead wood, litter)	dimensionless	10		defined	each renewal of fixed baseline period
$Pburnt_{p,icl}$	Average proportion of mass burnt in the carbon pool *p* in the forest class *icl*;	%	14		measured or estimated from literature	only once at project start
$PCab_{pl}$	Carbon stock in above-ground biomass in plot *pl*	tC ha^{-1}	A3-13		calculated	only once at project start and when mandatory
$PCbb_{pl}$	Carbon stock in below-ground biomass in plot *pl*	tC ha^{-1}	A3-16		calculated	only once at project start and when mandatory

Notation	Description	Unit	Equation	Observation	Source	Monitoring
$Pcom_{icl}$	Commercial volume as a percent of total aboveground volume in initial forest class *icl*	dimensionless	A3-36, A3-38		measured or estimated from literature	only once at project start and when mandatory
PCx_i	Average in situ production costs for one ton of product *Px* in stratum *i*	$/t	1	This variable may have different values within different strata of the reference region	measured or estimated from literature	each renewal of fixed baseline period
$Pforage_t$	Production of forage at year *t*	kg d. m. yr^{-1}	A4-2, Table 32		calculated *ex ante*, measured *ex post*	each renewal of fixed baseline period
pl	1, 2, 3, … *PLcl* plots in LU/LC class *cl*	dimensionless	A3-14, A3-17, A3-24, A3-33		calculated	only once at project start and when mandatory
PL_{cl}	Total number of plots in LU/LC class *cl*	dimensionless	A3-14, A3-17, A3-24, A3-34		calculated	only once at project start and when mandatory
Po	Anhydrous weight of sample	g	A3-28		measured or estimated from literature	only once at project start and when mandatory
$Population_t$	Equivalent number of forage-fed livestock at year *t*	number of heads	A4-1, Table 32		calculated *ex ante*, measured *ex post*	annually
$PP_{i,t}$	Proportion of stratum *i* that is within the project area at time *t*	%			calculated	each renewal of fixed baseline period

Notation	Description	Unit	Equation	Observation	Source	Monitoring
PPx_l	Potential profitability of product *Px* at the location *l* (pixel or polygon)	$/t	1		calculated	each renewal of fixed baseline period
Ps	Saturated weight of sample	g	A3-28		measured or estimated from literature	only once at project start and when mandatory
Px	Product x produced in the reference region	dimensionless	1		measured or estimated from literature	each renewal of fixed baseline period
r1	Radius at the base of the tree	meters	A3-27		measured or estimated from literature	only once at project start and when mandatory
r2	Radius at the top of the tree	meters	A3-27		measured or estimated from literature	only once at project start and when mandatory
$RBSLRR_{i,t}$	Percentage of remaining forest area at year t -1 in stratum *i* to be deforested at year *t*	%	3	Used as an alternative to $ABSLRR_{i,t}$ in baseline approach "c"	calculated	each renewal of fixed baseline period
RF_t	Risk factor used to calculate VCS buffer credits	%	21		estimated	each renewal of fixed baseline period
R_j	Root-shoot ratio appropriate for species, group of species or forest type *j*	dimensionless	A3-18		measured or estimated from literature	only once at project start
$R_{j,pl,tr}$	Root-shoot ratio, applicable to tree *tr* of species *j* in plot *pl*	dimensionless	A3-22		measured or estimated from literature	only once at project start

Notation	Description	Unit	Equation	Observation	Source	Monitoring
S_{cl}	standard deviation of LU/LC class *cl*		A3-4			
$S\$_x$	Selling price of product *Px*	$/t	1		measured or estimated from literature	each renewal of fixed baseline period
SLF_w	Fraction of wood products that will be emitted to the atmosphere within 5 years of timber harvest	dimensionless	A3-35, A3-37		measured or estimated from literature	only once at project start
SPx_l	Selling point *l* of product *Px*	map	1		measured or estimated from literature	each renewal of fixed baseline period
STF_w	Fraction of wood products and waste that will be emitted to the atmosphere within 3 years; all carbon shall be assumed to be lost immediately; dimensionless		A3-35, A3-37, A3-40, A3-41			
t	1, 2, 3 … *T* a year of the proposed project crediting period	dimensionless	almost all equations		defined	
*t**	the year at which the area $ABSLPA_{icl,t}$ is deforested in the baseline case	dimensionless	10, A3-34		defined	
t1	Start date of the historical reference period	dimensionless				
t2	End date of the historical reference period	dimensionless				

Notation	Description	Unit	Equation	Observation	Source	Monitoring
$Taverage_i$	Number of years in which $Aaverage_i$ is deforested in the baseline case	yr			calculated	each renewal of fixed baseline period
$taverage_i$	Year at which $Taverage_i$ ends	yr	6, 7		calculated	each renewal of fixed baseline period
$TBab_j$	above-ground biomass of a tree of species, or species group, or forest type *j*	kg $tree^{-1}$ or t $tree^{-1}$	A3-10		calculated	only once at project start
$TBab_{tr}$	Above-ground biomass of tree *tr*	kg $tree^{-1}$ or t $tree^{-1}$	A3-11, A3-13, A3-21		calculated	only once at project start
$TCab_{tr}$	Carbon stock in above-ground biomass of tree $_{tr}$	kg C $tree^{-1}$ or t C $tree^{-1}$	A3-11, A3-21		calculated	only once at project start
$TCbb_{tr}$	Carbon stock in below-ground biomass of tree $_{tr}$	kg C $tree^{-1}$	A3-16, A3-22		calculated	only once at project start and when mandatory
TC_v	Average Transport Cost per kilometer for one ton of product *Px* on land, river or road of type *v*	$/t/km	1		measured or estimated from literature	each renewal of fixed baseline period
TD_v	Transport Distance on land, river or road of type *v*	$/t/km	1		calculated	each renewal of fixed baseline period
Thrp	Duration of the historical reference period	yr			defined	only once at project start
$Toptimal_i$	Number of years since the start of the AUD project activity in which *Aoptimal* in stratum *i* is deforested in the baseline case	yr			calculated	each renewal of fixed baseline period

Notation	Description	Unit	Equation	Observation	Source	Monitoring
$toptimal_i$	Year at which $Toptimal_i$ ends	yr	5, 6		calculated	each renewal of fixed baseline period
tr	1, 2, 3, … *TRpl* number of trees in plot *pl*	dimensionless	A3-13		measured or estimated from literature	only once at project start and when mandatory
t_{st}	t-student value for a 95% confidence level (initial value t = 2)	dimensionless	A3-1			t_{st}
$Tsub\text{-}optimal_i$	Number of years in which $Asub\text{-}optimal_i$ is deforested in the baseline case	yr			calculated	each renewal of fixed baseline period
v	1,2,3, …*V* type of surface on which transport occurs	dimensionless	1		measured or estimated from literature	each renewal of fixed baseline period
$V1_{i,t}$; $V2_{i,t}$; ...;$Vn_{i,t}$	Variables included in a deforestation model		8	Unit of each variable to be specified by the project proponent	measured or estimated from literature	each renewal of fixed baseline period
VBC_t	Number of Buffer Credits deposited in the VCS Buffer at time *t*;	t CO_2-e	20, 21, Table 36		calculated	annually
VCU_t	Number of Verified Carbon Units (VCUs) to be made available for trade at time *t*	t CO_2-e	20,Table 36		calculated	annually
VEF	Volume Expansion Factor	dimensionless	A3-9		measured or estimated from literature	only once at project start

Notation	Description	Unit	Equation	Observation	Source	Monitoring
$VEX_{w,j,fcl,t}$	Volume of timber for product class *w*, of species *j*, extracted from within forest class *fcl* at time *t*	m^3	A3-34		measured or estimated from literature	only once at project start and when mandatory
VOB10	Volume Over Bark above 10 cm *DBH*	m^3	A3-9		measured or estimated from literature	only once at project start
VOB30	Volume Over Bark above 30 cm *DBH*	m3	A3-9		measured or estimated from literature	only once at project start
$Volume_{dc}$	Volume of lying dead wood in the density class *dc*	m^3	A3-30		measured or estimated from literature	only once at project start and when mandatory
V_{pl}	Commercial volume of plot *pl*	m^3 $plot^{-1}$	A3-19		measured or estimated from literature	only once at project start and when mandatory
V_{tr}	Commercial volume of tree *tr*	m^3	A3-18, A3-21		measured or estimated from literature	only once at project start and when mandatory
w	1, 2, 3 … *W* Wood product class (sawn-wood, wood-based panels, other industrial round-wood, paper and paper board, and other);	dimensionless	A3-34		defined	only once at project start and when mandatory
W_{cl}	N_{cl}/N		A3-4			
WW_w	Wood waste for wood product class *w*. The fraction	dimensionless	A3-35, A3-37		measured or estimated from	only once at project start

Notation	Description	Unit	Equation	Observation	Source	Monitoring
	immediately emitted through mill inefficiency				literature	
XF	Plot expansion factor from per plot values to per hectare values	dimensionless	A3-12, A3-13, A3-16, A3-19, A3-20, A3-24		calculated	only once at project start and when mandatory
z	1, 2, 3, … Z post deforestation zones having a characteristic mixture of final post-deforestation classes (*fcl*)					

APPENDIX 6: LIST OF TABLES USED IN THIS METHODOLOGY

Table		*Ex ante*	*Ex post*	
		At validation	At verification	At baseline update
Table 1	Scope of the methodology	I		
Table 2	Criteria determining the applicability of existing baselines	I		
Table 3	Carbon pools included or excluded within the boundary of the proposed AUD project activity	Y		Y
Table 4	Sources and GHG included or excluded within the boundary of the proposed AUD project activity	Y		Y
Table 5	Data used for historical LU/LC change analysis	Y	Y	Y
Table 6	List of all land use and land cover classes existing at the project start date within the reference region	Y		Y
Table 7.a	Potential land-use and land-cover change matrix (initial forest classes *icl* to final post-deforestation classes *fcl*)	Y-M2,ct		Y-M2,ct
Table 7.b	List of land-use and land-cover change categories *ct* (initial forest classes *icl* to final post-deforestation classes *fcl*)	Y-M2,ct		Y-M2,ct
Table 8	Stratification of the reference region	Y		Y
Table 9.a	Annual areas of baseline deforestation in the reference region	Y		Y
Table 9.b	Annual areas of baseline deforestation in the project area	Y	Y	Y
Table 9.c	Annual areas of baseline deforestation in the leakage belt	Y	Y	Y
Table 10	List of variables, maps and factor maps	Y		Y
Table 11.a	Annual areas deforested per forest class *icl* within the reference region in the baseline case (baseline activity data per forest class)	Y		Y

Table		*Ex ante*	*Ex post*	
		At validation	At verification	At baseline update
Table 11.b	Annual areas deforested per forest class *icl* within the project area in the baseline case (baseline activity data per forest class)	Y	Y	Y
Table 11.c	Annual areas deforested per forest class *icl* within the leakage belt area in the baseline case (baseline activity data per forest class)	Y	Y	Y
Table 12	Zones of the reference region* encompassing different combinations of potential post-deforestation LU/LC classes (*A smaller area than the reference region can be considered, but this smaller area must at least contain the project area, the leakage belt and the leakage management areas.)	Y		Y
Table 13.a	Annual areas deforested in each zone within the reference region in the baseline case (baseline activity data per zone)	Y	Y	Y
Table 13.b	Annual areas deforested in each zone within the project area in the baseline case (baseline activity data per zone)	Y	Y	Y
Table 13.c	Annual areas deforested in each zone within the leakage belt area in the baseline case (baseline activity data per zone)	Y	Y	Y
Table 14.a	Baseline activity data for LU/LC change categories (*ct*) in the reference region	Y-M2,ct		Y-M2,ct
Table 14.b	Baseline activity data for LU/LC change categories (*ct*) in the project area	Y-M2,ct	Y-M2,ct	Y-M2,ct
Table 14.c	Baseline activity data for LU/LC change categories (*ct*) in the leakage belt	Y-M2,ct	Y-M2,ct	Y-M2,ct
Table 15.a	Carbon stocks per hectare of initial forest classes *icl* existing in the project area and leakage belt (the selection of carbon pools is subject to the latest VCS requirements on this matter, see Table 3): Estimated values	Y	Y-E	Y

Table		*Ex ante*	*Ex post*	
		At validation	At verification	At baseline update
Table 15.b	Carbon stocks per hectare of initial forest classes *icl* existing in the project area and leakage belt (the selection of carbon pools is subject to the latest VCS requirements on this matter, see Table 3): Values to be used after discounts for uncertainties (see 6.1.1.f, and Appendix 2)	Y	Y-E	Y
Table 16	Long-term (20-years) average carbon stocks per hectare of post-deforestation LU/LC classes present in the reference region (the selection of carbon pools is subject to the latest VCS requirements on this matter, see table 3)	Y		Y
Table 17	Long-term (20-years) area weighted average carbon stock per zone zone* (* If Method 2 was used in step 5.2, then each zone will have only one post-deforestation class *fcl*)	Y		Y
Table 18.a	Potential land-use and land-cover change matrix (initial forest classes *icl* to post-deforestation zones *z*)	Y-M2,ctz		Y-M2,ctz
Table 18.b	List of land-use and land-cover change categories (*ctz*) (initial forest classes *icl* to post-deforestation zones *z*)	Y-M2,ctz		Y-M2,ctz
Table 19.a	Annual areas deforested in each category *ctz* within the reference region in the baseline case (baseline activity data per category (*ctz*)	Y-M2,ctz		Y-M2,ctz
Table 19.b	Annual areas deforested in each category *ctz* within the project area in the baseline case (baseline activity data per category (*ctz*)	Y-M2,ctz	Y-M2,ctz	Y-M2,ctz
Table 19.c	Annual areas deforested in each category *ctz* within the leakage belt in the baseline case (baseline activity data per category (*ctz*)	Y-M2,ctz	Y-M2,ctz	Y-M2,ctz
Table 20.a	Carbon stock change factors for initial forest classes *icl* (Method 1)	Y-M1		Y-M1
Table 20.b	Carbon stock change factors for final classes *fcl* or zones *z* (Method 1)	Y-M1		Y-M1

Table		*Ex ante*	*Ex post*	
		At validation	At verification	At baseline update
Table 20.c	Carbon stock change factors for land-use change categories (*ct* or *ctz*) (Method 2)	Y-M2,ct Y-M2,ctz		Y-M2,ct Y-M2,ctz
Table 21.a.1	Baseline carbon stock change in the above-ground biomass in the reference region	(Y-M1)		(Y-M1)
Table 21.a.2	Baseline carbon stock change in the below-ground biomass in the reference region	(Y-M1)*		(Y-M1)*
Table 21.a.3	Baseline carbon stock change in the dead wood in the reference region	(Y-M1)*		(Y-M1)*
Table 21.a.4	Baseline carbon stock change in the litter in the reference region	(Y-M1)*		(Y-M1)*
	Baseline carbon stock change in the soil organic carbon in the reference region	Method 2 must be used		
Table 21.a.6	Baseline carbon stock change in the wood products in the reference region	(Y-M1)*		(Y-M1)*
Table 21.b.1	Baseline carbon stock change in the above-ground biomass in the project area	Y-M1	Y-M1 (A)	Y-M1
Table 21.b.2	Baseline carbon stock change in the below-ground biomass in the project area	Y-M1*	Y-M1* (A)	Y-M1*
Table 21.b.3	Baseline carbon stock change in the dead wood in the project area	Y-M1*	Y-M1* (A)	Y-M1*
Table 21.b.4	Baseline carbon stock change in the litter in the project area	Y-M1*	Y-M1* (A)	Y-M1*
	Baseline carbon stock change in the soil organic carbon in the project area	Method 2 must be used		
Table 21.b.6	Baseline carbon stock change in the wood products in the project area	Y-M1*	Y-M1* (A)	Y-M1*
Table 21.c.1	Baseline carbon stock change in the above-ground biomass in the leakage belt area	Y-M1*	Y-M1* (A)	Y-M1*
Table 21.c.2	Baseline carbon stock change in the below-ground biomass in the leakage belt area	Y-M1*	Y-M1* (A)	Y-M1*
Table 21.c.3	Baseline carbon stock change in the dead wood in the leakage belt area	Y-M1*	Y-M1* (A)	Y-M1*

Table		*Ex ante*	*Ex post*	
		At validation	At verification	At baseline update
Table 21.c.4	Baseline carbon stock change in the litter in the leakage belt area	Y-M1*	Y-M1* (A)	Y-M1*
	Baseline carbon stock change in the soil organic carbon in the leakage belt area	Method 2 must be used		
Table 21.c.6	Baseline carbon stock change in the wood products in the leakage belt area	Y-M1*	Y-M1* (A)	Y-M1*
Table 22.a.1	Baseline carbon stock change in the above-ground biomass in the reference region	(Y-M2)		(Y-M2)
Table 22.a.2	Baseline carbon stock change in the below-ground biomass in the reference region	(Y-M2)*		(Y-M2)*
Table 22.a.3	Baseline carbon stock change in the dead wood in the reference region	(Y-M2)*		(Y-M2)*
Table 22.a.4	Baseline carbon stock change in the litter in the reference region	(Y-M2)*		(Y-M2)*
Table 22.a.5	Baseline carbon stock change in the soil organic carbon in the reference region	(Y-M2)*		(Y-M2)*
Table 22.a.6	Baseline carbon stock change in the wood products in the reference region	(Y-M2)*		(Y-M2)*
Table 22.b.1	Baseline carbon stock change in the above-ground biomass in the project area	Y-M2	Y-M2 (A)	Y-M2
Table 22.b.2	Baseline carbon stock change in the below-ground biomass in the project area	Y-M2*	Y-M2* (A)	Y-M2*
Table 22.b.3	Baseline carbon stock change in the dead wood in the project area	Y-M2*	Y-M2* (A)	Y-M2*
Table 22.b.4	Baseline carbon stock change in the litter in the project area	Y-M2*	Y-M2* (A)	Y-M2*
Table 22.b.5	Baseline carbon stock change in the soil organic carbon in the project area	Y-M2*	Y-M2* (A)	Y-M2*
Table 22.b.6	Baseline carbon stock change in the wood products in the project area	Y-M2*	Y-M2* (A)	Y-M2*
Table 22.c.1	Baseline carbon stock change in the above-ground biomass in the leakage belt area	Y-M2	Y-M2 (A)	Y-M2
Table 22.c.2	Baseline carbon stock change in the below-ground biomass in the leakage belt area	Y-M2*	Y-M2* (A)	Y-M2*

Table		*Ex ante*	*Ex post*	
		At validation	At verification	At baseline update
Table 22.c.3	Baseline carbon stock change in the dead wood in the leakage belt area	Y-M2*	Y-M2* (A)	Y-M2*
Table 22.c.4	Baseline carbon stock change in the litter in the leakage belt area	Y-M2*	Y-M2* (A)	Y-M2*
Table 22.c.5	Baseline carbon stock change in the soil organic carbon in the leakage belt area	Y-M2*	Y-M2* (A)	Y-M2*
Table 22.c.6	Baseline carbon stock change in the wood products in the leakage belt area	Y-M2*	Y-M2* (A)	Y-M2*
Table 23	Parameters used to calculate non-CO_2 emissions from forest fires	Y*	Y*	Y*
Table 24	Baseline non-CO_2 emissions from forest fires in the project area (The selection of gases is subject to the latest VCS guidance on this matter, see table 4)	Y*	Y* (A)	Y*
Table 25.a	*Ex ante* estimated actual carbon stock decrease due to planned deforestation in the project area	Y*	Y*	Y*
Table 25.b	*Ex ante* estimated actual carbon stock decrease due to planned logging activities in the project area	Y*	Y*	Y*
Table 25.c	*Ex ante* estimated actual carbon stock decrease due to planned fuel wood collection and charcoal production in the project area	Y*	Y*	Y*
Table 25.d	Total *ex ante* carbon stock decrease due to planned activities in the project area	Y*	Y*	Y*
Table 26.a	*Ex ante* estimated carbon stock increase due to planned protection without harvest in the project area	Y*	Y*	Y*
Table 26.b	*Ex ante* estimated carbon stock increase following planned logging activities in the project area	Y*	Y*	Y*
Table 26.c	*Ex ante* estimated carbon stock increase following planned fuel-wood and charcoal activities in the project area	Y*	Y*	Y*

Table		*Ex ante*	*Ex post*	
		At validation	At verification	At baseline update
Table 26.d	Total *ex ante* estimated carbon stock increase due to planned activities in the project area	Y*	Y*	Y*
Table 26.e	*Ex post* carbon stock increase on areas affected by forest fires		Y*	
Table 26.f	*Ex post* carbon stock increase on areas affected by catastrophic events (see below and section 1.1.4).		Y*	
Table 26.g	*Ex post* carbon stock increase on areas recovering after forest fires and catastrophic events		Y*	
Table 27	*Ex ante* estimated net carbon stock change in the project area under the project scenario	Y	Y	Y
Table 28	Total *ex ante* estimated actual emissions of non-CO_2 gasses due to forest fires in the project area	Y*	Y*	Y*
Table 29	Total *ex ante* estimated actual net carbon stock changes and emissions of non-CO_2 gasses in the project area	Y	Y	Y
Table 30.a	*Ex ante* estimated carbon stock change in leakage management areas in the baseline case	Y*	Y*	Y*
Table 30.b	*Ex ante* estimated carbon stock change in leakage management areas in the project case	Y*	Y*	Y*
Table 30.c	*Ex ante* estimated net carbon stock change in leakage management areas	Y*	Y*	Y*
Table 31	Parameters used for the *ex ante* estimation of GHG emissions from grazing activities	Y*	Y*	Y*
Table 32	*Ex ante* estimation of leakage emissions above the baseline from grazing animals in leakage management areas	Y*	Y*	Y*
Table 33	*Ex ante* estimated total emissions above the baseline from leakage prevention activities	Y*	Y*	Y*
Table 34	*Ex ante* estimated leakage due to activity displacement	Y	Y	Y

Table		*Ex ante*	*Ex post*	
		At validation	At verification	At baseline update
Table 35	*Ex ante* estimated total leakage	Y	Y	Y
Table 36	*Ex ante* estimated net anthropogenic GHG emission reductions ($\Delta REDD_t$) and Voluntary Carbon Units (VCU_t)	Y	Y	Y

I	Informative
Y	Yes, to be prepared
Y-M1	Yes, to be prepared if Method 1 (Activity Data per classes) is used
Y-M2,ct	Yes, to be prepared if Method 2 (activity data per category *ct*) is used
Y-M2,ctz	Yes, to be prepared if Method 2 (activity data per category *ctz*) is used
Y-E	Yes, to be prepared if carbon stock enhancement is accounted
()	Optional
*	To be prepared only if applicable
(A)	Actual changes instead of baseline changes

DOCUMENT HISTORY

Version	Date	Comment
v1.0	12 Jun 2011	Initial version released.
v1.1	3 Dec 2012	The methodology was revised to account for the decay of carbon from the below-ground biomass, dead wood, soil carbon and meditum-term harvested wood products pools Revisions were made to section 6.1.2 and Appendix 3. Additional revisions have also been incorporated into the methodology. Specifically, litter is included as an optional pool, sampling techniques are provided as an option for developing land-use/land cover maps, the steps to analyse deforestation constraints is removed, and a process to project future land-use/land cover with zones is provided. The following minor updates have also been incorporated into the methodology: • The word “guidelines” when referring to Jurisdictional and Nested REDD was changed to “requirements”. • Equations 6.a, 6.b and 6.c were corrected to avoid negative areas. • Equations 7.b and 12.c were corrected (“e” is the Euler Number). • The minimum threshold requirements for the Figure of Merit (FOM) were changed and made consistent with the corresponding module of VM0007. • The definition of the minimum mapping unit was updated to be consistent with the definition found in the VCS *JNR Requirements*. • An error was corrected in equation A3-17 (the factor 44/12 to convert tons of C to tons of CO_2-e was missing).

VCS Methodology

VM0016

Recovery and Destruction of Ozone-Depleting Substances

Version 1.1

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Sectoral Scope 11

Prepared by:

Energy Changes Projekt Entwicklung GmbH

Obere Donaustraße 12/128

1020 Vienna, Austria

www.energy-changes.com

and

USG Umweltservice GmbH

Franz-Fritsch-Straße 11/Süd/104

4600 Wels, Austria

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1 SOURCES

This methodology refers to the latest version of the following approved methodologies:

- Climate Action Reserve (CAR) methodology *U.S. Ozone Depleting Substances Project Protocol, Destruction of U.S. Ozone Depleting Substances Banks*
- Climate Action Reserve (CAR) methodology *Article 5 Ozone Depleting Substances Project Protocol, Destruction of Article 5 Ozone Depleting Substances Banks*
- RAL Deutsches Institut für Gütesicherung: Quality Assurance and Test Specifications for the Demanufacture of Refrigeration Equipment

This methodology refers to the latest version of the following approved tools and modules:

- CDM tool *Tool for the demonstration and assessment of additionality*
- CDM tool *Tool to calculate the emission factor for an electricity system*
- VCS module *VMD0048 Activity method for the determination of additionality for recovered and stockpiled ODS refrigerant projects*

The following have also informed the development of the methodology:

- CDM tool *Tool to calculate project or leakage CO2 emissions from fossil fuel combustion*
- CDM tool *Tool to calculate baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	Project / Activity Method
Crediting Baseline	Project

This methodology quantifies the GHG emission reductions from activities that recover and destroy Ozone-Depleting Substances (ODS) from products where a partial or total atmospheric release of ODS occurs in the baseline scenario. Project activities can be implemented in Montreal Protocol Article 5 and Non-Article 5 countries.

Project activities may recover and destroy ODS refrigerants, ODS blowing agents or both.

3 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions and acronyms apply to this methodology:

Article 5 Country

Any party to the Montreal Protocol that is a developing country and whose annual calculated level of consumption of the controlled substances in Annex A (of the Montreal Protocol) is less than 0.3 kilograms per capita

Non Article 5 Country

Any party to the Montreal Protocol which is not an Article 5 country

Destruction Facility

The facility where the destruction of the ODS takes place and which meets the screening criteria for destruction technologies set out in the report, as may be updated from time to time, by the UNEP Technology and Economic Assessment Panel (TEAP) Task Force on Destruction Technologies. *UNEP Technology and Economic Assessment Panel (TEAP) Report of the Task Force on Destruction Technologies*, UNEP, 2002.

Ozone-Depleting Substance (ODS)

A family of man-made compounds that includes, but is not limited to, chlorofluorocarbons (CFCs), bromofluorocarbons (halons), methyl chloroform, carbon tetrachloride, methyl bromide, and hydrochlorofluorocarbons (HCFCs). These compounds have been shown to deplete stratospheric ozone, and therefore are typically referred to as ODS. Many Ozone-Depleting Substances also have a Global Warming Potential (GWP) and are therefore Greenhouse Gases (GHG).

> CFC ODS: An ODS listed in Annex A, Group 1 or Annex B, Group 1 of Appendix I of this methodology.
>
> HCFC ODS: An ODS listed in Annex C, Group 1 of Appendix I of this methodology.

ODS blowing agent

A chemical (being an ODS) added to plastics and rubbers that generates inert gases on heating, causing the resin to assume a cellular structure

ODS refrigerant

A chemical (being an ODS) used or intended for use in a cooling mechanism, such as an air conditioner or refrigerator, as the heat carrier which changes from gas to liquid and then back to gas in the refrigeration cycle

Product

Any of the following: refrigeration, air conditioning or fire suppression equipment, systems or appliances, or thermal insulation foams

Recovery

To remove ODS refrigerants and blowing agents in any condition from a system and store it in an external container

Recovery Facility
The facility where the project proponent recovers ODS refrigerants and blowing agents from appliances, or the facility where collected refrigerant is aggregated by the project proponent in preparation for destruction. The location where refrigerant is recovered from stationary equipment, such as a chiller, is not a recovery facility.

Recycle
To extract ODS refrigerants from an appliance and clean it using oil separation and single or multiple passes through filter-driers, which reduce moisture, acidity, and particulate matter

Reclaim
To reprocess used ODS refrigerants or blowing agents, typically by distillation, to specifications similar to that of virgin product specifications

Refrigerator appliance
Any appliance whose main purpose is the cooling of foodstuffs and other temperature-sensitive products and which are further defined as following *(according to RAL Deutsches Institut für Gütesicherung: Quality Assurance and Test Specifications for the Demanufacture of Refrigeration Equipment):*

Domestic fridges: These are refrigerators of a typical domestic design with a storage capacity of up to 180 litres. The appliances may or may not be equipped with a separate deep-freeze compartment. (Type 1 appliances).

Domestic fridge-freezers: These are refrigeration appliances of a typical domestic design with a storage capacity ranging from 180 to 350 litres. Generally, these appliances have a separate deep-freeze compartment. (Type 2 appliances).

Domestic chest freezers and upright freezers: These are deep-freeze appliances of a typical domestic design with a storage capacity up to 500 litres. (Type 3 appliances).

Stockpile
A CFC ODS refrigerant stored in an external container(s) by a single person or entity (including but not limited to private companies, organizations, and/or government agencies), or by multiple people or entities at a single location. A stockpile may be composed of one or more containers of any size. Containers in a stockpile may consist of recovered, reclaimed, recycled, or unused (manufactured for use but never so used) CFC ODS.

4 APPLICABILITY CONDITIONS

This methodology applies to project activities that recover and destroy ODS where the baseline scenario is the partial or total atmospheric release of ODS. This methodology does not apply to ODS refrigerant or ODS blowing agents that are manufactured for the sole purpose of their subsequent destruction.

Project activities can be implemented in Article 5 as well as in Non-Article 5 countries[1].

Only ODS listed in Appendix I of this methodology, and for which the VCS rules (as may be updated from time to time) apply**,** are eligible. ODS in a stockpile must be CFC ODS in order to be eligible under this methodology.

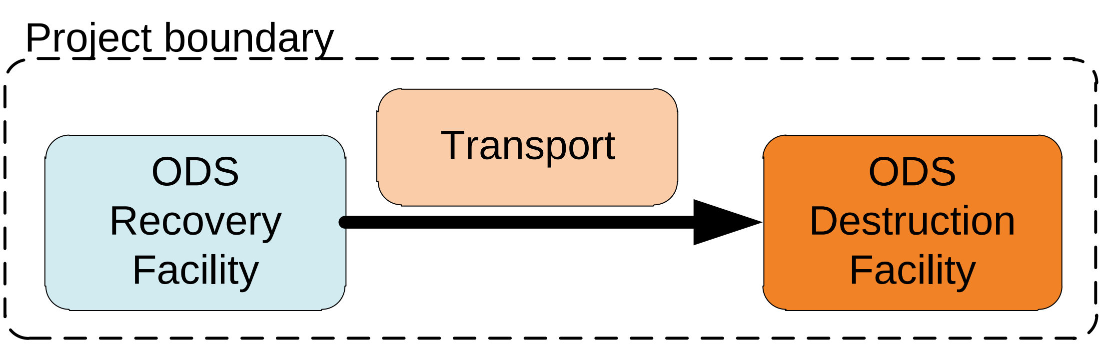
The methodology can be applied to either ODS refrigerants and/or ODS blowing agents. In the case of ODS blowing agents the methodology is only applicable to project activities recovering and destroying ODS blowing agents contained in insulation foam of end-of-life refrigerator appliances. The ODS blowing agent must be extracted from the foam to a concentrated form prior to destruction. This must be done under negative pressure to ensure that fugitive release of ODS cannot occur.

All ODS must be collected, stored, and transported in cylinders or other hermetically sealed containers.

5 PROJECT BOUNDARY

The spatial extent of the project boundary encompasses:

- The recovery facility
- Transportation from the recovery facility to the destruction facility
- The destruction facility



The greenhouse gases included in or excluded from the project boundary are shown in Table below.

[1] For the avoidance of doubt: Recovery and destruction activities can take place in separate countries.

Table 1: GHG Sources Included In or Excluded From the Project Boundary

	Source	Gas	Included?	Justification/Explanation
Baseline	Emissions through the release of ODS refrigerants into the atmosphere	$\sum_{i=1}^{n} ODS_i$	Yes	Main emission source in the baseline
	Emissions through the release of ODS blowing agent into the atmosphere	$\sum_{i=1}^{n} ODS_i$	Yes	Main emission source in the baseline
Project	Emissions through on-site fossil fuel and electricity consumption at the recovery facility	CO_2	Yes	May be an important emission source
		CH_4	No	Excluded for simplification. This emission source is assumed to be very small
		N_2O	No	Excluded for simplification. This emission source is assumed to be very small
	Emissions through transportation of ODS from the recovery facility to the destruction facility	CO_2	Yes	May be an important emission source
		CH_4	No	Excluded for simplification. This emission source is assumed to be very small
		N_2O	No	Excluded for simplification. This emission source is assumed to be very small
	Emissions associated to the destruction process of ODS	CO_2	Yes	May be an important emission source
		CH_4	No	Excluded for simplification. This emission source is assumed to be very small
		N_2O	No	Excluded for simplification. This emission source is assumed to be very small
		$\sum_{i=1}^{n} ODS_i$	Yes	May be an important emission source

6 BASELINE SCENARIO

The project proponent must use Step 1 of the latest version of the CDM *Tool for the demonstration and assessment of additionality*, to identify all realistic and credible baseline alternatives. In doing so, relevant policies and regulations related to the management of ODS banks should be taken into account. Such policies or regulations may include mandatory ODS capture or destruction requirements because of regional or local environmental regulations. In addition, the assessment of alternative scenarios should take into account regional economic and technological circumstances.

For ODS refrigerants the realistic and credible alternative(s) may include, *inter alia*

R1 Project activity not performed as emission reduction project

R2 Products are disposed of into an incineration facility and thereby ODS refrigerants are destroyed

R3 Atmospheric release of the ODS refrigerant or partial capture and destruction

R4 Atmospheric release of the ODS refrigerant or partial capture and reuse in existing products or continued storage in stockpile

For ODS blowing agents the realistic and credible alternative(s) may include, *inter alia*

BAF1 Project activity not performed as emission reduction project

BAF2 The refrigerators containing foams (blowing agents) are disposed of into an incineration facility and thereby ODS blowing agents are destroyed

BAF3 The refrigerators containing foams (blowing agents) are disposed of at a landfill/dump

BAF4 Before final disposal, the refrigerators containing foam are shredded. The foams are subsequently:

BAF4.1 disposed of at an incineration facility

BAF4.2 disposed of at a landfill/dump

BAF4.3 disposed of by open burning

BAF4.4 extracted and ODS blowing agents are partly captured and destroyed

The methodology is only applicable for ODS refrigerants if the most plausible baseline scenario for the ODS refrigerant is either R3 or R4 or a combination of both. In respect of ODS blowing agents the methodology is only applicable if the most plausible baseline scenario for ODS blowing agents from foam is either one of BAF4.1, BAF4.2, BAF4.3 or BAF4.4 or any combination of these scenarios.

7 ADDITIONALITY

The project proponent should use the two-step process set out in Section 7.1 for the demonstration of additionality for projects that destroy CFC refrigerant and fulfill the applicability conditions of VCS activity method module *Activity method for the determination of additionality for recovered and stockpiled ODS refrigerant projects*. The project proponent must use the project method set out in Section 7.2 for all other projects eligible under this methodology.

7.1 Destruction of CFC refrigerant

Step 1: Regulatory surplus

The project proponent must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the *VCS Standard*.

Step 2: Positive list

The applicability conditions of VCS activity method module *Activity method for the determination of additionality for recovered and stockpiled ODS refrigerant projects* represent the positive list. The positive list was established using the revenue streams option (Option C in the *VCS Standard*). Projects that meet all of the applicability conditions of this methodology and the VCS activity method module *Activity method for the determination of additionality for recovered and stockpiled ODS refrigerant projects* are deemed additional.

7.2 Destruction of ODS refrigerant and/or ODS blowing agents

This methodology uses a project method for the demonstration of additionality of all project activities that are not eligible to apply the activity method described above. Such projects include the destruction of ODS blowing agents and the destruction of other ODS refrigerants where the activity method is not applicable or preferred, in which case project proponents shall apply the latest version of the CDM *Tool for the demonstration and assessment of additionality*.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

Baseline emissions from existing ODS contained in products and/or stockpiles are determined with the following equation:

$$BE_{ODS,y} = BE_{ODS\_ref,y} + BE_{ODS\_foam,y} \quad (1)$$

Where:

$BE_{ODS,y}$	=	Total quantity of baseline emissions from ODS refrigerants and blowing agents (foam) which would be released into the atmosphere in the absence of the project activity in year y [tCO_2e]
$BE_{ODS\_ref,y}$	=	Baseline emissions from ODS refrigerants which would be released into the atmosphere in the absence of the project activity in year y [tCO_2e]
$BE_{ODS\_foam,y}$	=	Baseline emissions from ODS blowing agents contained in insulation foams of refrigeration appliances which would be released into the atmosphere in the absence of the project activity in year y [tCO_2e]

Baseline emissions from ODS refrigerants are determined as follows:

$$BE_{ODS\_ref,y} = \sum_{i=1}^{n}\Big(\big(M_{DESTR,refr,i,y} \times VR_{refr} \times EF_{VR}\big) + \big(M_{DESTR,refr,i,y} \times RR_{refr,i,y} \times EF_{RR,refr,i,y}\big) + \big(M_{DESTR,refr,i,y} \times DR_{refr} \times EF_{DR}\big)\Big) \times GWP_{refr,i} \quad (2)$$

$$1 = VR_{refr} + RR_{refr,i,y} + DR_{refr} \quad (3)$$

Where:

$BE_{ODS\_ref,y}$	=	Baseline emissions from ODS refrigerants which would be released into the atmosphere in the absence of the project activity in year y [tCO_2e]
$M_{DESTR,refr,i,y}$	=	Quantity of ODS refrigerant i destroyed by the project activity in year y [$tODS_i$]
VR_{refr}	=	Rate of ODS refrigerants (destroyed) which would be vented into the atmosphere in the baseline [%,0-100%]
EF_{VR}	=	Emission factor for the rate of ODS refrigerants (destroyed) which would be vented into the atmosphere [1]
DR_{refr}	=	Rate of ODS refrigerants (destroyed) by the project activity which would also be destroyed in the baseline [%,0-100%]
EF_{DR}	=	Emission factor for the rate of ODS refrigerants (destroyed) by the project activity which would also be destroyed in the baseline [0]
$RR_{refr,i,y}$	=	Rate of ODS refrigerants i which would be used, reused or remain in storage in the baseline [%,0-100%]
$EF_{RR,refr,i,y}$	=	Emission factor for the rate of ODS refrigerant i (destroyed) which would be reused in the baseline [0-1.0]
$GWP_{refr,i}$	=	Global warming potential of ODS refrigerant type i that converts 1 ton of ODS i to tons of CO_2 equivalents. [$tCO_2e/tODS_i$]

$$EF_{VR} = 1 \tag{4}$$

$$EF_{DR} = 0 \tag{5}$$

$$EF_{RR,refr,i} = 1 - \left(1 - LR_{refr,i}\right)^{tcp} \tag{6}$$

Where:

$EF_{RR,refr,i}$	=	Emission factor for the rate of ODS refrigerant i (destroyed) which would be reused in the baseline [0-1.0]
$LR_{refr,i}$	=	Leak rate of ODS refrigerant i (destroyed), which would be used as refrigerant for existing equipment or remain in storage in the baseline [%,0-100%]
tcp	=	Project crediting period [10]

When destruction of the ODS refrigerants by the project activity is mandated by law, statute or other regulatory framework applying in the host country, the baseline shall be the gradually increasing compliance with such law, statute or other regulatory framework, and the baseline GHG emissions shall be calculated as follows:

$$BE_{ODS\_ref,y,a} = BE_{ODS\_ref,y} \times \left(1 - CR_y\right) \tag{7}$$

Where:

$BE_{ODS\_ref,y}$	=	Baseline emissions from ODS refrigerants which would be released into the atmosphere in the absence of the project activity in year y [tCO_2e]
$BE_{ODS\_ref,y,a}$	=	Adjusted baseline emissions to be used for the calculation of emission reductions in year y [tCO_2e]
CR_y	=	Host country-level compliance rate of the law, statute or other regulatory framework in the year y. Calculation of the compliance rate shall exclude other projects implemented under GHG programs. If the compliance rate exceeds 50%, the project shall receive no further credit [%, 0-100%]

Baseline emissions from ODS blowing agents are determined as follows:

$$BE_{ODS\_foam,y} = \sum_{i=1}^{n} \left(\left(M_{APPLIANCE,foam,i,y} \times ER_{foam,i} - \left(M_{APPLIANCE,foam,i,y} - M_{DESTR,foam,i,y} \right) \right) \times GWP_{foam,i} \right) \tag{8}$$

Where:

$BE_{ODS\_foam,y}$	=	Baseline emissions from ODS blowing agents contained in insulation foams of refrigeration appliances which would be released into the atmosphere in the absence of the project activity in year y [tCO_2e]
$M_{DESTR,foam,i,y}$	=	Quantity of ODS blowing agent i destroyed by the project activity in year y [$tODS_i$]
$M_{APPLIANCE,foam,i,y}$	=	Total quantity of ODS blowing agent i contained in the total number of refrigerator appliances from which ODS is recovered in year y [$tODS_i$]
$ER_{foam,i}$	=	Rate by which ODS blowing agent i contained in foam of refrigeration appliances would be released into atmosphere based on the disposal practice (baseline) in the respective host country [%,0-100%]
$GWP_{foam,i}$	=	Global warming potential of ODS blowing agent type i that converts 1 ton of ODS i to tons of CO2 equivalents. [$tCO_2e/tODS_i$]

$$M_{APPLIANCE,foam,i,y} = M_{APPLIANCE,1,foam,i,y} + M_{APPLIANCE,2,foam,i,y} + M_{APPLIANCE,3,foam,i,y} \quad (9)$$

Where:

$M_{APPLIANCE,1,foam,i,y}$	=	Total quantity of ODS blowing agent i contained in the total number of type 1 refrigerator appliances from which ODS is recovered in year y [$tODS_i$]
$M_{APPLIANCE,2,foam,i,y}$	=	Total quantity of ODS blowing agent i contained in the total number of type 2 refrigerator appliances from which ODS is recovered in year y [$tODS_i$]
$M_{APPLIANCE,3,foam,i,y}$	=	Total quantity of ODS blowing agent i contained in the total number of type 3 refrigerator appliances from which ODS is recovered in year y [$tODS_i$]

$$M_{APPLIANCE,1,foam,i,y} = \sum_{1}^{J} M_{app,1,foam,i,y} \quad (10)$$

Where:

$M_{APPLIANCE,1,foam,i,y}$	=	Quantity of ODS blowing agent i contained in <u>one</u> type 1 refrigerator appliance from which ODS is recovered during year y [$tODS_i$]
J	=	Total number of type 1 refrigerator appliances from which ODS blowing agent i is recovered in year y [Number]

$$M_{APPLIANCE,2,foam,i,y} = \sum_{1}^{K} M_{app,2,foam,i,y} \quad (11)$$

Where:

$M_{app,2,foam,i,y}$	=	Quantity of ODS blowing agent i contained in one type 2 refrigerator appliance from which ODS is recovered during year y [$tODS_i$]
K	=	Total number of type 2 refrigerator appliances from which ODS blowing agent i is recovered in year y [Number]

$$M_{APPLIANCE,3,foam,i,y} = \sum_{1}^{L} M_{app,3,foam,i,y} \quad (12)$$

Where:

$M_{app,3,foam,i,y}$	=	Quantity of ODS blowing agent i contained in one type 3 refrigerator appliance from which ODS is recovered during year y [$tODS_i$]
L	=	Total number of type 3 refrigerator appliances of which ODS blowing agent i is recovered in year y [Number]

For baseline scenarios BAF4.1 and BAF4.2 the following default factors shall be used for $ER_{foam,i}$

Table 2: Default Factors

Disposal Practice (Baseline)	Applicable default factor		
BAF4.1: disposed of at an incineration facility	ODSi	$ER_{foam,i}$	Source
	CFC-11	0.24	Same as used in CAR U.S. Ozone Depleting Substances Project Protocol Table 5.3 and 5.4 Based on Scheutz, C. et al. (2007a)
	CFC-12	0.24	
	HCFC-22	0.24	
	HCFC-141b	0.24	
BAF4.2: disposed of at a landfill/dump	CFC-11	0.44	Same as used in CAR U.S. Ozone Depleting Substances Project Protocol Table 5.3 and 5.4 Based on Scheutz, C. et al. (2007a/b) Fredenslund, A. et al. (2005)
	CFC-12	0.55	
	HCFC-22	0.75	
	HCFC-141b	0.5	

For BAF4.3 and BAF4.4, $ER_{foam,i}$ shall be based on host country officially published data, research studies or industry data.

When destruction of the ODS blowing agents by the project activity is mandated by law, statute or other regulatory framework applying in the host country, the baseline shall be the gradually increasing compliance with such law, statute or other regulatory framework, and the baseline GHG emissions shall be calculated as follows:

$$BE_{ODS\_foam,y,a} = BE_{ODS\_foam,y} \times (1 - CR_y) \quad (13)$$

Where:

$BE_{ODS\_foam,y,a}$	=	Adjusted baseline emissions to be used for the calculation of emission reductions in year y [tCO_2e]
$BE_{ODS\_foam,y}$	=	Baseline emissions from ODS blowing agents contained in insulation foams of refrigeration appliances which would be released into the atmosphere in the absence of the project activity in year y [tCO_2e]
CR_y	=	Host country-level compliance rate of the law, statute or other regulatory framework in the year y. Calculation of the compliance rate shall exclude other projects implemented under GHG programs. If the compliance rate exceeds 50%, the project shall receive no further credit [%,0-100%]

8.2 Project Emissions

Project emissions in year y are:

- Emissions that are caused by the project activity due to energy consumption at the ODS recovery facility
- Emissions that are caused by the project activity due to ODS transportation
- Emissions that are caused by the project activity due to ODS destruction

$$PE_y = PE_{Energy\_Consump,y} + PE_{ODS\_Transport,y} + PE_{ODS\_Destruction,y} \quad (14)$$

PE_y	=	Project emissions during year y [tCO_2e]
$PE_{Energy\_Consump,y}$	=	Project emissions from energy consumption at the ODS recovery facility during year y [tCO_2e]
$PE_{ODS\_Transport,y}$	=	Project emission from ODS transportation during year y [tCO_2e]
$PE_{ODS\_Destruction,y}$	=	Project emission from ODS destruction during year y [tCO_2e]

Determination of $PE_{Energy\_Consump,y}$:

$$PE_{Energy\_Consump,y} = PE_{EC,y} + PE_{FC,j,y} \quad (15)$$

Where:

$PE_{Energy\_Consump,y}$	=	Project emissions from energy consumption attributable to the ODS recovery facility during year y [tCO_2e]
$PE_{EC,y}$	=	Project emissions from electricity consumption from the grid at the ODS recovery facility during year y [tCO_2e]
$PE_{FC,j,y}$	=	Project emissions from fossil fuel consumption attributable to the ODS recovery facility including third party used fossil fuel to generate energy for the ODS recovery facility during year y [tCO_2e]

Determination of $PE_{EC,y}$:

$$PE_{EC,y} = EC_{PJ,y} \times EF_{grid,y} \times (1 + TDL_y) \quad (16)$$

Where:

$PE_{EC,y}$	=	Project emissions from electricity consumption from the grid at the ODS recovery facility during year y [tCO_2e]
$EC_{PJ,y}$	=	Amount of electricity consumed at the ODS recovery facility from the grid during year y [MWh]
$EF_{grid,y}$	=	Grid emission factor during monitoring period y [tCO_2e /MWh]
TDL_y	=	Average technical transmission and distribution losses in the grid for the voltage level at which electricity is obtained from the grid at the project site during year y [%,0-100%]

For determination of $EF_{grid,y}$ the project proponent shall choose one of the following options:

- Calculate the combined margin emission factor, using the procedures in the latest approved version of the CDM “Tool to calculate the emission factor for an electricity system”; or
- Use a conservative default value of 1.3 tCO_2/MWh

For determination of TDL_y

- Use recent, accurate and reliable data available within the country; or
- Use a conservative default value of 20%

Determination of $PE_{FC,j,y}$:

$$PE_{FC,j,y} = \sum_i FC_{i,j,y} \times COEF_{i,y} \quad (17)$$

Where:

$PE_{FC,j,y}$ = Project emissions from fossil fuel consumption attributable to the ODS recovery facility including third party used fossil fuel to generate energy for the ODS recovery facility during year y [tCO_2e]

$FC_{i,j,y}$ = Amount of fuel type i combusted in process j at the ODS recovery facility or at any third party generating energy for the ODS recovery facility during year y [mass or volume unit]

$COEF_{i,y}$ = CO_2 emission coefficient of fuel type i in year y [tCO_2e / mass or volume unit] i are the fuel types combusted in process j

The CO_2 emission coefficient $COEF_{i,y}$ can be calculated according to two different procedures, depending on the available data about the fossil fuel type *i*,:

- **Option A:** The CO_2 emission coefficient $COEF_{i,y}$ is calculated based on the chemical composition of the fossil fuel type *i*, using the following approach:

If $FC_{i,j,y}$ is measured in a mass unit: $COEF_{i,y} = w_{C,i,y} \times 44/12$

If $FC_{i,j,y}$ is measured in a volume unit: $COEF_{i,y} = w_{C,i,y} \times \rho_{i,y} \times 44/12$

Where:

$COEF_{i,y}$ = CO_2 emission coefficient of fuel type i during year y [tCO_2e / mass or volume unit]

$w_{C,i,y}$ = Weighted average mass fraction of carbon in fuel type i during year y [tC / mass unit of the fuel]

$\rho_{i,y}$ = Weighted average density of fuel type i during year y [mass unit / volume unit of the fuel]

- **Option B:** The CO_2 emission coefficient $COEF_{i,y}$ is calculated based on net calorific value and CO_2 emission factor of the fuel type i, as follows:

$$COEF_{i,y} = NCV_{i,y} \times EF_{CO2,i,y} \tag{18}$$

Where:

$COEF_{i,y}$ = CO_2 emission coefficient of fuel type i during year y [tCO_2e / mass or volume unit]

$NCV_{i,y}$ = Weighted average net calorific value of the fuel type i during year y [GJ/mass or volume unit]

$EF_{CO2,i,y}$	=	Weighted average CO_2 emission factor of fuel type i during year y [tCO_2e /GJ]

Where necessary data is available option A should be used.

Determination of $PE_{ODS\_Transport,y}$ and $PE_{ODS\_Destruction,y}$:

For project emissions due to ODS transportation and destruction, the project proponent shall apply the default factors provided by the latest version of the *CAR Article 5 Ozone Depleting Substances Project Protocol: (Calculating Default Project Emissions from ODS Destruction and Transportation)*

$$PE_{ODS_{Transport},y} + PE_{ODS_{Destruction},y} = \left(M_{DESTR,refr,i,y} + M_{DESTR,foam,i,y}\right) \times EF_{ODS\_Transport+Destruction,y} \tag{19}$$

Where:

$PE_{ODS\_Transport,y}$	=	Project emission from ODS transportation during year y [tCO_2e]
$PE_{ODS\_Destruction,y}$	=	Project emission from ODS destruction during year y [tCO_2e]
$M_{DESTR,refr,i,y}$	=	Quantity of ODS refrigerant i sent for destruction by the project activity, including eligible and ineligible material, during year y [tODSi]
$M_{DESTR,foam,i,y}$	=	Quantity of ODS blowing agent i sent for destruction by the project activity, including eligible and ineligible material, during year y [$tODS_i$]
$EF_{ODS\_Transport+Destruction,y}$	=	Default emission factor aggregating both transportation and destruction emissions [tCO_2] (sourced from CAR, as above)

8.3 Leakage

Leakage emissions occur where in the baseline ODS refrigerant would have been re-used and in the project scenario must be substituted by other chemicals. Reuse may result in a gradual release of ODS over the project crediting period. When refrigerant ODS are destroyed, continued demand for refrigeration will lead to the production and consumption of other refrigerant chemicals whose production is still legally allowed.

$$LE_{ODS\_Substitute,y} = \sum_i^n M_{Destr,refr,i,y} \times TLR_{substitute,i} \times GWP_{substitute,i} \tag{20}$$

Where:

$LE_{ODS\_Substitute,y}$	=	Leakage emissions through ODS substitute i during year y [tCO_2e]

$M_{Destr,refr,i,y}$	=	Quantity of ODS refrigerant i which is sent to destruction by the project activity in year y [tODSi]
$TLR_{substitute,i}$	=	Total leakage of substitute chemical i over the project crediting period [0-1]
$GWP_{substitute,i}$	=	Global warming potential of substitute chemical i [tonsCO_2e/substitute,i]

$$TLR_{substitute,i} = 1 - \left(1 - LR_{substitute,i;y}\right)^{tcp} \quad (21)$$

Where:

$TLR_{substitute,i}$	=	Total leakage of substitute chemical i over the project crediting period [0-1]
$LR_{substitute,i;y}$	=	Leak rate of substitute chemical i in year y [0-1]
tcp	=	Project crediting period

For project activities taking place in Article 5 countries, the project proponent shall apply a substitute chemical derived from either official published data, research, industry studies, or default values provided in the latest version of the *CAR Article 5 Ozone Depleting Substances Project Protocol*. The leak rate $LR_{substitute,i;y}$ shall be obtained from either official published data, research, industry studies, or default values provided in the latest version of the *CAR Article 5 Ozone Depleting Substances Project Protocol*.

For project activities taking place in Non-Article 5 countries, the project proponent shall apply substitute chemicals derived from either official published data, research, industry studies, or default values provided in the latest version of the CAR *U.S. Ozone Depleting Substances Project Protocol*. The leak rate $LR_{substitute,i;y}$ shall be obtained from either official published data, research, industry studies, or default values provided in the latest version of the CAR *U.S. Ozone Depleting Substances Project Protocol.*

8.4 Net GHG Emission Reduction and Removals

Emission reductions are calculated as follows:

$$ER_{ODS,y} = BE_{ODS\_refr,y} + BE_{ODS\_foam,y} - PE_y - LE_y \quad (22)$$

Where:

$ER_{ODS,y}$	=	means total emission reductions during year y [tCO_2e]

$BE_{ODS\_refr,y}$	=	means the baseline emissions from ODS refrigerants banks which would be released into the atmosphere in the absence of the project activity during year y [tCO_2e]
$BE_{ODS\_foam,y}$	=	means baseline emissions from ODS blowing agents contained in insulation foams of refrigeration appliances which would be released into the atmosphere in the absence of the project activity during year y [tCO_2e]
PE_y	=	means the project emissions by the project activity during year y [tCO_2e]
LE_y	=	means the leakage emissions by the project activity during year y [tCO_2e]

9 MONITORING

9.1 Data and Parameters Available at Validation

Data / Parameter:	GWP_{ODSi} (refrigerants, blowing agents and substitute chemical)
Data unit:	tCO2e/tODS$_i$
Description:	Global Warming Potential of ODS$_i$
Source of data:	IPCC
Description of measurement methods and procedures to be applied:	See value Appendix I of this methodology for the first commitment period. Shall be updated according to any future COP/MOP decisions.
Comments:	

Data / Parameter:	VR_{refr}
Data unit:	% expressed as number [0-100%]
Description:	Rate of ODS refrigerants (destroyed) which would be vented into the atmosphere in the baseline
Source of data:	Default value(s) given below or project-specific rate(s) sourced from officially published country data, research studies, industry data, etc. In non-Article 5 countries, it is conservatively assumed that no intentional venting occurs and all ODS refrigerant is either used, reused or stored as a stockpile. As such, the default rate is 0%.

	In Article 5 countries, the default rate is similarly 0% unless the project proponent demonstrates that all or a portion of the ODS refrigerant destroyed as part of the project was recovered from products at end-of-life. In the absence of any regulatory prohibition on venting, all ODS refrigerant recovered from products at end-of-life is assumed to be vented directly to the atmosphere (100%) in the baseline.
Description of measurement methods and procedures to be applied:	In Article 5 countries, maintain point of origin documentation to demonstrate the portion of ODS refrigerant sourced from products at end-of-life.
Comments:	Calculated as a cumulative rate over the 10-year period following ODS destruction.

Data / Parameter:	DR_{refr}
Data unit:	% expressed as number [0-100%]
Description:	Rate of ODS refrigerants (destroyed) which would be destroyed in the baseline
Source of data:	Default value given below or project-specific rate(s) sourced from officially published data, research studies, industry data, etc. In the absence of a government mandate, product stewardship scheme, or other program that creates an incentive or mechanism for ODS refrigerant destruction in the country(ies) where the project activity occurs, the default rate is 0%.
Description of measurement methods and procedures to be applied:	
Comments:	Calculated as a cumulative rate over the 10-year period following ODS destruction.

Data / Parameter:	$RR_{refr,i}$
Data unit:	% expressed as number [0-100%]
Description:	Rate of ODS refrigerant i (destroyed) which would be used, reused or remain in storage in the baseline

Source of data:	Default value(s) given below or project-specific rate(s) sourced from officially published data, research studies, industry data, etc. In non-Article 5 countries, it is conservatively assumed that all ODS refrigerant recovered from products is recycled or reclaimed for reuse. If in a stockpile, it is assumed that the ODS refrigerant is used to recharge existing equipment, or in the case of a government stockpile of ODS refrigerant that cannot legally be sold into the commercial refrigerant market, remains in storage. As such, the default rate is 100%. In Article 5 countries, the default rate is similarly 100% unless the project proponent demonstrates that all or a portion of the ODS refrigerant destroyed as part of the project was recovered from products at end-of-life. The portion of ODS refrigerant not recovered from products at end-of-life is assumed to be recycled or reclaimed, used in existing equipment and/or remain in storage (as in the case of a government stockpile of ODS refrigerant that cannot legally be sold into the commercial refrigerant market).
Description of measurement methods and procedures to be applied:	Maintain point of origin documentation to demonstrate the quantity of ODS refrigerant sourced from a government stockpile that cannot legally be sold into the commercial refrigerant market. In Article 5 countries, maintain point of origin documentation to demonstrate the quantity of ODS refrigerant not sourced from products at end-of-life.
Comments:	Calculated as a cumulative rate over the 10-year period following ODS destruction.

Data / Parameter:	$LR_{refr,i}$
Data unit:	% expressed as number [0-100%]
Description:	Leak rate of ODS refrigerant i (destroyed), which would be used as refrigerant for existing equipment or remain in storage in the baseline
Source of data:	Default value(s) given below or project-specific rate(s) sourced from officially published data, research studies, industry data, etc. In non-Article 5 countries, default values for ODS refrigerant used or reused in existing equipment are the annual weighted average emission rates given in the latest version of the Climate Action Reserve's *U.S. ODS Project Protocol*.

	In Article 5 countries, default values for ODS refrigerant used or reused in existing equipment are the applicable annual emission rates given in the latest version of the Climate Action Reserve's *Article 5 ODS Project Protocol*. In the case of government stockpiles of ODS refrigerant that cannot legally be sold into the commercial refrigerant market and therefore remain in storage in either non-Article 5 or Article 5 countries, the default rate is 10%[2].
Description of measurement methods and procedures to be applied:	
Comments:	

Data / Parameter:	$ER_{foam,i}$
Data unit:	% expressed as number [0-100%]
Description:	Rate by which ODS blowing agents contained in foam of refrigeration appliances would be released into atmosphere based on the disposal practice (baseline) in the respective host country
Source of data:	Depending on baseline scenario (BAF1-4). For BAF4.1-4.2 see scientific sources Appendix II to this methodology and/or default values provided by the latest version of the *Climate Action Reserve (CAR): U.S. Ozone Depleting Substances Project Protocol*. For baseline scenarios BAF4.3 and BAF4.4 officially published data, research studies or industry data shall be used.
Description of measurement methods and procedures to be applied:	
Comments:	

[2] United Nations Environment Programme. (2013). Report on Progress and Experiences gained in Demonstration Projects for the Disposal of Unwanted ODS, Annex III. Executive Committee of the Multilateral Fund. Document No. 7054, Bangkok. Available at: http://www.multilateralfund.org/70/English/1/7054.pdf

Data / Parameter:	$LR_{substitute,i}$
Data unit:	% expressed as number [0-100%]
Description:	Leak rate of substitute chemical I in year y [0-1]
Source of data:	For project activities taking place in Article 5 countries, the leak rate shall be obtained from either official published data, research, industry studies, or default values provided in the latest version of the *CAR Article 5 Ozone Depleting Substances Project Protocol*. For project activities taking place in Non Article 5 countries, officially published data, research studies, industry data, or default values from the latest version of the *CAR U.S. Ozone Depleting Substances Project Protocol* shall be used.
Description of measurement methods and procedures to be applied:	
Comments:	

Data / Parameter:	Substitute chemical i
Data unit:	
Description:	Chemical i substituting ODS refrigerant i where in the baseline refrigerant ODS would have been re-used and in the project scenario must be substituted by other chemicals
Source of data:	For project activities taking place in Article 5 countries, the project proponent shall apply a substitute chemical derived from either official published data, research, industry studies, or default values provided in the latest version of the *CAR Article 5 Ozone Depleting Substances Project Protocol*. For project activities taking place in Non-Article 5 countries, officially published data, research studies, industry data, or the latest version of the *CAR U.S. Ozone Depleting Substances Project Protocol* shall be used.
Description of measurement methods and procedures to be applied:	
Comments:	

Data / Parameter:	$M_{app,1,foam,i,y}$, $M_{app,2,foam,i,y}$, $M_{app,3,foam,i,y}$
Data unit:	t ODSi/appliance type 1, 2 and 2
Description:	Amount of blowing agent ODSi contained in foam of refrigeration appliance types 1-3 in host country • Type 1 appliances, Domestic fridges: These are refrigerators of a typical domestic design with a storage capacity of up to 180 litres. The appliances may or may not be equipped with a separate deep-freeze compartment. • Type 2 appliances, Domestic fridge-freezers: These are refrigeration appliances of a typical domestic design with a storage capacity ranging from 180 to 350 litres. Generally, these appliances have a separate deep-freeze compartment. • Type 3 appliances, Domestic chest freezers and upright freezers: These are deep-freeze appliances of a typical domestic design with a storage capacity up to 500 litres.
Source of data:	If official national values are available those national values shall be used. In cases where no such official values are available it shall be determined by RAL *RAL Quality Assurance and Test Specifications for the Demanufacture of Refrigeration Equipment*
Description of measurement methods and procedures to be applied:	
Comments:	

Data / Parameter:	$EF_{ODS\_Transport+Destruction,y}$
Data unit:	tCO_2
Description:	Default emission factor aggregating both transportation and destruction emissions
Source of data:	Provided by the latest version of the *CAR Article 5 Ozone Depleting Substances Project Protocol: (Calculating Default Project Emissions from ODS Destruction and Transportation)*
Description of measurement methods	

and procedures to be applied:	
Comments:	

9.2 Data and Parameters Monitored

Data / Parameter:	$M_{DESTR,refr,i,y}$
Data unit:	tODSi
Description:	Quantity of ODS refrigerant i destroyed by the project activity in year y
Source of data:	• Operation logbook of recovery facility • Identification note for each individual ODS container by a bill of lading • Certificate of Destruction for each individual ODS container (refer to Section 9.3 of this methodology "Monitoring Methodology")
Description of measurement methods and procedures to be applied:	Refer to Section 9.3 of this methodology "Monitoring Methodology"
Frequency of monitoring/recording:	Each container with ODS sent to destruction
QA/QC procedures to be applied:	All measurements should be conducted with calibrated measurement equipment according to relevant industry standards (refer to Section 9.3 of this methodology "Monitoring Methodology")
Comments:	

Data / Parameter:	$M_{DESTR,foam,i,y}$
Data unit:	tODSi
Description:	Quantity of ODS blowing agent i contained in insulation foams of refrigeration appliances destroyed by the project activity in year y
Source of data:	• Operation logbook of recovery facility • Identification note for each individual ODS container by a bill of lading

	• Certificate of Destruction for each individual ODS container (refer to Section 9.3 of this methodology “Monitoring Methodology”)
Description of measurement methods and procedures to be applied:	Refer to Section 9.3 of this methodology “Monitoring Methodology”
Frequency of monitoring/recording:	Each container with ODS sent to destruction
QA/QC procedures to be applied:	All measurements should be conducted with calibrated measurement equipment according to relevant industry standards (refer to section 9.3 of this methodology “Monitoring Methodology”)
Comments:	

Data / Parameter:	Input flow of appliances (and types) J, K, L into the section of the recovery facility where removal of foams and extraction of ODS blowing agents from foams takes place
Data unit:	Number of refrigeration appliances [Number] and mass unit [e.g. kg]
Description:	Documentation of all input flows into the section of the recovery facility where removal of foams and extraction of ODS from foams takes place according to appliance types (type 1 domestic fridges; type 2 domestic fridge-freezers; type 3 domestic chest freezers and upright freezers;) and by weight.
Source of data:	Operation logbook of recovery facility
Description of measurement methods and procedures to be applied:	Weight measured by calibrated weighing scales.
Frequency of monitoring/recording:	Continuous monitoring, recording monthly, once annually: Test of 1000 appliances
QA/QC procedures to be applied:	All measurements should be conducted with calibrated measurement equipment according to relevant industry standards
Comments:	

Data / Parameter:	Total weight of output fractions from the section of the recovery facility where removal of foams and extraction of ODS blowing agents from foams takes place (test procedure)
Data unit:	Mass unit [e.g. kg]
Description:	Documentation of output flows (type and weight) The following fractions shall be documented: • Polyurethane • Ferrous metals • Non-ferrous metals • Plastics • Non-ferrous/plastic fraction • Residual waste • Process water • ODS blowing agents • Other components
Source of data:	Operation logbook of the recovery facility
Description of measurement methods and procedures to be applied:	Weight measured by calibrated weighing scales.
Frequency of monitoring/recording:	Continuous monitoring, recording monthly, once annually: Test of 1000 appliances
QA/QC procedures to be applied:	All measurements should be conducted with calibrated measurement equipment according to relevant industry standards
Comments:	

Data / Parameter:	$CR_{ODSi,y}$
Data unit:	Number
Description:	Host country-level compliance rate of the law, statute or other regulatory framework in the year y in relation to ODSi. Calculation of the compliance rate shall exclude other projects implemented under GHG programs. If the compliance rate exceeds 50%, the project shall receive no further credit.
Source of data:	Officially published data, research studies, industry data etc…

Description of measurement methods and procedures to be applied:	
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	
Comments:	

Data / Parameter:	$FC_{i,j,y}$
Data unit:	Mass or volume unit per year (e.g. ton/y or m³/y)
Description:	Quantity of fuel type i combusted in process j
Source of data:	Onsite measurements
Description of measurement methods and procedures to be applied:	Use utility bills or invoices for purchased fuel, or alternatively, either mass or volume meters onsite. In cases where fuel is supplied from small daily tanks, rulers can be used to determine mass or volume of the fuel consumed, with the following conditions: The ruler gauge must be part of the daily tank and calibrated at least once a year and have a book of control for recording the measurements (on a daily basis or per shift); Accessories such as transducers, sonar and piezoelectronic devices are accepted if they are properly calibrated with the ruler gauge and receiving a reasonable maintenance; In case of daily tanks with pre-heaters for heavy oil, the calibration will be made with the system at typical operational conditions.
Frequency of monitoring/recording:	Continuously
QA/QC procedures to be applied:	If onsite measurements are used, the consistency of metered fuel consumption quantities should be cross-checked by an annual energy balance that is based on purchased quantities and stock changes. Where the purchased fuel invoices can be identified specifically for the project activity, the metered fuel consumption quantities should also be cross-checked with available purchase invoices from the financial records.
Comments:	

Data / Parameter:	$W_{C,i,y}$
Data unit:	ton C/mass unit of the fuel
Description:	Weighted average mass fraction of carbon in fuel type i in year y
Source of data:	The following data sources may be used if the relevant conditions apply: **Data source** — **Conditions for using the data source** a) Values provided by the fuel supplier in invoices — Where relevant information is available use option a) b) Measurements by the project proponent — If a) is not available
Description of measurement methods and procedures to be applied:	Measurements should be undertaken in line with national or international fuel standards.
Frequency of monitoring/recording:	The mass fraction of carbon should be obtained for each fuel delivery, from which weighted average annual values should be calculated.
QA/QC procedures to be applied:	Verify if the values under a) and b) are within the uncertainty range of the IPCC default values as provided in Table 1.2, Vol. 2 of the 2006 IPCC Guidelines. If the values fall below this range collect additional information from the testing laboratory to justify the outcome or conduct additional measurements. The laboratories in b) should have ISO17025 accreditation or justify that they can comply with similar quality standards.
Comments:	Applicable where option A is used

Data / Parameter:	$\rho_{i,y}$
Data unit:	Mass unit/volume unit
Description:	Weighted average density of fuel type i in year y
Source of data:	The following data sources may be used if the relevant conditions apply: **Data source** — **Conditions for using the data source** a) Values provided by the fuel supplier in invoices — Where relevant information is available use option a)

	b) Measurements by the project proponent — If a) is not available c) Regional or national default values — If a) is not available. These sources can only be used for liquid fuels and should be based on well documented, reliable sources (such as national energy balances).
Description of measurement methods and procedures to be applied:	Measurements should be undertaken in line with national or international fuel standards.
Frequency of monitoring/recording:	The density of the fuel should be obtained for each fuel delivery, from which weighted average annual values should be calculated.
QA/QC procedures to be applied:	
Comments:	Applicable where option A is used and where $FC_{i,j,y}$ is measured in a volume unit. Preferably the same data source should be used for $W_{C,i,y}$ and $\rho_{i,y}$.

Data source	Conditions for using the data source
b) Measurements by the project proponent	If a) is not available
c) Regional or national default values	If a) is not available These sources can only be used for liquid fuels and should be based on well documented, reliable sources (such as national energy balances).

Data / Parameter:	$NCV_{i,y}$
Data unit:	GJ per mass or volume unit (e.g. GJ/m³, GJ/ton)
Description:	Weighted average net calorific value of fuel type i in year y
Source of data:	The following data sources may be used if the relevant conditions apply:

Data source	Conditions for using the data source
a) Values provided by the fuel supplier in invoices	Where relevant information is available use option a)
b) Measurements by the project proponent	If a) is not available
c) Regional or national default values	If a) is not available. These sources can only be used for liquid fuels and should be based on well documented,

	<table><tr><td></td><td>reliable sources (such as national energy balances).</td></tr><tr><td>d) IPCC default values at the upper limit of the uncertainty at a 95% confidence interval as provided in Table 1.2 of Chapter 1 of Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories</td><td>If a) is not available</td></tr></table>
Description of measurement methods and procedures to be applied:	For a) and b): Measurements should be undertaken in line with national or international fuel standards
Frequency of monitoring/recording:	For a) and b): The NCV should be obtained for each fuel delivery, from which weighted average annual values should be calculated For c): Review appropriateness of the values annually For d): Any future revision of the IPCC Guidelines should be taken into account
QA/QC procedures to be applied:	Verify if the values under a), b) and c) are within the uncertainty range of the IPCC default values as provided in Table 1.2, Vol. 2 of the 2006 IPCC Guidelines. If the values fall below this range collect additional information from the testing laboratory to justify the outcome or conduct additional measurements. The laboratories in a), b) or c) should have ISO17025 accreditation or justify that they can comply with similar quality standards.
Comments:	Applicable where option B of this methodology is used

Data / Parameter:	$EF_{CO2,i,y}$
Data unit:	tCO_2/GJ
Description:	Weighted average CO_2 emission factor of fuel type i in year y
Source of data:	The following data sources may be used if the relevant conditions apply: <table><tr><td>**Data source**</td><td>**Conditions for using the data source**</td></tr><tr><td>a) Values provided by the fuel supplier in invoices</td><td>Where relevant information is available use option a).</td></tr></table>

	b) Measurements by the project proponents	If a) is not available
	c) Regional or national default values	If a) is not available These sources can only be used for liquid fuels and should be based on well documented, reliable sources (such as national energy balances).
	d) IPCC default values at the upper limit of the uncertainty at a 95% confidence interval as provided in table 1.4 of Chapter1 of Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories	If a) is not available
Description of measurement methods and procedures to be applied:	For a) and b): Measurements should be undertaken in line with national or international fuel standards.	
Frequency of monitoring/recording:	For a) and b): The CO_2 emission factor should be obtained for each fuel delivery, from which weighted average annual values should be calculated For c): Review appropriateness of the values per monitoring interval y For d): Any future revision of the IPCC Guidelines should be taken into account	
QA/QC procedures to be applied:		
Comments:	Applicable where option B is used. For a): If the fuel supplier does provide the NCV value and the CO_2 emission factor on the invoice and these two values are based on measurements for this specific fuel, this CO_2 factor should be used. If another source for the CO_2 emission factor is used or no CO_2 emission factor is provided, options b), c) or d) should be used	

Data / Parameter:	$EC_{PJ,y}$

Data unit:	MWh
Description:	Amount of electricity consumed at the ODS recovery facility from the grid during year y
Source of data:	Onsite measurements and recorded by a computer system and/or by printed journals; or, alternatively, utility bills or invoices for purchased electricity
Description of measurement methods and procedures to be applied:	Directly measured by calibrated electricity meter installed at the project site.
Frequency of monitoring/recording:	Continuously, aggregated at least annually
QA/QC procedures to be applied:	If onsite measurements are used, cross check measurement results with invoices for purchased electricity if relevant
Comments:	

Data / Parameter:	$EF_{grid,y}$
Data unit:	tons CO_2/MWh
Description:	Grid emission factor during the monitoring period y
Source of data:	Choose one of the following options: • Calculate the combined margin emission factor, using the procedures in the latest approved version of the CDM "Tool to calculate the emission factor for an electricity system"; Use a conservative default value of 1.3 tCO_2/MWh.
Description of measurement methods and procedures to be applied:	
Frequency of monitoring/recording:	
QA/QC procedures to be applied:	If the "Tool to calculate the emission factor for an electricity system" will be used the source and/or the calculation shall be available by printed journals.
Comments:	

Data / Parameter:	TDL_y
Data unit:	
Description:	Average technical transmission and distribution losses in the grid for the voltage level at which electricity is obtained from the grid at the project site during year y
Source of data:	Choose one of the following options: a) Use recent, accurate and reliable data available within the country; b) Use a default value of 20%
Description of measurement methods and procedures to be applied:	For a) TDL_y should be estimated for the distribution and transmission networks of the electricity grid of the same voltage as the connection where the proposed project activity is connected to. The technical distribution losses should not contain other types of grid losses (e.g. commercial losses/theft). The distribution losses can either be calculated by the project proponent or be based on references from utilities, network operators or other official documentation.
Frequency of monitoring/recording:	
QA/QC procedures to be applied:	In the absence of data from the relevant year, most recent figures should be used, but not older than 5 years.
Comments:	

9.3 Description of the Monitoring Plan[3]

Composition and Quantity Analysis Requirements

The requirements of this section must be followed to determine the quantities of both ODS refrigerants and ODS blowing agents. Prior to destruction, the precise mass and composition of ODS to be destroyed must be determined. The following analysis must be conducted:

Mass shall be determined by individually measuring the weight of each container of ODS:

1. When it is full prior to destruction; and

[3] This section is mainly based on Climate Action Reserve (CAR): U.S. Ozone Depleting Substances Project Protocol Version 2 February 27 2012 and on RAL Quality Assurance and Test Specifications for the Demanufacture of Refrigeration Equipment version: 2007/09

2. After it has been emptied and the contents have been fully purged and destroyed. The mass of ODS and any contaminants is equal to the difference between the full and empty weight, as measured

The following requirements must be met when weighing the containers of ODS:

1. A single scale must be used for generating both the full and empty weight tickets at the destruction facility
2. Weighing instruments must comply with the relevant national requirements and/or international standards – such as EC Directive 2009/23/EC or International Organization for Legal Metrology OIML R 76-1 – and be subject to regular calibration, as set out in the relevant national requirements and/or international standards to accuracy appropriate to its accuracy class. These instruments shall have a measuring range corresponding to the capacity of containers and tanks weighed. If a scale is found to be out of tolerance, it must be recalibrated.
3. The full weight must be measured no more than two days prior to commencement of destruction per the Certificate of Destruction
4. The empty weight must be measured no more than two days after the conclusion of destruction per the Certificate of Destruction

Composition and concentration of ODS shall be established for each individual container by taking a sample from each container of ODS and having it analyzed for composition and concentration at a lab accredited to perform analyses in compliance with the applicable International Organization for Standardization (ISO) standard or equivalent standards. Further, where national standards exist they may be used in lieu of ISO standards provided that they have been the subject of a verification or validation process addressing their accuracy and representativeness. In the case where no such standards exist, the US Air-Conditioning, Heating and Refrigeration Institute *700-2006* standard shall be applied.

The laboratory performing the composition analysis must not be affiliated with the project proponent or the project activities beyond performing these services.

The following requirements must be met for each sample:

1. The sample must be taken while ODS is in the possession of the company that will destroy the ODS
2. Samples must be taken by a technician unaffiliated with the project developer
3. Samples must be taken with a clean, fully evacuated sample bottle that meets applicable U.S. DOT requirements or an equivalent national (host country) or ISO standard
4. The technician must ensure that the sample is representative of the contents of the container

5. Each sample must be taken in liquid state
6. A minimum sample size of 0.453592 kg (1 pound) must be drawn for each sample
7. Each sample must be individually labeled and tracked according to the container from which it was taken, and the following information recorded:
    - Time and date of sample
    - Name of project developer
    - Name of technician taking sample
    - Employer of technician taking sample
    - Volume of container from which sample was extracted
    - Ambient air temperature at time of sampling
8. Chain of custody for each sample from the point of sampling lab must be documented by paper bills of lading or electronic, third-party tracking that includes proof of delivery

All project samples shall be analyzed using the International Organization for Standardization (ISO) standard applicable. Further, where national standards exist they may be used in lieu of ISO standards provided that they have been the subject of a verification or validation process addressing their accuracy and representativeness. In the case where no such standards exist, the US Air-Conditioning, Heating and Refrigeration Institute *700-2006* standard shall be applied. The analysis shall provide:

1. Identification of the refrigerant
2. Purity (%) of the ODS mixture by weight using gas chromatography
3. Moisture level in parts per million. The moisture content of each sample must be less than 75% of the saturation point for the ODS based on the temperature recorded at the time the sample was taken. For containers that hold mixed ODS, the sample's saturation point shall be assumed to be that of the ODS species in the mixture with the lowest saturation point that is at least 10 percent of the mixture by mass.
4. Analysis of high boiling residue, which must be less than 10% by mass
5. Analysis of other ODS in the case of mixtures of ODS, and their percentage by mass

If any of the requirements above are not met, no GHG reductions may be verified for ODS destruction associated with that container. If a sample is tested and does not meet one of the requirements as defined above, the project proponent may elect to have the material re-sampled and re-analyzed. The project proponent may sample for moisture content and perform any necessary de-watering prior to the required sampling and laboratory analysis.

If the container holds non-mixed ODS (defined as greater than 90% composition of a single ODS species) no further information or sampling is required to determine the mass and composition of the ODS. If the container holds mixed ODS, which is defined as less than 90% composition of a single ODS species, the project proponent must meet additional requirements as provided below.

Composition and Quantity Analysis Requirements for Mixed ODS

If a container holds mixed ODS, its contents must also be processed and measured for composition and concentration according to the requirements of this section. The sampling required under this section may be conducted at the final destruction facility or prior to delivery to the destruction facility. However, the circulation and sampling activities must be conducted by a third-party organization (i.e., not the project proponent), and by individuals who have been properly trained for the functions they perform. Circulation and sampling may be conducted at the project proponent's facility, but all activities must be directed by a properly trained and contracted third-party. The project description must specify the procedures by which mixed ODS are analyzed.

The composition and concentration of ODS on a mass basis must be determined using the results of the analysis of this section for each container. The results of the composition analysis in the section above shall be used by verifiers to confirm that the destroyed ODS is in fact the same ODS that is sampled under these requirements. Prior to sampling, the ODS mixture must be circulated in a container that meets all of the following criteria:

1. The container has no solid interior obstructions[4]
2. The container was fully evacuated prior to filling
3. The container must have sampling ports to sample liquid and gas phase ODS
4. The liquid port intake must be at the bottom of the container, and the vapor port intake must be at the top of the container. For horizontally-oriented mixing containers, the intakes must be located in the middle third of the container
5. The container and associated equipment can circulate the mixture via a closed loop system from the bottom to top

If the original mixed ODS container does not meet these requirements, the mixed ODS must be transferred into a temporary holding tank or container that meets all of the above criteria. The weight of the contents placed into the temporary container shall be calculated and recorded. During transfer of ODS into and out of the temporary container, ODS shall be recovered to the vacuum levels required by the U.S. EPA for that ODS (see 40 CFR 82.156) or any national (host country) or ISO standard.

[4] Mesh baffles or other interior structures that do not impede the flow of ODS are acceptable.

Once the mixed ODS is in a container or temporary storage unit that meets the criteria above, circulation of mixed ODS must be conducted as follows:

1. Liquid mixture shall be circulated from the liquid port to the vapor port.
2. A volume of the mixture equal to two times the volume in the container shall be circulated
3. Circulation must occur at a rate of at least 113.6l/minute
4. Start and end times shall be recorded

Within 30 minutes of the completion of circulation, a minimum of two samples shall be taken from the bottom liquid port and analyzed according to the procedures above. The mass composition and concentration of the mixed ODS shall be equal to the lesser of the two GWP-weighted concentrations.

Determination of Recovery Efficiency of Blowing Agents Contained in Foam of Refrigeration Appliances

An annual test shall be conducted in which at least 1000 refrigeration appliances with ODS containing insulation materials are processed at the recovery facility of the project proponent.

Every appliance used in the test shall be intact, i.e. there shall be no damage to the appliance carcass and the doors typical of that appliance type shall still be attached. No other doors, appliance components or other products containing foam insulation shall be processed during the test. Systematically sorting out refrigeration appliances from the mass flow of incoming devices for the purpose of manipulating the quantity of recovered ODS is strictly forbidden.

To compile a mass balance analysis, the total weight of all the appliances used in the test shall be determined and recorded. In addition, the weight of all material fractions recovered from the processing plant during the test shall be determined.

- Polyurethane
- Ferrous metals
- Non-ferrous metals
- Plastics
- Non-ferrous/plastic fraction
- Residual waste
- Process water
- ODS
- Other components

The gas cylinders used to store the recovered ODS are weighed when empty (i.e. before processing commences) and again when filled (i.e. after processing has been completed). The dry weight in kilograms of ODS recovered is divided by the number of appliances processed. The result is recorded as the quantity of ODS recovered in grams per appliance.

The quantities of ODS blowing agents to be recovered for each appliance type (domestic fridge, domestic fridge-freezers, domestic chest freezers and upright freezers) as specified in Section 3, “Definitions” shall be sourced from official national values. In cases where no such official values are available it shall be determined by RAL *RAL Quality Assurance and Test Specifications for the Demanufacture of Refrigeration Equipment*. The recovery facility must achieve a recovery efficiency of at least 90% otherwise no credits can be generated for the respective monitoring period.

The RAL test protocol shall be used for the annual test.

Since this methodology requires the extraction of ODS from the foam to a concentrated form prior to destruction the overall Recovery and Destruction Efficiency will be achieved when the destruction facility meets the requirements of *UNEP Technology and Economic Assessment Panel (TEAP) Report of the Task Force on Destruction Technologies*, UNEP, 2002. A minimum Recovery and Destruction Efficiency (RDE) of 85% shall be achieved otherwise no credits can be generated for the respective monitoring period.

Destruction Facility Requirements

Destruction of ODS must occur at a facility that has a valid host country permit for ODS destruction and meets the screening criteria for destruction technologies set out in the report, as may be updated from time to time, by the UNEP Technology and Economic Assessment Panel (TEAP) Task Force on Destruction Technologies (reproduced in full in Appendix III from TEAP *Report of the Task Force on Destruction Technologies*, Chapter 2 (2002)).

Operating parameters of the destruction unit while destroying ODS material shall be monitored and recorded as described in the Code of Good Housekeeping[5] (as reproduced in full in Appendix II) approved by the Montreal Protocol.

10 REFERENCES

Scheutz, C. et al. (2007a) Release of fluorocarbons from insulation foam in home appliances during shredding. J of the Air & Waste Mgmt Assn, 57: 1452-1460

[5] TEAP, Code of Good Housekeeping in *Handbook for the Montreal Protocol on Substances that Deplete the Ozone Layer - 7th Edition* (2006)

Scheutz, C., et al. (2007b) Attenuation of insulation foam released fluorocarbons in landfills. Environ Sci & Tech., 41:7714-7722)

Fredenslund, A. et al. (2005) Disposal of Refrigerators-Freezers in the U.S.: State of the Practice. Technical University of Denmark

TEAP, Code of Good Housekeeping in *Handbook for the Montreal Protocol on Substances that Deplete the Ozone Layer - 7th Edition* (2006)

UNEP Technology and Economic Assessment Panel (TEAP) Report of the Task Force on Destruction Technologies, UNEP, 2002. Available at: http://ozone.unep.org/teap/Reports/Other_Task_Force/TEAP02V3b.pdf

APPENDIX I: ODS (ANNEX I, GROUPS) AND THEIR GWP

Substance terms and ODP (Ozone-Depleting Potential) values and based on The Montreal Protocol on Substances that Deplete the Ozone Layer http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/27571

GWP (Global warming potential) values based on the IPCC Fourth assessment report 2007 - Working group I report "The physical science basis of climate change" - Chapter 2 "Changes in Atmospheric Constituents and in Radiative Forcing" table 2.14/page 212 http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf

Annex A: Controlled substances – Group I			
Substance		**ODP** Ozone-Depleting Potential	**GWP** Global warming potential for 100 year Kyoto time horizon
CFCl3	CFC-11	1.0	4750
CF2Cl2	CFC-12	1.0	10900
C2F3Cl3	CFC-113	0.8	6130
C2F4Cl2	CFC-114	1.0	10000
C2F5Cl	CFC-115	0.6	7370

Annex B: Controlled substances – Group I			
Substance		**ODP** Ozone-Depleting Potential	**GWP** Global warming potential for 100 year Kyoto time horizon
CF3Cl	CFC-13	1.0	14400
C2FCl5	CFC-111	1.0	n.a.
C2F2Cl4	CFC-112	1.0	n.a.
C3FCl7	CFC-211	1.0	n.a.
C3F2Cl6	CFC-212	1.0	n.a.
C3F3Cl5	CFC-213	1.0	n.a.
C3F4Cl4	CFC-214	1.0	n.a.
C3F5Cl3	CFC-215	1.0	n.a.

C3F6Cl2	CFC-216	1.0	n.a.
C3F7Cl	CFC-217	1.0	n.a.

Annex C: Controlled substances – Group I			
Substance		**ODP** Ozone-Depleting Potential	**GWP** Global warming potential for 100 year Kyoto time horizon
CHFCl2	HCFC-21**	0.04	
CHF2Cl	HCFC-22**	0.055	1810
CH2FCl	HCFC-31	0.02	n.a.
C2HFCl4	HCFC-121	0.01-0.04	n.a.
C2HF2Cl3	HCFC-122	0.02-0.08	n.a.
C2HF3Cl2	HCFC-123	0.02-0.06	n.a.
CHCl2CF3	HCFC-123**	0.02	77
C2HF4Cl	HCFC-124	0.02-0.04	n.a.
CHFClCF3	HCFC-124**	0.022	609
C2H2FCl3	HCFC-131	0.007-0.05	n.a.
C2H2F2Cl2	HCFC-132	0.008-0.05	n.a.
C2H2F3Cl	HCFC-133	0.02-0.06	n.a.
C2H3FCl2	HCFC-141	0.005-0.07	n.a.
CH3CFCl2	HCFC-141b**	0.11	725
C2H3F2Cl	HCFC-142	0.008-0.07	n.a.
CH3CF2Cl	HCFC-142b**	0.065	2310
C2H4FCl	HCFC-151	0.003-0.005	n.a.
C3HFCl6	HCFC-221	0.015-0.07	n.a.
C3HF2Cl5	HCFC-222	0.01-0.09	n.a.
C3HF3Cl4	HCFC-223	0.01-0.08	n.a.
C3HF4Cl3	HCFC-224	0.01-0.09	n.a.
C3HF5Cl2	HCFC-225	0.02-0.07	n.a.
CF3CF2CHCl2	HCFC-225ca**	0.025	122

CF2ClCF2CHClF	HCFC-225cb**	0.033	595
C3HF6Cl	HCFC-226	0.02-0.10	n.a.
C3H2FCl5	HCFC-231	0.05-0.09	n.a.
C3H2F2Cl4	HCFC-232	0.008-0.10	n.a.
C3H2F3Cl3	HCFC-233	0.007-0.23	n.a.
C3H2F4Cl2	HCFC-234	0.01-0.28	n.a.
C3H2F5Cl	HCFC-235	0.03-0.52	n.a.
C3H3FCl4	HCFC-241	0.004-0.09	n.a.
C3H3F2Cl3	HCFC-242	0.005-0.13	n.a.
C3H3F3Cl2	HCFC-243	0.007-0.12	n.a.
C3H3F4Cl	HCFC-244	0.009-0.14	n.a.
C3H4FCl3	HCFC-251	0.001-0.01	n.a.
C3H4F2Cl2	HCFC-252	0.005-0.04	n.a.
C3H4F3Cl	HCFC-253	0.003-0.03	n.a.
C3H5FCl2	HCFC-261	0.002-0.02	n.a.
C3H5F2Cl	HCFC-262	0.002-0.02	n.a.
C3H6FCl	HCFC-271	0.001-0.03	n.a.

** Identifies the most commercially viable substances with ODP values listed against them to be used for the purposes of the Montreal Protocol.

APPENDIX II: CODE OF GOOD HOUSEKEEPING[6]

To provide additional guidance to facility operators, in May 1992 the Technical Advisory Committee prepared a "Code of Good Housekeeping" as a brief outline of measures that should be considered to ensure that environmental releases of ozone-depleting substances (ODS) through all media are minimized. This Code, updated by the Task Force on Destruction Technologies and amended by the Parties at their Fifteenth Meeting, in 2003, is also intended to provide a framework of practices and measures that should normally be adopted at facilities undertaking the destruction of ODS.

Not all measures will be appropriate to all situations and circumstances and, as with any code, nothing specified should be regarded as a barrier to the adoption of better or more effective measures if these can be identified.

Pre-delivery

This refers to measures that may be appropriate prior to any delivery of ODS to a facility.

The facility operator should generate written guidelines on ODS packaging and containment criteria, together with labelling and transportation requirements. These guidelines should be provided to all suppliers and senders of ODS prior to agreement to accept such substances.

The facility operator should seek to visit and inspect the proposed sender's stocks and arrangements prior to movement of the first consignment. This is to ensure awareness on the part of the sender of proper practices and compliance with standards.

Arrival at the facility

This refers to measures that should be taken at the time ODS are received at the facility gate. These include an immediate check of documentation prior to admittance to the facility site, coupled with a preliminary inspection of the general condition of the consignment. Where necessary, special or "fast-track" processing and repackaging facilities may be needed to mitigate risk of leakage or loss of ODS. Arrangements should exist to measure the gross weight of the consignment at the time of delivery.

Unloading from delivery vehicle

This refers to measures to be taken at the facility in connection with the unloading of ODS. It is generally assumed that ODS will normally be delivered in some form of container, drum or other vessel that is removed from the delivery vehicle in total. Such containers may be returnable.

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[6] Reproduced in full from: TEAP, Code of Good Housekeeping in *Handbook for the Montreal Protocol on Substances that Deplete the Ozone Layer - 7th Edition* (2006)

All unloading activities should be carried out in properly designated areas, to which restricted access of personnel applies. Areas should be free of extraneous activities likely to lead to, or increase the risk of, collision, accidental dropping, spillage, etc. Materials should be placed in designated quarantine areas for subsequent detailed checking and evaluation.

Testing and verification

This refers to the arrangements made for detailed checking of the ODS consignments prior to destruction.

Detailed checking of delivery documentation should be carried out, along with a complete inventory, to establish that delivery is as advised and appears to comply with expectations.

Detailed checks of containers should be made both in respect of accuracy of identification labels, etc, and of physical condition and integrity. Arrangements must be in place to permit repackaging or “fast-track” processing of any items identified as defective. Sampling and analysis of representative quantities of ODS consignments should be carried out to verify material type and characteristics. All sampling and analysis should be conducted using approved procedures and techniques.

Storage and stock control

This refers to matters concerning the storage and stock control of ODS.

ODS materials should be stored in specially designated areas, subject to the regulations of the relevant local authorities. Arrangements should be put in place as soon as possible to minimize, to the extent practicable, stock emissions prior to destruction.

Locations of stock items should be identified through a system of control that should also provide a continuous update of quantities and locations as stock is destroyed and new stock delivered. In regard to storage vessels for concentrated sources of ODS, these arrangements should include a system for regular monitoring and leak detection, as well as arrangements to permit repackaging of leaking stock as soon as possible.

Measuring quantities destroyed

It is important to be aware of the quantities of ODS processed through the destruction equipment. Where possible, flow meters or continuously recording weighing equipment for individual containers should be employed. As a minimum, containers should be weighed “full” and “empty” to establish quantities by difference.

Residual quantities of ODS in containers that can be sealed and are intended to be returned for further use, may be allowed. Otherwise, containers should be purged of residues or destroyed as part of the process.

Facility design

This refers to basic features and requirements of plant, equipment and services deployed in the facility.

In general, any destruction facility should be properly designed and constructed in accordance with the best standards of engineering and technology and with particular regard to the need to minimize, if not eliminate, fugitive losses.

Particular care should be taken when designing plants to deal with dilute sources such as foams. These may be contained in refrigeration cabinets or may be part of more general demolition waste. The area in which foam is first separated from other substrates should be fully enclosed wherever possible and any significant emissions captured at that stage.

Pumps: Magnetic drive, sealers or double mechanical seal pumps should be installed to eliminate environmental releases resulting from seal leakage.

Valves: Valves with reduced leakage potential should be used. These include quarter-turn valves or valves with extended packing glands.

Tank vents (including loading vents): Filling and breathing discharges from tanks and vessels should be recovered or vented to a destruction process.

Piping joints: Screwed connections should not be used and the number of flanged joints should be kept to the minimum that is consistent with safety and the ability to dismantle for maintenance and repair.

Drainage systems: Areas of the facility where ODS are stored or handled should be provided with sloped concrete paving and a properly designed collection system. Water that is collected should, if contaminated, be treated prior to authorized discharge.

Maintenance

In general, all maintenance work should be performed according to properly planned programmes and should be executed within the framework of a permit system to ensure proper consideration of all aspects of the work.

ODS should be purged from all vessels, mechanical units and pipework prior to the opening of these items to the atmosphere. The contaminated purge should be routed to the destruction process or treated to recover the ODS.

All flanges, seals, gaskets and other sources of minor losses should be checked routinely to identify developing problems before containment is lost. Leaks should be repaired as soon as possible.

Consumable or short-life items, such as flexible hoses and couplings, must be monitored closely and replaced at a frequency that renders the risk of rupture negligible.

Quality control and quality assurance

All sampling and analytical work connected with ODS, the process and the monitoring of its overall performance should be subject to quality assessment and quality control measures in line with current recognized practices. This should include at least occasional independent verification and confirmation of data produced by the facility operators.

Consideration should also be given to the adoption of quality management systems and environment quality practices covering the entire facility.

Training

All personnel concerned with the operation of the facility (with “operation” being interpreted in its widest sense) should have training appropriate to their task. Of particular relevance to the ODS destruction objectives is training in the consequences of unnecessary losses and in the use, handling and maintenance of all equipment in the facility. All training should be carried out by suitably qualified and experienced personnel and the details of such training should be maintained in written records. Refresher training should be conducted at appropriate intervals.

Code of transportation

In the interest of protecting the stratospheric ozone layer, it is essential that used ODS and products containing ODS are collected and moved efficiently to facilities practising approved destruction technologies. For transportation purposes, used ODS should receive the same hazard classification as the original substances or products. In practice, this may introduce restrictions on hazardous waste shipment under the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal and this should be consulted separately. In the absence of such specific restrictions, the following proposed code of transportation for ODS from customer to destruction facilities is provided as a guide to help minimize damage caused to the ozone layer as a result of ODS transfers. Additional guidance is contained in the United Nations Transport of Dangerous Goods Model Regulations.

It is important to supervise and control all shipments of used ODS and products containing ODS according to national and international requirements to protect the environment and human health. To ensure that ODS and products containing ODS do not constitute an unnecessary risk, they must be properly packaged and labelled. Instructions to be followed in the event of danger or accident must accompany each shipment to protect human beings and the environment from any danger that might arise during the operation.

Notification of the following information should be provided at any intermediate stage of the shipment from the place of dispatch until its final destination. When making notification, the notifier should supply the information requested on the consignment note, with particular regard to:

a. The source and composition of the ODS and products containing ODS, including the customer’s identity;

b. Arrangements for routing and for insurance against damage to third parties;

c. Measures to be taken to ensure safe transport and, in particular, compliance by the carrier with the conditions laid down for transport by the States concerned;

d. The identity of the consignee, who should possess an authorized centre with adequate technical capacity for the destruction;

e. The existence of a contractual agreement with the consignee concerning the destruction of ODS and products containing ODS.

This code of transportation does not necessarily apply to the disposal of ODS-containing rigid insulation foams. The most appropriate way to dispose of such products may be by direct incineration in municipal waste incinerators or rotary kiln incinerators.

Monitoring

The objectives of monitoring should be to provide assurance that input materials are being destroyed with an acceptable efficiency generally consistent with the destruction and removal efficiency (DRE) recommendations listed in annex II to the present report and that the substances resulting from destruction yield environmentally acceptable emission levels consistent with, or better than, those required under national standards or other international protocols or treaties.

As there are as yet no International Organization for Standardization (ISO) standards applicable for the sampling and analysis of ODS or the majority of the other pollutants listed in annex IV to the present report, where national standards exist they should be employed. Further, where national standards exist they may be used in lieu of ISO standards provided that they have been the subject of a verification or validation process addressing their accuracy and representativeness.

As ISO develops international standards for pollutants listed in annex IV to the present report, the technical bodies charged with developing such standards should take note of the existing national standards including those identified in appendix F to the report of the Technology and Economic Assessment Panel (TEAP) of April 2002 (volume 3, report of the Task Force on Destruction Technologies) and strive to ensure consistency between any new ISO standards and the existing standard test methods, provided that there is no finding that those existing methods are inaccurate or unrepresentative.

Where national standards do not exist, the Technical Advisory Committee recommends adoption of the following guidelines for monitoring of destruction processes operating using an approved technology.

Recognizing that the Unites States of America Environmental Protection Agency (EPA) methods have been the subject of verification procedures to ensure that they are reasonably accurate and representative, that they cover all of the pollutants of interest (although not all ODS compounds have been the specific subject of verification activities), that they provide a comprehensive level of detail that should lead to replicability of the methods by trained personnel in other jurisdictions and that they are readily available for reference and downloading from the Internet without the payment of a fee, applicable EPA methods as described in appendix F to the 2002 report of TEAP may be employed.

In the interest of ensuring a common international basis of comparison for those pollutants or parameters where ISO standards exist (currently particulates, carbon monoxide, carbon dioxide and oxygen), use of those standards is encouraged and jurisdictions are encouraged to adopt them as national standards or acceptable alternatives to existing national standards.

The use of EPA or other national standards described in appendix F is also considered acceptable, however. The precedence given to the EPA methods in the present code is based on the relative comprehensiveness of the methods available (both in scope and content), and the relative ease of access to those methods.

Measurement of ODS

Operators of destruction facilities should take all necessary precautions concerning the storage and inventory control of ODS-containing material received for destruction. Prior to feeding the ODS to the approved destruction process, the following procedures are recommended:

a. The mass of the ODS-containing material should be determined, where practicable;

b. Representative samples should be taken, where appropriate, to verify that the concentration of ODS matches the description given on the delivery documentation;

c. Samples should be analysed by an approved method. If no approved methods are available, the adoption of United States EPA methods 5030 and 8240 is recommended;

d. All records from these mass and ODS-concentration measurements should be documented and kept in accordance with ISO 9000 or equivalent.

Control systems

Operators should ensure that destruction processes are operated efficiently to ensure complete destruction of ODS to the extent that it is technically feasible for the approved process. This will normally include the use of appropriate measurement devices and sampling techniques to monitor the operating parameters, burn conditions and mass concentrations of the pollutants that are generated by the process.

Gaseous emissions from the process need to be monitored and analysed using appropriate instrumentation. This should be supplemented by regular spot checks using manual stack-sampling methods. Other environmental releases, such as liquid effluents and solid residues, require laboratory analysis on a regular basis.

The continuous monitoring recommended for ongoing process control, including off-gas cleaning systems, is as follows:

a. Measurement of appropriate reaction and process temperatures;

b. Measurement of flue gas temperatures before and after the gas cleaning system;

c. Measurement of flue gas concentrations for oxygen and carbon monoxide.

Any additional continuous monitoring requirements are subject to the national regulatory authority that has jurisdiction. The performance of online monitors and instrumentation systems must be periodically checked and validated. When measuring detection limits, error values at the 95 per cent confidence level should not exceed 20 per cent.

Approved processes must be equipped with automatic cut-off control systems on the ODS feed system, or be able to go into standby mode whenever:

a. The temperature in the reaction chamber falls below the minimum temperature required to achieve destruction;

b. Other minimum destruction conditions stated in the performance specifications cannot be maintained.

Performance measurements

The approval of technologies recommended by TEAP is based on the destruction capability of the technology in question. It is recognized that the parameters may fluctuate during day-to-day operation from this generic capability. In practice, however, it is not possible to measure against performance criteria on a daily basis. This is particularly the case for situations where ODS only represents a small fraction of the substances being destroyed, thereby requiring specialist equipment to achieve detection of the very low concentrations present in the stack gas. It is therefore not uncommon for validation processes to take place annually at a given facility.

With this in mind, TEAP is aware that the measured performance of a facility may not always meet the criteria established for the technology. Nonetheless, TEAP sees no justification for reducing the minimum recommendations for a given technology. Regulators, however, may need to take these practical variations into account when setting minimum standards.

The ODS destruction and removal efficiency[7] for a facility operating an approved technology should be validated at least once every three years. The validation process should also include an assessment of other relevant stack gas concentrations identified in annex II to decision XV/[…] and a comparison with maximum levels stipulated in relevant national standards or international protocols/treaties.

Determination of the ODS destruction and removal efficiency and other relevant substances identified in annex IV to the present report should also be followed when commissioning a new or rebuilt facility or

[7] Destruction and removal efficiency has traditionally been determined by subtracting from the mass of a chemical fed into a destruction system during a specific period of time the mass of that chemical alone that is released in stack gases and expressing that difference as a percentage of the mass of that chemical fed into the system

when any other significant change is made to the destruction procedures in a facility to ensure that all facility characteristics are completely documented and assessed against the approved technology criteria.

Tests shall be done with known feed rates of a given ODS compound or with well-known ODS mixtures. In cases where a destruction process incinerates halogen-containing wastes together with ODS, the total halogen load should be calculated and controlled. The number and duration of test runs should be carefully selected to reflect the characteristics of the technology.

In summary, the destruction and removal efficiency recommended for concentrated sources means that less than 0.1 gram of total ODS should normally enter the environment from stack-gas emissions when 1,000 grams of ODS are fed into the process. A detailed analysis of stack test results should be made available to verify emissions of halogen acids and polychlorinated dibenzodioxin and dibenzofuran (PCDD/PCDF). In addition, a site-specific test protocol should be prepared and made available for inspection by the appropriate regulatory authorities. The sampling protocol shall report the following data from each test:

a. ODS feed rate;
b. Total halogen load in the waste stream;
c. Residence time for ODS in the reaction zone;
d. Oxygen content in flue gas;
e. Gas temperature in the reaction zone;
f. Flue gas and effluent flow rate;
g. Carbon monoxide in flue gas;
h. ODS content in flue gas;
i. Effluent volumes and quantities of solid residues discharged;
j. ODS concentrations in the effluent and solid residues;
k. Concentration of PCDD/PCDF, particulates, HCl, HF and HBr in the flue gases;
l. Concentration of PCDD/PCDF in effluent and solids.

APPENDIX III: TECHNOLOGY SCREENING PROCESS[8]

Criteria for Technology Screening

The following screening criteria were developed by the UNEP TFDT. Technologies for use by the signatories to the Montreal Protocol to dispose of surplus inventories of ODS were assessed on the basis of:

1. Destruction and Removal Efficiency (DRE)
2. Emissions of dioxins/furans
3. Emissions of other pollutants (acid gases, particulate matter, & carbon monoxide)
4. Technical capability

The first three refer to technical performance criteria selected as measures of potential impacts of the technology on human health and the environment. The technical capability criterion indicates the extent to which the technology has been demonstrated to be able to dispose of ODS (or a comparable recalcitrant halogenated organic substance such as PCB) effectively and on a commercial scale.

For convenience, the technical performance criteria are summarized in Table 3-1. These represent the minimum destruction and removal efficiencies and maximum emission of pollutants to the atmosphere permitted by technologies that qualify for consideration by the TFDT for recommendation to the Parties of the Montreal Protocol for approval as ODS destruction technologies. The technologies must also satisfy the criteria for technical capability as defined below.

Table 3-1: Summary of Technical Performance Qualifications[9]

Performance Qualification	Units	Diluted Sources	Concentrated Sources
DRE	%	95	99.99
PCDDs/PCDFs	ng-ITEQ/NM^3	0.5	0.2
HCL/CL_2	mg/NM^3	100	100

[8] Reproduced in full from: *UNEP Technology and Economic Assessment Panel (TEAP) Report of the Task Force on Destruction Technologies*, UNEP, 2002. Available at: http://ozone.unep.org/teap/Reports/Other_Task_Force/TEAP02V3b.pdf

[9] All concentrations of pollutants in stack gases and stack gas flow rates are expressed on the basis of dry gas at normal conditions of 0ºC and 101.3 kPa, and with the stack gas corrected to 11% O2.

HF	mg/NM^3	5	5
HBr/Br_2	mg/NM^3	5	5
Particulates	mg/NM^3	50	50
CO	mg/NM^3	100	100

Destruction and Removal Efficiency

Destruction Efficiency (DE)[10] is a measure of how completely a particular technology destroys a contaminant of interest – in this case the transformation of ODS material into non-ODS by-products. There are two commonly used but different ways of measuring the extent of destruction – DE and Destruction and Removal Efficiency (DRE)[11]. For a more detailed explanation of how DRE is calculated, see section 4.2.1. The terms are sometimes interchanged or used inappropriately. DE is a more comprehensive measure of destruction than DRE, because DE considers the amount of the chemical of interest that escapes destruction by being removed from the process in the stack gases and in all other residue streams. Most references citing performance of ODS destruction processes only provide data for stack emissions and thus, generally, data is only available for DRE and not DE.

Because of the relatively volatile nature of ODS and because, with the exception of foams, they are generally introduced as relatively clean fluids, one would not expect a very significant difference between DRE and DE. For these reasons this update of ODS destruction technologies uses DRE as the measure of destruction efficiency. For the purposes of screening destruction technologies, the minimum acceptable DRE is:

- 95% for foams; and,
- 99.99% for concentrated sources.

It should be noted that measurements of the by-products of destruction of CFCs, HCFCs and halons in a plasma destruction process have indicated that interconversion of ODS can occur during the process. For example, under some conditions, the DRE of CFC-12 (CCl_2F_2) was measured as 99.9998%, but this was accompanied by a conversion of 25% of the input CFC-12 to CFC-13 ($CClF_3$), which has the same

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[10] Destruction Efficiency (DE) is determined by subtracting from the mass of a chemical fed into a destruction system during a specific period of time the mass of that chemical that is released in stack gases, fly ash, scrubber water, bottom ash, and any other system residues and
expressing that difference as a percentage of the mass of the chemical fed into the system.
[11] Destruction and Removal Efficiency (DRE) has traditionally been determined by subtracting from the mass of a chemical fed into a destruction system during a specific period of time the mass of that chemical alone that is released in stack gases, and expressing that difference as a percentage of the mass of that chemical fed into the system.

ozone-depleting potential. The interconversion is less severe when hydrogen is present in the process, but can nonetheless be significant.[12] For this reason, it is important to take into account all types of ODS in the stack gas in defining the DRE.

For the reasons described in the previous paragraph, the Task Force recommends that future calculations of DRE use the approach described below[13].

DRE of an ODS should be determined by subtracting from the number of moles of the ODS fed into a destruction system during a specific period of time, the total number of moles of all types of ODS that are released in stack gases, and expressing that difference as a percentage of the number of moles of the ODS fed into the system.

In mathematical terms, $DRE = \frac{N_I^{in} - \sum_i N_i^{out}}{N_I^{in}}$ where N_I^{in} is the number of moles of the ODS fed into the destruction system and N_i^{out} is the number of moles of the *i*th type of ODS that is released in the stack gases.

Emissions of Dioxins and Furans

Any high temperature process used to destroy ODS has associated with it the potential formation (as by-products) of polychlorinated dibenzo-paradioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). These substances are among the products of incomplete combustion (or PICs) of greatest concern for potential adverse effects on public health and the environment. The internationally recognized measure of the toxicity of these compounds is the toxic equivalency factor (ITEQ),[14] which is a weighted measure of

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[12] R. T. Deam, A. R. Dayal, T. McAllister, A. E. Mundy, R. J. Western, L. M. Besley, A. J. D. Farmer, E. C. Horrigan, and A. B. Murphy, Interconversion of chlorofluorocarbons in plasmas, *J. Chem. Soc.: Chem. Commun.* No. 3 (1995) 347-348; A. B. Murphy, A. J. D. Farmer, E. C. Horrigan, and T. McAllister, Plasma destruction of ozone depleting substances, *Plasma Chem. Plasma Process.* **22** (2002) 371-385.

[13] Since different ODS have different ODP, consideration should be given to taking into account the ODP of each type of ODS present in the stack gas in calculating the DRE. An appropriate definition that takes into account the differences in ODP is: *DRE of an ODS is determined by subtracting from the number of moles of the ODS fed into a destruction system during a specific period of time, the total number of moles of all types of ODS that are released in stack gases, weighted by their ODP relative to that of the feed ODS, and expressing that difference as a percentage of the number of moles of the ODS fed into the system.*

[14] There are 75 chlorinated dibenzo-p-dioxins and 135 chlorinated dibenzofurans that share a similar chemical structure but that have a wide range in degree of chlorination and a corresponding wide range in toxicity. Of these, one specific dioxin [2,3,7,8- Tetrachlorodibenzo-p-dioxin, or (TCDD)] is the most toxic and best characterized of this family of compounds. Since PCDDs and PCDFs are generally released to the environment as mixtures of these compounds, the scientific community has developed a system of toxic equivalency factors (TEFs) which relate the biological potency of compounds in the dioxin/furan family to the reference TCDD compound. The concentration of each specific compound is multiplied by its corresponding TEF value, and the resulting potency-weighted concentration values are summed to form an expression of the mixture's overall toxic equivalence (TEQ). The result of this exercise is a standardized expression of toxicity of a given mixture in terms of an equivalent amount of TCDD (the reference compound). The internationally accepted protocol for determining TEQ – *i.e.,* ITEQ – was established by NATO in 1988. [*Scientific Basis for the Development of International Toxicity Equivalency Factor (I-TEF), Method of Risk Assessment for Risk Assessment of Complex Mixtures of Dioxins and Related Compounds*. North Atlantic Treaty Organization/Committee on the Challenge of Modern Society. Report No. 176, Washington, D.C. 1988.]

the toxicity for all the members of the families of these toxic compounds that are determined to be present.

The task force members note that the World Health Organization has developed a new system for calculating TEQs, however, most of the existing data on emissions is expressed in the former ITEQ system established in 1988.

For purposes of screening destruction technologies, the maximum concentration of dioxins and furans in the stack gas from destruction technologies is:

- 0.5 ng-ITEQ/Nm^3 for foams; and,
- 0.2 ng-ITEQ/Nm^3 for concentrated sources.

These criteria were determined to represent a reasonable compromise between more stringent standards already in place in some industrialized countries [for example, the Canada-Wide Standard of 0.08 ng/m^3 (ITEQ)], and the situation in developing countries where standards may be less stringent or non-existent. Although a previous standard of 1.0 ng/m^3 (ITEQ) had been suggested in the UNEP 1992 report, advances in technology in recent years, and the level of concern for emissions of these highly toxic substances justified a significantly more stringent level.

Emissions of Acid Gases, Particulate Matter and Carbon Monoxide

Acid gases are generally formed when ODS are destroyed and these must be removed from the stack gases before the gases are released to the atmosphere. The following criteria for acid gases have been set for purposes of screening destruction technologies:

- A maximum concentration in stack gases of 100 mg/Nm^3 HCl/Cl_2
- A maximum concentration in stack gases of 5 mg/Nm^3 HF; and,
- A maximum concentration in stack gases of 5 mg/Nm^3 HBr/Br_2.

Particulate matter is generally emitted in the stack gases of incinerators for a variety of reasons and can also be emitted in the stack gases of facilities using non-incineration technologies. For the purposes of screening technologies, the criterion for particulate matter is established as:

- A maximum concentration of total suspended particulate (TSP) of 50 mg/Nm^3.

Carbon monoxide (CO) is generally released from incinerators resulting from incomplete combustion and may be released from some ODS destruction facilities because it is one form by which the carbon content of the ODS can exit the process. Carbon monoxide is a good measure of how well the destruction process is being controlled. For the purposes of screening technologies, the following criterion has been established:

- A maximum CO concentration in the stack gas of 100 mg/Nm^3.

These maximum concentrations apply to both foams and concentrated sources. They were set to be achievable by a variety of available technologies while ensuring adequate protection of human health and the environment.

Technical Capability

As well as meeting the above performance requirements it is necessary that the destruction technologies have been demonstrated to be technically capable at an appropriate scale of operation. In practical terms, this means that the technology should be demonstrated to achieve the required DRE while satisfying the emissions criteria established above. Demonstration of destruction of ODS is preferred but not necessarily required. Destruction of halogenated compounds that are refractory, *i.e.,* resistant to destruction, is acceptable. For example, demonstrated destruction of polychlorinated biphenyls (PCBs) was often accepted as an adequate surrogate for demonstrated ODS destruction.

For this evaluation, an ODS destruction technology is considered technically capable if it meets the following minimum criteria:

- It has been demonstrated to have destroyed ODS to the technical performance standards, on at least a pilot scale or demonstration scale (designated in Table 2-2 as “Yes”).
- *It has been demonstrated to have destroyed a refractory chlorinated* organic compound other than an ODS, to the technical performance standards, on at least a pilot scale or demonstration scale (designated in Table 2-2 as “P,” which indicates that the technology is considered to have a high potential for application with ODS, but has not actually been demonstrated with ODS).
- The processing capacity of an acceptable pilot plant or demonstration plant must be no less than 1.0 kg/hr of the substance to be destroyed, whether ODS or a suitable surrogate.

These criteria of technical capability will minimize the risk associated with technical performance and ensure that destruction of ODS will be performed in a predictable manner consistent with protecting the environment.

DOCUMENT HISTORY

Version	Date	Comment
v1.0	20 Sep 2011	Initial version released.
v1.1	30 Nov 2017	Updated to account for destruction of unused and stockpiled ODS.

Approved VCS Methodology
VM0017

Version 1.0
Sectoral Scope 14

Adoption of Sustainable Agricultural Land Management

Table of Contents

Section I: Summary and applicability of the baseline and monitoring methodology

Acknowledgements: The BioCarbon Fund acknowledges the lead author of this methodology: Neil Bird. We are also grateful to external reviewers, Timm Tennigkeit, Matthias Seebauer, Giuliana Zanchi, and internal reviewers from the World Bank, Neeta Hooda and Rama Chandra Reddy that contributed to the development of this methodology.

I.1 Brief description

This methodology proposes to estimate and monitor greenhouse gas emissions of project activities that reduce emissions in agriculture through adoption of sustainable land management practices (SALM) in the agricultural landscape. In this methodology, SALM is defined as any practice that increases the carbon stocks on the land. Examples of SALM are (but are not limited to) manure management, use of cover corps, and returning composted crop residuals to the field and the introduction of trees into the landscape. The methodology is applicable to areas where the soil organic carbon would remain constant or decrease in the absence of the project.

The methodology in its current form is applicable only for use of Roth-C model. The estimates of uncertainty and Activity Baseline and Monitoring Survey (ABMS[a]) in the current methodology are adapted for the Roth-C model only. Application of the methodology for use of other models will require at a minimum, revisions to estimates of uncertainty and ABMS specific to the model applied. If however, the parameters used by another model correspond to some or all parameters included in this methodology, then the methodology is applicable, provided applicability conditions of the methodology are met.

This methodology is based on the project "Western Kenya Smallholder Agriculture Carbon Finance project" in Kenya. The baseline study, monitoring and project document are being prepared by the Foundation Vi Planterar trad ("We plant trees") with assistance from Unique Forestry Consultants ltd., the Swedish International Agency (Sida) and the International Bank for Reconstruction and Development as Trustee of the Biocarbon Fund.

I.2 Applicability conditions

This methodology is applicable to projects that introduce sustainable agriculture land management practices (SALM) into an agricultural landscape subject to the following conditions:

a) Land is either cropland or grassland at the start of the project;
b) The project does not occur on wetlands;
c) The land is degraded and will continue to be degraded or continue to degrade;
d) The area of land under cultivation in the region is constant or increasing in absence of the project;
e) Forest land, as defined by the national CDM forest definition, in the region is constant or decreasing over time;
f) There must be studies (for example: scientific journals, university theses, local research studies or work carried out by the project proponent) that demonstrate that the use of the Roth-C model[1] is appropriate for: (a) the IPCC climatic regions of 2006 IPCC AFOLU

[1] For ROTH-C see http://www.rothamsted.bbsrc.ac.uk/aen/carbon/rothc.htm.

Guidelines[b,] or (b) the agroecological zone (AEZ) in which the project is situated, using one of options presented below:[2]

Option 1: The studies used in support of the project should meet the guidance on model applicability as outlined in IPCC AFOLU 2006 guidelines in order to show that the model is applicable for the relevant IPCC climatic region. The guidance notes that an appropriate model should be capable of representing the relevant management practices and that the model inputs (i.e., driving variables) are validated from country or region-specific locations that are representatives of the variability of climate, soil and management systems in the country.

Option 2: Where available, the use of national, regional or global[3] level agroecological zone (AEZ) classification is appropriate to show that the model has been validated for similar AEZs. It is recognized that national level AEZ classifications are not readily available; therefore this methodology allows the use of the global and regional AEZ classification[4].

Where a project area consists of multiple sites, it is recognized that studies demonstrating model validity using either Option 1 or Option 2 may not be available for each of the sites in the project area. In such cases the study used should be capable of demonstrating that the following two conditions are met:

(i) The model is validated for at least 50% of the total project area where the project area covers up to 50,000 ha[5]; or at least 75% of the total project area where project area covers greater than 50,000 ha; and

(ii) The area for which the model is validated generates at least two-thirds of the total project emission reductions.

Explanation / justification

Applicability conditions (a) - (d) allow for the simplification of the baseline. With these conditions we conservatively assume that the lands of a given land use type are degrading in absence of the project.

Specifically it is likely that:

a) if the land is cropland, then it will remain cropland in absence of the project; otherwise
b) the land is grasslands that will remain grassland or be converted to croplands in absence of the project.

[2] The IPCC climatic regions are shown in Figure 3A.5.1 page 3.38.
[3] The agro-ecological zone (AEZ) methodology is standardized framework for the characterization of climate, soil and terrain conditions relevant to agricultural production. Crop modelling and environmental matching procedures are used to identify crop-specific limitations of prevailing climate, soil and terrain resources, under assumed levels of inputs and management conditions.
[4] The details of global agroecological zones classification outlined by Food and Agricultural Organization of United Nations (FAO), Rome, Italy and International Institute for Applied Systems Analysis, Laxenburg, Austria are available at: http://www.iiasa.ac.at/Research/LUC/GAEZ/index.htm
[5] The project area of 50,000 ha is reasonable taking into account the wide range of soil carbon sequestration rates, which depend on climate, soil and land use characteristics. The project area is also influenced by the rates of SALM adoption that are in turn influenced by factors such as farmer awareness to SALM, institutional support and extension systems. Assuming a conservative soil sequestration rate of 0.5 tC/ ha/ yr applied in CDM A/R methodologies, a project of 50, 000 ha is likely to generate 25,000 tC/ ha/yr, and is considered reasonable taking into account the implementation, monitoring and verification costs.

Degradation shall be demonstrated using the latest version of the CDM EB approved tool *Tool for the identification of degraded or degrading lands for consideration in implementing CDM A/R project activities*.[c]

Applicability condition (e) ensures that, in absence of the project, the land would likely not have been:

a) abandoned and allowed to naturally regenerate to forest, or
b) afforested or reforested.

With these applicability conditions we can conservatively assume that the soil organic carbon would remain constant or decrease with time in absence of the project.

Finally, the methodology relies on modelled soil organic carbon. To assure that the model results are reasonable, there must be studies (for example; scientific journals, university theses, local research studies or work carried out by the project proponent) that demonstrate the use of the selected model is valid for the project region. This is fulfilled with applicability condition (f) in accordance with the VCS guidance included in Section 2.3 of the VCS Standard Version 3.1 on quantification of GHG emissions and/or removals related to the methodology.

I.3 Selected carbon pools and emission sources

Table 1: Selected carbon pools

Carbon pools	Selected (answer with Yes or No)	Explanation / justification
Above ground	Yes	A carbon pool covered by SALM practices. The increase in above ground biomass of woody perennials planted as part of the SALM practices is part of the methodology. The increase in above ground biomass of annual crops is not considered since in the IPCC accounting system, annual crops are ignored. The above ground biomass is calculated using the CDM A/R Tool *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*[d] and *Simplified baseline and monitoring methodologies for small-scale afforestation and reforestation project activities under the clean development mechanism implemented on grasslands or croplands* AR-AMS0001[e]
Below ground	Yes	Below-ground biomass stock is expected to increase due to the implementation of the SALM activities. The increase in below ground biomass of woody perennials planted as part of the SALM practices is part of the methodology. The increase in below ground biomass of annual crops is not considered since in the IPCC accounting system, annual crops are ignored. The below ground biomass is calculated using the CDM A/R Tool *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*[d] and *Simplified baseline and monitoring methodologies for small-scale afforestation and reforestation project activities under the clean development mechanism implemented on*

		grasslands or croplands AR-AMS0001[e]
Dead wood	No	None of the applicable SALM practices decrease dead wood. It can be conservatively ignored.
Litter	No	None of the applicable SALM practices decrease the amount of litter. It can be conservatively ignored.
Soil organic carbon	Yes	A major carbon pool covered by SALM practices.
Wood products	No	None of the applicable SALM practices decrease the amount of wood products. It can be conservatively ignored.

Table 2: Emissions sources included in or excluded from the project boundary

Sources	Gas	Included/ excluded	Explanation / justification
Use of fertilizers	CO_2	Excluded	Not applicable
	CH_4	Excluded	Not applicable
	N_2O	Included	Main gas for this source. These are calculated using the CDM A/R Tool *Estimation of direct nitrous oxide emission from nitrogen fertilization (version 01)*[f]
Use of N-fixing species	CO_2	Excluded	Not applicable
	CH_4	Excluded	Not applicable
	N_2O	Included	Main gas for this source. These are calculated using the tool *Estimation of direct nitrous oxide emission from N-fixing species and crop residues* (Section VI.1)
Burning of biomass	CO_2	Excluded	However, carbon stock decreases due to burning are accounted as a carbon stock change
	CH_4	Included	Non-CO_2 emissions from the burning of biomass. These are calculated using the tool *Estimation of non-CO2 emissions from the burning of crop residues* (Section VI.3)
	N_2O	Included	Non-CO_2 emissions from the burning of biomass. These are calculated using *Estimation of non-CO2 emissions from the burning of crop residues* (Section VI.3)
Burning of fossil fuels	CO_2	Included	CO_2 and non-CO_2 emissions are calculated using the tool *Estimation of emissions from the use of fossil fuels in agricultural management*
	CH_4	Included	
	N_2O	Included	

I.4 Summary description of major baseline and project methodological steps

I.4.1 Baseline methodology

The baseline emissions and removals are estimated using the following steps:

1. Identify and delineate the project boundary;

2. Identify the baseline scenario and demonstrate additionality;
3. Estimate the annual emissions from the use of synthetic fertilizers;
4. Estimate the annual emissions from the use of N-fixing species;
5. Estimate the annual emissions from the burning of agricultural residues;
6. Estimate the annual removals from existing woody perennials;
7. Estimate the annual emissions from the use of fossil fuels for agricultural management; and
8. Estimate the equilibrium soil organic carbon in the baseline assuming no changes in agricultural management or agricultural inputs.

I.4.2 Project methodology

The project emissions and removals are estimated using the following steps:

1. Estimate the annual emissions from the use of synthetic fertilizers;
2. Estimate the annual emissions from the use of N-fixing species;
3. Estimate the annual emissions from the burning of agricultural residues;
4. Estimate the annual emissions and removals from woody perennials;
5. Estimate the annual emissions from the use of fossil fuels for agricultural management;

Using the model estimate the parameters in 6, 7 and 8 below:

6. Estimate the equilibrium soil organic carbon in the project based on estimated or measured changes in agricultural management or agricultural inputs;
7. Convert the equilibrium soil organic carbon in the project to transient soil organic carbon assuming a linear transition period;
8. Estimate the annual emissions and removals from soil organic carbon; and
9. Estimate leakage from the increase in the use of non-renewable biomass that occurs from the displacement of biomass used for energy to agricultural inputs.

I.4.3 Monitoring methodology

The following steps are required as part of the monitoring methodology:

1. Record the amount of fossil fuels used in the project;
2. Record the amount of synthetic fertilizers used in the project;
3. Estimate the amount of production of biomass by N-fixing species in the project;
4. Estimate the amount of agricultural residues burnt in the project;
5. Record the production from areas of various types of agricultural land management;
6. Measure the changes in biomass in woody perennials;
7. Estimate the reduction in the amount of biomass used for energy that is a result of the project.

The summary description of major baseline and project methodological steps noted above has been elaborated in the sections II, III and IV of the methodology.

Section II: Baseline methodology description

II.1 Project boundary

The "project boundary" geographically delineates all lands that are under the control of the project proponent for the proposed sustainable agricultural land management (SALM) activities[6].

The SALM project activities may contain more than one discrete area of land.

II.2 Procedure for selection of most plausible baseline scenario

The baseline scenario is identified as existing or historical land management practices. The project proponent shall use the most recent version of the *Combined tool to identify the baseline scenario and demonstrate the additionality in A/R CDM project activities*[g], *mutatis mutandis*.

II.3 Additionality

The project proponent shall use the most recent version of the *Combined tool to identify the baseline scenario and demonstrate the additionality in A/R CDM project activities, mutatis mutandis*.

II.4 Estimation of baseline GHG emissions and removals

II.4.1 Baseline emissions due to fertilizer use

The baseline emissions from synthetic fertilizer use, BEF_t, are calculated using the latest version of the CDM A/R Tool *Estimation of direct nitrous oxide emission from nitrogen fertilization*[f].

Emissions from manure application are not expected to change with the project, as the project activity does not result in a change in animal population. For this reason the baseline emissions from manure application can be ignored.

II.4.2 Baseline emissions due to the use of N-fixing species

The baseline emissions from the use of N-fixing species, BEN_t, are not calculated, but the project proponent shall record the area under N-fixing species prior to project implementation.

II.4.3 Baseline emissions due to burning of biomass

The baseline emissions due to burning of biomass, $BEBB_t$, are calculated using the tool *Estimation of non-CO2 emissions from the burning of crop residues* (Section VI.3).

II.4.4 Baseline removals from existing woody perennials

The baseline removals from woody perennials, $BRWP_t$, are calculated using the latest version of the CDM A/R Tool *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*[d].

II.4.5 Baseline emissions from use of fossil fuels in agricultural management

The baseline emissions due to combustion of fossil fuels in agricultural management in baseline, $BEFF_t$, is calculated using the tool *Estimation of emissions from combustion the use of fossil fuels in agricultural management* (Section VI.2).

[6] In accordance with the VCS rules.

II.4.6 Equilibrium soil organic carbon density in management systems

Using an analytic model that has been accepted in scientific publications (for example: Roth-C soil organic carbon model[h]) estimate the soil organic carbon (SOC) density to a depth of 30 cm, at equilibrium in identified management practices on cropland and grassland. Soil carbon modelling should count only biomass inputs to soil from within the project boundary.

The SOC density should be estimated using area-weighted average values of model input parameters for each management practice identified in Step 4 under uncertainty analysis.

The baseline soil organic carbon at equilibrium can be estimated using:

$$BS_{equil,t} = \sum_{m_C} BA_{C,m_C,t} \bullet SOC_{C,m_C} + \sum_{m_G} BA_{G,m_G,t} \bullet SOC_{G,m_G} \qquad 1$$

Where:

$BS_{equil,t}$	Baseline SOC in equilibrium year t, tC
$BA_{C,m_C,t}$	Baseline areas in cropland with management practice, m_C, year t, ha
SOC_{C,m_C}	Soil organic carbon density at equilibrium for cropland with management practice, m_C, tC/ha
m_C	An index for cropland management types, unit less
$BA_{G,m_G,t}$	Baseline areas in grassland with management practice, m_G, year t, ha
SOC_{G,m_G}	Soil organic carbon density to a depth of 30 cm, at equilibrium for grassland with management practice, m_G, tC/ha
m_G	An index for grassland management types, unit less

II.4.7 Baseline removals due to changes in soil organic carbon

Since the applicability conditions limit the project to lands that are under agricultural pressure and are degrading, it can be conservatively assumed that the baseline removals due to changes in SOC are zero. Therefore

$$BRS_t = 0 \qquad 2$$

Where:

BRS_t	Baseline removals due to changes in soil organic carbon in year t, t CO_2e.

II.4.8 Total baseline emissions and removals

The total baseline emissions and removals are given by:

$$BE_t = BEF_t + BEFF_t + BEBB_t - BRWP_t \qquad 3$$

Where:

BE_t	Baseline emissions in year t, t CO_2e
BEF_t	Baseline emissions due to nitrogen fertilizer use in year t, t CO_2e.

$BEFF_t$	Baseline emissions due to use of fossil fuels in agricultural management in year t, t CO_2e.
$BEBB_t$	Baseline emissions due to biomass burning in year t, t CO_2e.
$BRWP_t$	Baseline removals due to changes in woody perennials in year t, t CO_2e.

Section III: Project methodology description

III.1 Estimation of project GHG emissions and removals

Where the sum of increase in greenhouse gas emissions from each of the identified emission sources in the methodology and leakage due to displacement of renewable biomass is insignificant these can be ignored[7].

III.1.1 Project emissions due to fertilizer use

The project emissions from synthetic fertilizer use, PEF_t, are calculated using the latest version of the CDM A/R Tool *Estimation of direct nitrous oxide emission from nitrogen fertilization (version 01)*[f.]

Emissions from manure application are not expected to change with the project, as the project activity does not result in a change in the animal population. For this reason the project emissions from manure application can be ignored.

III.1.2 Project emissions due to the use of N-fixing species

Only the emissions due to increased area under N-fixing species shall be accounted.

If the area cropped with N-fixing species in the project is more than 50% larger than the area under N-fixing species in the baseline then the project emissions from the use of N-fixing species, PEN_t, are calculated using the tool *Estimation of direct nitrous oxide emission from N-fixing species and crop residues* (Section VI.1).

In all other cases estimation of emissions from N-fixing species is not required.

This differentiation is based on the assumption that:

a) the project does not occur on wetlands;

b) the project occurs on degraded lands so that the lands are likely nitrogen deficient.

These assumptions mean that the nitrogen emissions tend to be smaller than estimated by the Tier 1 IPCC estimation methodology.

III.1.3 Project emissions due to burning of biomass

The project emissions due to burning of biomass, $PEBB_t$, are calculated using the tool *Estimation of non-CO2 emissions from the burning of crop residues* (Section VI.3).

[7] Significance is defined so that the sum of increase in greenhouse gas emissions from the displacement of renewable biomass and each of emission sources identified in the methodology is less than 5% of the emission reductions by the project. The significance of the emission will be tested using the latest version of the CDM EB approved *Tool for testing significance of GHG emissions in A/R CDM project activities* (http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-04-v1.pdf

III.1.4 Project removals from woody perennials

The project removals from woody perennials, $PRWP_t$, are calculated using portions of CDM A/R *Simplified baseline and monitoring methodologies for small-scale afforestation and reforestation project activities under the clean development mechanism implemented on grasslands or croplands* AR-AMS0001e.

III.1.5 Project emissions due to use of fossil fuels for agricultural management

The project emissions due to the use of fossil fuels for agricultural management, $PEFF_t$, are calculated using the tool *Estimation of emissions from the use of fossil fuels in agricultural management* (Section VI.2)

III.1.6 Project equilibrium soil organic carbon density in management systems

Undertake an Activity Baseline and Monitoring Survey (ABMS) to identify the dominant agricultural management practices for croplands and grasslands. The ABMS should estimate or record details of each management practice. For example when using the Roth-C model, one should record;

1. its area;
2. the average annual biomass production from within the project boundary;
3. the average biomass left on site or input;
4. the average number and type of grazing animals;
5. the amount of manure input; and
6. the amount of nitrogen fertilizers input.

Using an analytic model that has been accepted in scientific publications and validated for the project region (for example: Roth-C soil organic carbon model[i]) estimate the soil organic carbon (SOC) density, to a depth of 30 cm, at equilibrium in each of the identified management practices in each of the land use categories (cropland and grassland). The soil carbon modelling should count only biomass inputs to soil from within the project boundary.

The details of each management practice that are recorded will depend on the choice of soil model selected and the type of activity being promoted. For example, if the activity is improving the use of crop residues then for use with the Roth-C model, the ABMS should record:

- Area of each crop (ha)
- Productivity of each crop (kg/ha)
- The amount of crop residues (kg/ha)[8]
- Existing crop residue management practices and their frequency
- Future crop residue management practices that will be implemented with the project

If the project activity includes improving the management of manure, then for use with the Roth-C model, the ABMS should also record:

- Area of grazing (ha)
- The number of livestock per animal type
- The amount of manure produced (kg/ha or kg/an)[9]
- Existing manure management practices and their frequency

[8] Amount of crop residues need not be measured directly. It can also be estimated from the crop production using equations listed in Table 11.2 in Volume 4 of the 2006 IPCC Guidelines
[9] Amount of manure need not be measured directly. It can also be estimated from the number and type of animal using values from Table 10A-4 in Chapter 10 of the 2006 IPCC Guidelines.

- Future manure management practices that will be implemented with the project

If the project activity includes improved tillage practices, then for use with the Roth-C model, the ABMS should record:

- Area under tillage (ha)
- Type and depth of tillage
- Existing tilling practices and their frequency
- Future tilling practices that will be implemented with the project

If the project activity includes agroforestry, then, for use with the Roth-C model, the ABMS should record:

- Area of agroforestry (ha)
- Number and species of trees used
- Diameter at breast height (DBH) of trees
- Future numbers of trees that will be implemented with the project

The applicability of the selected model and parameters recorded for the various activities, and soil and climate types are dependent on the actual project. Since these are project specific and not methodology specific, they should be discussed in detail in the project description.

The SOC density should be estimated using area-weighted average values of model input parameters for each management practice identified.

The project soil organic carbon at equilibrium can be estimated using:

$$PS_{equil,t} = \sum_{m_C} PA_{C,m_C,t} \bullet SOC_{C,m_C,t} + \sum_{m_G} PA_{G,m_G,t} \bullet SOC_{G,m_G,t} \quad (4)$$

Where:

$PS_{equil,t}$	Project SOC in equilibrium year t, tC
$PA_{C,m_C,t}$	Project areas in cropland with management practice, m_C, year t, ha
$SOC_{C,m_C,t}$	Soil organic carbon density at equilibrium for cropland, to a depth of 30 cm, with management practice, m_C, at year t, tC/ha
m_C	An index for cropland management types, unit less
$PA_{G,m_G,t}$	Project areas in grassland with management practice, m_G, year t, ha
$SOC_{G,m_G,t}$	Soil organic carbon density at equilibrium, to a depth of 30 cm, for grassland with management practice, m_G, at year t, tC/ha
m_G	An index for grassland management types, unit less

III.1.7 Project estimate of soil organic carbon with transitions

The estimate of soil organic carbon with transitions can be estimated using:

$$PS_t = \frac{1}{D} \sum_{t-D+1}^{t} PS_{equil,t} \bullet \Delta t \quad (5)$$

Where:

PS_t	Estimate of the project SOC in year t, tC
$PS_{equil,t}$	Estimate of the project SOC in equilibrium year t, tC
D	The transition period required for SOC to be at equilibrium after a change in land use or management practice, year
Δt	Time increment = 1 year

For values of t-D+1 less than zero (the start of the project) assume that $PS_{equil,t} = BS_{equil,t=0}$.

These values are required if one is trying to estimate the absolute soil organic carbon in the baseline. Since the ultimate goal of the methodology is the increase or decrease in SOC with the project these values are not required since they appear in both the baseline and project estimation technique.

Value of D may be chosen from published data from local or regional studies or the modelling exercise. In absence of such data, the IPCC Tier 1 methodology default factor of 20 years may also be used.

III.1.8 Estimate of project removals due to changes in soil organic carbon

The estimate of project removals due to changes in soil organic carbon is given by:

$$PRS_t = \left(PS_t - PS_{t-1}\right) \bullet \frac{44}{12} \quad 6$$

Where:

PRS_t	Estimate of project removals due to changes in soil organic carbon in year t, t CO_2e.
PS_t	Estimate of the project SOC in year t, tC
PS_{t-1}	Estimate of the project SOC in year t-1, tC

III.1.9 Actual net GHG emissions and removals by sinks

The actual net GHG emissions and removals by sinks are given by:

$$PE_t = PEF_t + PEFF_t + PEN_t + PEBB_t - PRWP_t - PRS_t \quad 7$$

Where:

PE_t	Estimate of actual net project GHG emissions and removals by sinks in year t, t CO_2e
PEF_t	Estimate of project emissions due to nitrogen fertilizer use in year t, t CO_2e.
$PEFF_t$	Estimate of project emissions due to burning of fossil fuels for agricultural management in year t, t CO_2e.
PEN_t	Estimate of project emissions due to the increase use of N-fixing species in year t, t CO_2e.
$PEBB_t$	Estimate of project emissions due to biomass burning in year t, t CO_2e.
$PRWP_t$	Estimate of project removals due to changes in biomass of woody perennials in year t, t CO_2e.

PRS_t Estimate of project removals due to changes in soil organic carbon in year t, t CO_2e.

III.2 Estimation of leakage

The one potential source of leakage is an increase in the use of fuel wood and/or fossil fuels from non-renewable sources for cooking and heating purposes due to the decrease in the use of manure and/or residuals as an energy source.

Leakage due to the increase in the use of fuel wood from non-renewable sources for cooking and heating purposes may be a significant source of leakage if manure or other agricultural residuals used for cooking and heating are transferred to the fields as part of the project. In the project, this could be minimized by the introduction of woody perennials for fuel in the landscape and/or improvement of energy efficiency of biomass for cooking and heating. In situations of this form of leakage, the leakage from a switch to non-renewable biomass use, $LNRB_t$, is calculated in accordance with Section IV.2.6 (which is adapted from the small scale methodology AMS-I.E. *Switch from Non-Renewable Biomass for Thermal Applications by the User* [j]*.)*

However, where this is significant, leakage due to switch to fossil fuels (LFF_t) shall be estimated in accordance with Equation 11 in Section IV.2.6.

Table 3: Emissions sources included in or excluded from leakage

Sources	**Gas**	**Included/ excluded**	**Justification / Explanation of choice**
Soil organic carbon stock changes	CO_2	Excluded	Applicability condition
	CH_4	Excluded	Not applicable
	N_2O	Excluded	Not applicable
Increase fossil fuel for cooking	CO_2	Included	
	CH_4	Excluded	Not applicable
	N_2O	Excluded	Not applicable
Increase non-renewable biomass for cooking	CO_2	Included	
	CH_4	Excluded	Not applicable
	N_2O	Excluded	Not applicable

III.3 Estimation of net anthropogenic GHG emissions and removals

The estimation of net anthropogenic GHG removal by sinks is made using:

$$\Delta R_t = BE_t - PE_t - LHE_t \qquad 8$$

Where:

ΔR_t Estimate of net anthropogenic GHG emissions and removals in year t, t CO_2e

PE_t Estimate of actual net project GHG emissions and removals in year t, t CO_2e

BE_t Baseline emissions and removals in year t, t CO_2e

LHE_t The leakage from a switch to non-renewable biomass or fossil fuel in place of the biomass used for cooking/heating diverted to agricultural system in year t, t CO_2e

Section IV: Monitoring methodology description

IV.1 Baseline GHG emissions and removals

IV.1.1 Sampling design

The project proponent shall use the CDM EB approved *General Guidelines For Sampling And Surveys For Small-Scale CDM Project Activities*[k] for sampling and survey design. At the start of the project, the project proponent shall undertake an Activity Baseline and Monitoring Survey (ABMS) to identify the dominant agricultural management practices for croplands and grasslands. The ABMS should estimate or record details of each management practice. For example when using the Roth-C model, one should record;

1. its area;
2. the annual biomass production from within the project boundary;
3. the annual biomass left on the fields;
4. the number and type of grazing animals;
5. the amount of manure input;
6. the amount of nitrogen fertilizers input;
7. the amount of N-fixing species;
8. the amount of biomass burnt; and
9. the existence and amount of woody perennials (trees and bushes).

The information recorded will depend on the choice of soil model selected and the type of activity being promoted. For example, if the project activity is improving the use of crop residues then for use with the Roth-C model, the ABMS should record in the baseline:

- Area of each crop (ha)
- Productivity of each crop (kg/ha)
- The amount of crop residues (kg/ha)[10]
- Existing crop residue management practices and their frequency
- Future crop residue management practices that will be implemented with the project

If the project activity includes improving the management of manure, then for use with the Roth-C model, the ABMS should record in the baseline:

- Area of grazing (ha)
- The number of livestock per animal type
- The amount of manure produced (kg/ha or kg/an)[11]

[10] Amount of crop residues need not be measured directly. It can also be estimated from the crop production using equations listed in Table 11.2 in Volume 4 of the 2006 IPCC Guidelines.
[11] Amount of manure need not be measured directly. It can also be estimated from the number and type of animal using values from Table 10A-4 in Chapter 10 of the 2006 IPCC Guidelines.

- Existing manure management practices and their frequency
- Future manure management practices that will be implemented with the project

If the project activity includes improved tillage practices, then for use with the Roth-C model, the ABMS should record in the baseline:

- Area under tillage (ha)
- Type and depth of tillage
- Existing tilling practices and their frequency
- Future tilling practices that will be implemented with the project

If the project activity includes agroforestry, then for use with the Roth-C model, the ABMS should record in the baseline:

- Area of agroforestry (ha)
- Number and species of trees used
- Diameter at breast height (DBH) of trees
- Future numbers of trees that will be implemented with the project

The applicability of the selected model and parameters recorded for the various activities, and soil and climate types are dependent on the actual project. Since these are project specific and not methodology specific, they should be discussed in detail in the project description.

Other model input parameters that may be required by the selected model, such as climatic data, clay content and texture of soils[l] can be acquired from global or national data sets and do not need to be measured by the project proponent. The project proponent may use climatic data collected by the meteorological station/s in proximity to the project area or use published data and determine the relevance of this data to the project in the following ways:

- The data being applied to the project has been obtained from one or more meteorological station/s whose meteorological coverage includes the project area.
- The data being applied to the project has been obtained from one or more meteorological station/s whose meteorological coverage can be shown to be applicable to the project area based on expert opinion.
- Where data from a meteorological station/s is not available, project entities may use published climatic data by demonstrating that such data is applicable to the project area, using expert opinion.

It is recommended that the project proponent stratifies by crop system, tillage system, use of crop residues, application of manure and clay content of soils and relevant climatic variables as a minimum.

IV.1.2 Data to be collected and archived for baseline GHG emissions and removals

Section	Data / Parameter	Unit	Description	Recording frequency	Source
II.4.1	$BSN_{t=0}$	kg	Synthetic fertilizer use	Project start	ABMS
II.4.2	$Crop_{i,t=0}$	kg d.m./ha	Harvested annual dry matter yield for crop *i*	Project start	ABMS
II.4.2	$Area_{i,t=0}$	ha	total annual area harvested of crop *i* or N-fixing trees *i*	Project start	ABMS
II.4.2	$Areaburnt_{i,t=0}$	ha	annual area of crop *i* or N-fixing trees *i* burnt	Project start	ABMS

II.4.3	$MB_{C,t=0}$	t d.m.	Mass of crop residues burnt	Project start	ABMS
II.4.3	$MB_{G,t=0}$	t d.m.	Mass of grasslands residues burnt	Project start	ABMS
II.4.3	C_F	unitless	Combustion factors that depend on vegetation type	Project start	National or regional studies
II.4.4	See A/R Methodological Tool *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities* [d] for a complete list of data and parameters collected and archived.				
II.4.5	$FC_{j,t}$	Litres	Fossil fuel consumed in vehicle or equipment recorded by vehicle and fuel type	Project start	ABMS
II.4.6	$BA_{C,m_C,t=0}$	ha	Baseline areas in cropland with management practice, m_C	Project start	ABMS
II.4.6	$SOC_{C,m_C,t=0}$	tC/ha	Soil organic carbon density, to a depth of 30 cm, at equilibrium for cropland with management practice, m_C	Project start	Modelled
II.4.6	$BP_{C,m_C,t=0}$	t/ha/month	Baseline production in cropland per month with management practice from within the project , m_C	Project start	ABMS
II.4.6	$BR_{C,m_C,t=0}$	t/t prod/ month	Baseline fraction of production returned as residues per month (calculated from $BP_{C,m_C,t=0}$) in cropland with management practice, m_C	Project start	ABMS
II.4.6	$BM_{C,m_C,t=0}$	t/ha/month	Baseline manure input in cropland per month with management practice, m_C	Project start	ABMS
II.4.6	$BCC_{C,m_C,t=0}$		Baseline cover crop flag per month in cropland per month with management practice, m_C	Project start	ABMS
II.4.6	$BA_{G,m_G,t=0}$	ha	Baseline areas in grassland with management practice, m_G,	Project start	ABMS
II.4.6	$SOC_{G,m_G,t=0}$	tC/ha	Soil organic carbon density, to a depth of 30 cm, at equilibrium for grassland with management practice, m_G	Project start	Modelled

II.4.6	$BP_{G,m_G,t=0}$	t/ha/month	Baseline production in grassland per month with management practice from within the project, m_G	Project start	ABMS
II.4.6	$BR_{G,m_G,t=0}$	t/t prod/ month	Baseline fraction of production returned as residuals per month (calculated from $BP_{G,m_G,t=0}$) in grassland with management practice, m_G	Project start	ABMS
II.4.6	$BM_{G,m_G,t=0}$	t/ha/month	Baseline manure input in grassland per month with management practice, m_G	Project start	ABMS
II.4.6	$BCC_{G,m_G,t=0}$		Baseline cover crop flag per month in grassland per month with management practice, m_G	Project start	ABMS
II.4.6	$\overline{Temp}_m$	°C	Average temperature per month	Project start	Data relevant to the project* area
II.4.6	$\overline{Prec}_m$	mm	Average precipitation per month	Project start	Data relevant to the project*area
II.4.6	$\overline{Evap}_m$	mm/day	Average evapotranspiration per month	Project start	Data relevant to the project area*

*IV.2 *Ex-ante and ex-post net anthropogenic GHG emissions and removals*

IV.2.1 Data to be collected and archived for *ex-ante* project GHG emissions and removals

Record all assumptions and sources of assumptions.

IV.2.2 Data to be collected and archived for *ex-ante* leakage

The only source of leakage possible as a result of the project is the leakage from a switch to non-renewable biomass use or fossil fuels. Procedures to estimate leakage have been included ex-post; the ex-ante estimate of leakage is zero.

IV.2.3 Monitoring of project implementation

The project proponent should record when each farmer within the project area enters into agreement to adopt sustainable agricultural land management practices.

Each farmer should be given a unique ID. Their name, location of their lands, and date of entering into the agreement and leaving the agreement should be recorded.

IV.2.4 Sampling design

The project proponent shall use the CDM EB approved *General Guidelines For Sampling And Surveys For Small-Scale CDM Project Activities*[m] for sampling and survey design. They should undertake an Activity Baseline and Monitoring Survey (ABMS) on a regular basis (annually or bi-annually) to identify the actual agricultural management practices adopted on croplands and grasslands. The ABMS should estimate or record details of each management practice. For example when using the Roth-C model, one should record;

1. its area;
2. the annual biomass production;
3. the annual biomass left on the fields;
4. the number and type of grazing animals;
5. the amount of manure input;
6. the amount of nitrogen fertilizers input;
7. the amount of N-fixing species;
8. the amount of biomass burnt; and
9. the biomass of woody perennials (trees and bushes).

The following parameters need to be recorded annually.

1. Regional total biomass production;
2. Annual temperature, precipitation and evapotranspiration and
3. Fertilizer price.
4. The amount of fossil fuel used for agricultural management

The information recorded will depend on the choice of soil model selected and the type of activity being promoted. For example, if the activity is improving the use of crop residues then for use with the Roth-C model, the ABMS should record:

- Area of each crop (ha)
- Productivity of each crop (kg/ha)
- The amount of crop residues (kg/ha)[12]
- Existing crop residue management practices and their frequency
- Future crop residue management practices that will be implemented with the project

If the project activity includes improving the management of manure, then for use with the Roth-C model, the ABMS should record:

- Area of grazing (ha)
- The number of livestock per animal type
- The amount of manure produced (kg/ha or kg/an)[13]
- Existing manure management practices and their frequency
- Future manure management practices that will be implemented with the project

If the project activity includes improved tillage practices, then for use with the Roth-C model, the ABMS should record:

- Area under tillage (ha)
- Type and depth of tillage
- Existing tilling practices and their frequency
- Future tilling practices that will be implemented with the project

[12] Amount of crop residues need not be measured directly. It can also be estimated from the crop production using equations listed in Table 11.2 in Volume 4 of the 2006 IPCC Guidelines.
[13] Amount of manure need not be measured directly. It can also be estimated from the number and type of animal using values from Table 10A-4 in Chapter 10 of the 2006 IPCC Guidelines.

If the project activity includes agroforestry, then for use with the Roth-C model, the ABMS should record:

- Area of agroforestry (ha)
- Number and species of trees used
- Diameter at breast height (DBH) of trees
- Future numbers of trees that will be implemented with the project

It is recommended that the project proponent stratifies the project area by crop system, tillage system, use of crop residues, application of manure and clay content of soils and relevant climatic variables as a minimum.

The applicability of the selected model and parameters recorded for the various activities, and soil and climate types are dependent on the actual project. Since these are project specific and not methodology specific, they should be discussed in detail in the project description.

Other model input parameters that may be required by the selected model, such as climatic data, clay content and texture of soils[1] can be acquired from global or national data sets and do not need to be measured by the project proponent.

IV.2.5 Data to be collected and archived for project GHG emissions and removals

Section	Data / Parameter	Unit	Description	Recording frequency	Source
III.1.1	PSN_t	kg/year	Synthetic fertilizer use per year	Annually	ABMS
III.1.1	$PA_{C,t}$	ha/year	Areas in cropland	Annually	ABMS
III.1.1	$PA_{G,t}$	ha/year	Areas in grassland	Annually	ABMS
III.1.1	PF_t	USD/kg	the price of inorganic fertilizer	Annually	National or regional studies
III.1.2	$Crop_{i,t}$	kg d.m./ha	Harvested annual dry matter yield for crop *i*	Annually	ABMS
III.1.2	$Area_{i,t}$	Ha/year	total annual area harvested of crop *i* or N-fixing trees *i*	Annually	ABMS
III.1.2	$Areaburnt_{i,t}$	Ha/year	annual area of crop *i* or N-fixing trees *i* burnt	Annually	ABMS
III.1.3	$MB_{C,t}$	t d.m./year	Mass of crop residues burnt	Annually	ABMS
III.1.3	$MB_{G,t}$	t d.m./year	Mass of grasslands residues burnt	Annually	ABMS
III.1.3	C_F	unitless	Combustion factors that depend on vegetation type	Project start	National or regional studies
III.1.4	See *Simplified baseline and monitoring methodologies for small-scale afforestation and reforestation project activities under the clean development mechanism implemented on grasslands or croplands* AR-AMS0001e for a complete list of data and parameters collected and archived.				
III.1.5	$FC_{j,t}$	Litres	Fossil fuel consumed in	Annually	ABMS

			vehicle or equipment recorded by vehicle and fuel type		
III.1.6	$PA_{C,m_C,t}$	ha	Project areas in cropland with management practice, m_C	Annually	ABMS
III.1.6	$SOC_{C,m_C,t}$	tC/ha	Soil organic carbon density, to a depth of 30 cm, at equilibrium for cropland with management practice, m_C	Every five years	Modelled
III.1.6	$PP_{C,m_C,t}$	t/ha/month	Production in cropland per month with management practice from within the project, m_C	Annually	ABMS
III.1.6	$PR_{C,m_C,t}$	t/t prod/ month	Project fraction of production returned as residues per month (calculated from $PP_{C,m_C,t}$) in cropland with management practice, m_C	Annually	ABMS
III.1.6	$PM_{C,m_C,t}$	t/ha/month	Project manure input in cropland per month with management practice, m_C	Annually	ABMS
III.1.6	$PCC_{C,m_C,t}$		Project cover crop flag per month in cropland per month with management practice, m_C	Annually	ABMS
III.1.6	$PA_{G,m_G,t}$	ha	Project areas in grassland with management practice, m_G	Annually	ABMS
III.1.6	$SOC_{G,m_G,t}$	tC/ha	Soil organic carbon density, to a depth of 30 cm, at equilibrium for grassland with management practice, m_G	Every five years	Modelled
III.1.6	$PP_{G,m_G,t}$	t/ha/month	Production in grassland per month with management practice, from within the project, m_G	Annually	ABMS
III.1.6	$PR_{G,m_G,t}$	t/t prod/ month	Project fraction of production returned as residuals per month (calculated from $PP_{G,m_G,t}$) in grassland with management practice, m_G	Annually	ABMS

III.1.6	$PM_{G,m_G,t}$	t/ha/month	Project manure input in grassland per month with management practice, m_G	Annually	ABMS
III.1.6	$PCC_{G,m_G,t}$		Project cover crop flag per month in grassland per month with management practice, m_G	Annually	ABMS
III.1.6	$\overline{Temp}_m$	°C	Average temperature per month	Over the previous five years	Data relevant to the project area
III.1.6	$\overline{Prec}_m$	mm	Average precipitation per month	Over the previous five years	Data relevant to the project area
III.1.6	$\overline{Evap}_m$	mm/day	Average evapotranspiration per month	Over the previous five years	Data relevant to the project area
III.1.6	D	Years	Transition period	Every five years	National or regional studies

IV.2.6 Data to be collected and archived for leakage

The only source of leakage possible as a result of the project is the leakage from a switch to non-renewable biomass use attributable to the project. If the project plan includes the diversion of biomass used for cooking and heating to the fields (for example, manure or agricultural residuals) then the project proponent should estimate the possible leakage.

The project proponent should record the amount of biomass used for cooking and heating purposes that is diverted to the agricultural system. It is conservatively assumed that this is replaced by non-renewable biomass or locally used fossil fuels.

The ABMS survey is expected to provide information to assess whether or not non-renewable biomass from outside the project or fossil fuels are used for the purpose of cooking or heating by the surveyed project households to replace the biomass diverted to agricultural fields. If the ABMS survey data shows that 10% or fewer project households use non-renewable biomass from outside the project or fossil fuels to replace the biomass diverted to agricultural fields, then the leakage is considered insignificant and ignored.

In situations where ABMS survey data shows that more than 10% of the project households use non-renewable biomass from outside the project or fossil fuels to replace the biomass diverted to agricultural fields, then the leakage is considered significant and shall be estimated based on the household energy use information collected through the ABMS Survey to calculate the leakage.

$$LHE_t = LNRB_t + LFF_t \qquad 9$$

Where:

LHE_t The leakage from a switch to non-renewable biomass or fossil fuel in place of the biomass used for cooking/heating diverted to agricultural system in year t, t CO2e

$LNRB_t$ Leakage from a switch to non-renewable biomass use in year t, , t CO_2e

LFF_t Leakage from switch to fossil fuel in year t , t CO_2e

$$LNRB_t = B_{biomass,t} * fNRB * NCV_{biomass} * EF_{fossil\ fuel} \quad 10$$

$LNRB_t$ Leakage from a switch to non-renewable biomass use in year t, t CO_2e

$B_{biomass,t}$ Quantity of biomass from outside the project that replaces biomass used for cooking/heating diverted to agricultural system in year t, tonnes

$fNRB$ Fraction of non-renewable biomass from outside the project in year t

$NCV_{biomass}$ Net calorific value of the non-renewable biomass from outside the project

$EF_{fossil\ fuel}$ Emission factor of fossil fuel as substitute for non-renewable biomass

$$LFF_t = B_{fossil\ fuel\ t} * NCV_{fossil\ fuel} * EF_{fossil\ fuel} \quad 11$$

$B_{fossilfuel,\ t}$ Quantity of fossil fuel that replaces the biomass used for cooking/heating diverted to agricultural system in year t, tonnes

$NCV_{fossil\ fuel}$ Net calorific value of the fossil fuel that is substituted

$EF_{fossil\ fuel}$ Emission factor of fossil fuel as a substitution for non-renewable biomass

Section	Data / Parameter	Unit	Description	Recording frequency	Source
III.2	$B_{biomass,t}$ $B_{fossilfuel,\ t}$	tonnes/ year	Quantity of biomass from outside the project or fossil fuel used in place of the amount of biomass used in cooking and heating diverted to the agricultural system in the project	Annually	ABMS

III.2	$f_{NRB,t}$	dimension less	Fraction of biomass that comes from non-renewable sources	Start of the project	If the data on $f_{NRB,t}$ is available, it is calculated as per the procedure of AMS I.E methodology. For situations, where the data on $f_{NRB,t}$ is not available $fNRB_{,t}$ =1 shall be used (i.e., $fNRB_{,t}$ value is fixed at 1), which is conservative.
III.2	$NCV_{biomass}$/ $NCV_{fossil\ fuel}$	TJ/ tonne	Net calorific value of the non-renewable biomass or fossil fuel substituted	Start of the project	IPCC defaults, National or regional studies
III.2	$EF_{fossilfuel}$	tCO2/ TJ	Emission factor for the projected fossil fuel consumption	Start of the project	Default value of 81.6 tCO2/TJ I as per AMS I.E

IV.2.7 Conservative approach

Since emissions reduced are calculated as the baseline emissions minus project emissions, an approach that:

1) ignores emissions in the baseline; and/or
2) ignores emission removals (sequestration) in the project

is conservative. Ignoring either of these two items will mean that emission reductions are underestimated.

The methodology uses a conservative approach because applicability conditions limit its use to:

a) Land is either cropland or grassland at the start of the project
b) The project does not occur on wetlands
c) The land is degraded and will continue to be degraded or continue to degrade
d) The area of land under cultivation is constant or increasing in absence of the project
e) Forest land, as defined by the national CDM forest definition, in the area is constant or decreasing over time

With these assumptions the methodology conservatively ignores emissions from SOC in the baseline.

The methodology uses a conservative approach because it assumes that leakage caused by the displacement of biomass used for cooking and heating purposes to the fields as the result of the project, causes an increase in the use of non-renewable biomass or fossil fuels.

IV.2.8 Uncertainty analysis

The project proponent shall use the CDM EB approved *General Guidelines for Sampling and Surveys for Small-Scale CDM Project Activities*[o] with a view to reducing uncertainty of model input parameters. The generation of model parameters follows the standard procedures on surveys and quality assurance in the collection and organization of data.

The project proponent will estimate the uncertainty of the agricultural input parameters to the soil organic model using the ABMS as required under Section 4.1 of VCS standard v3.1.

If the project area is stratified, the sampling effort should represent the relevant strata in the sample frame. Where there is no specific survey guidance from national institutions, the project proponent shall use a precision of 15% at the 95% confidence level as the criteria for reliability of sampling efforts. This reliability specification shall be applied to determine the sampling requirements for assessing parameter values. The sampling intensity could be increased to ensure that the model parameters estimated from the ABMS lead to the achievement of a desired precision of 15% at the 95% confidence level) for the estimate of greenhouse gas emission reductions from the project. The project proponent should calculate the soil model response using the model input parameters with the upper and lower confidence levels. The range of model responses demonstrates the uncertainty of the soil modelling.

Step 1: Calculate the values for all input parameters at the upper and lower confidence limit.

Calculate the mean, X_p and standard deviation, ∂_p for all parameters measured in ABMS, and then the standard error in the mean is given by:

$$SE_p = \frac{\partial_p}{\sqrt{n_p}} \qquad 12$$

Where:

SE_p	Standard error in the mean of parameter, *p* in year *t*
∂_p	The standard deviation of the parameter p in year t
n_p	Number of samples used to calculate the mean and standard deviation of parameter p

Assuming that values of the parameter are normally distributed about the mean, the minimum and maximum values for the parameters are given by.

$$P_{\min} = \overline{X_p} - 1.96 * SE_p$$
$$P_{\max} = \overline{X}_p + 1.96 * SE_p \qquad 13$$

Where:

$P_{\min}$	The minimum value of the parameter at the 95% confidence interval
$P_{\max}$	The maximum value of the parameter at the 95% confidence interval
SE_p	Standard error in the mean of parameter, *p* in year *t*
1.96	The value of the cumulative normal distribution at 95% confidence interval

Step 2: Calculate the project removals due to changes in soil organic carbon with the minimum and maximum values of the input parameters

The project removals due to changes in soil organic carbon using the minimum and maximum values of the parameters is given by

$$PRS_{\min,t} = Model(P_{\min}, Temperature_{\max}, Precipitation_{\max}, ClayContent_{\min})$$
$$PRS_{\max,t} = Model(P_{\max}, Temperature_{\min}, Precipitation_{\min}, ClayContent_{\max}) \quad 14$$

Where:

$PRS_{\min,t}$	The minimum value of project removals due to changes in soil organic carbon at the 95% confidence interval
$PRS_{\max,t}$	The maximum value of project removals due to changes in soil organic carbon at the 95% confidence interval

Step 3: Calculate the uncertainty in the model output

The uncertainty in the output model is given by:

$$UNC_t = \frac{\left|PRS_{\max,t} - PRS_{\min,t}\right|}{2 * PRS_t} \quad 15$$

Step 4: Adjust the estimate of soil sequestration based on the uncertainty in the model output

If the uncertainty of soil models is less than or equal to 15% of the mean value then the project proponent may use the estimated value without any deduction for conservativeness or increase in sampling.

If the uncertainty of soil models is greater than 15% but less than or equal to 30% of the mean value, then the project proponent may use the estimated value subject to a deduction calculated as

$$PRS_{Deduction,t} = PRS_t * (UNC_t - 15\%) \quad 16$$

And the following term will be used in equation 7 in place of PRS_t

$$PRS_{Adj,t} = PRS_t - PRS_{Deduction,t} \quad 17$$

Where:

PRS_t	Estimate of project removals due to changes in soil organic carbon in year t, t CO_2e.
PRS_{Unc}	Estimate of uncertainty in the mean of changes in soil organic carbon in year t, t CO_2e.
$PRS_{Deduction,t}$	A calculated deduction to the estimate of the change in soil organic removals year t, t CO_2e.
$PRS_{Adj,t}$	An adjusted estimate of project removals due to changes in soil organic carbon in year t, t CO_2e.

In this way, when the uncertainty is 15% or less than 15% there is no deduction and when the uncertainty is between 15 and 30% a deduction as calculated in Step 4 above will apply.

If the uncertainty of soil models is greater than 30% of the mean value then the project proponent should increase the sample size of the input parameters until the soil model uncertainty is better than ± 30%.

IV.2.9 Other information

Every five years the means of parameters will be tested for significant difference using t-tests. If the means are significantly different then the soil model shall be updated based on the new data and relevant data such as studies conducted in the region. It is not incumbent that the project proponent shall undertake such studies as part of the project activity but shall make use of data generated elsewhere as part of ongoing research/other efforts in the region for updating the model. Such data can be used to refine the model over time and decrease uncertainty.

Section V: Lists of variables, acronyms and references

V.1 Variables used in equations

Equation 1

$BS_{equil,t}$	Baseline SOC in equilibrium year t, tC
$BA_{C,m_C,t}$	Baseline areas in cropland with management practice, m_C, year t, ha
SOC_{C,m_C}	Soil organic carbon density at equilibrium for cropland with management practice, m_C, tC/ha
m_C	An index for cropland management types, unit less
$BA_{G,m_G,t}$	Baseline areas in grassland with management practice, m_G, year t, ha
SOC_{G,m_G}	Soil organic carbon density at equilibrium for grassland with management practice, m_G, tC/ha
m_G	An index for grassland management types, unit less

Equation 2

BRS_t	Baseline removals due to changes in soil organic carbon in year t, t CO_2e.

Equation 3

BE_t	Baseline emissions in year t, t CO_2e
BEF_t	Baseline emissions due to nitrogen fertilizer use in year t, t CO_2e.
$BEFF_t$	Baseline emissions due to use of fossil fuels in agricultural management in year t, t CO_2e.
BEN_t	Baseline emissions due to the use of N-fixing species in year t, t CO_2e.
$BEBB_t$	Baseline emissions due to biomass burning in year t, t CO_2e.
$BRWP_t$	Baseline removals due to changes in woody perennials in year t, t CO_2e.

Equation 4

$PS_{equil,t}$	Project SOC in equilibrium year t, tC
$PA_{C,m_C,t}$	Project areas in cropland with management practice, m_C, year t, ha
$SOC_{C,m_C,t}$	Soil organic carbon density at equilibrium for cropland with management practice, m_C, at year *t*, tC/ha
m_C	An index for cropland management types, unit less
$PA_{G,m_G,t}$	Project areas in grassland with management practice, m_G, year t, ha
$SOC_{G,m_G,t}$	Soil organic carbon density at equilibrium for grassland with management practice, m_G, at year *t*, tC/ha
m_G	An index for grassland management types, unit less

Equation 5

PS_t	Project estimate of the project SOC in year t, tC
$PS_{equil,t}$	Project estimate of the project SOC in equilibrium year t, tC
D	The transition period required for SOC to be at equilibrium after a change in land use or management practice, year
Δt	Time increment = 1 year

Equation 6

PRS_t	Estimate of project removals due to changes in soil organic carbon in year t, t CO_2e.
PS_t	Estimate of the project SOC in year t, tC

Equation 7

PE_t	Estimate of actual net GHG emissions and removals by sinks in year t, t CO_2e
PEF_t	Estimate of project emissions due to nitrogen fertilizer use in year t, t CO_2e.
$PEFF_t$	Estimate of project emissions due to burning of fossil fuels for agricultural management in year t, t CO_2e.
PEN_t	Estimate of project emissions due to the use of N-fixing species in year t, t CO_2e.
$PEBB_t$	Estimate of project emissions due to biomass burning in year t, t CO_2e.
$PRWP_t$	Estimate of project due to changes in biomass of woody perennials in year t, t CO_2e.
PRS_t	Estimate of project removals due to changes in soil organic carbon in year t, t CO_2e.

Equation 8

ΔR_t Estimate of net anthropogenic GHG emissions and removals in year t, t CO_2e

PE_t Estimate of actual net GHG emissions and removals in year t, t CO_2e

BE_t Baseline emissions and removals in year t, t CO_2e

LHE_t The leakage from a switch to non-renewable biomass or fossil fuel in place of the biomass used for cooking/heating diverted to agricultural system in year t, t CO_2e

Equation 9

LHE_t The leakage from a switch to non-renewable biomass or fossil fuel in place of the biomass used for cooking/heating diverted to agricultural system in year t, t CO2e

$LNRB_t$ Leakage from a switch to non-renewable biomass use in year t, , t CO_2e

LFF_t Leakage from switch to fossil fuel in year t , t CO_2e

Equation 10

$LNRB_t$ Leakage from a switch to non-renewable biomass use in year t, t CO_2e

$B_{biomass,t}$ Quantity of biomass from outside the project used in place of the biomass used for cooking/heating diverted to agricultural system in year t, tonnes

$fNRB$ Fraction of non-renewable biomass from outside the project in year t

$NCV_{biomass}$ Net calorific value of the non-renewable biomass from outside the project

$EF_{fossil\,fuel}$ Emission factor of fossil fuel as substitute for non-renewable biomass

Equation 11

$B_{fossilfuel,t}$ Quantity of fossil fuel used in place of the biomass used for cooking/heating diverted to agricultural system in year t, tonnes

$NCV_{fossil\,fuel}$ Net calorific value of the fossil that is substituted

$EF_{fossil\,fuel}$ Emission factor of fossil fuel as a substitution for non-renewable biomass

Equation 12

SE_p Standard error in the mean of parameter, *p* in year *t*

∂_p The standard deviation of the parameter p in year t

n_p Number of samples used to calculate the mean and standard deviation of parameter p

SE_p	Standard error in the mean of parameter, *p* in year *t*

Equation 13

$P_{\min}$	The minimum value of the parameter at the 95% confidence interval
$P_{\max}$	The maximum value of the parameter at the 95% confidence interval
SE_p	Standard error in the mean of parameter, *p* in year *t*
1.96	The value of the cumulative normal distribution at 95% confidence interval

Equation 14, 15

$PRS_{\min,t}$	The minimum value of project removals due to changes in soil organic carbon at the 95% confidence interval
$PRS_{\max,t}$	The maximum value of project removals due to changes in soil organic carbon at the 95% confidence interval

Equation 16, 17

PRS_t	Estimate of project removals due to changes in soil organic carbon in year t, t CO_2e.
PRS_{Unc}	Estimate of uncertainty in the mean of changes in soil organic carbon in year t, t CO_2e.
$PRS_{Deduction,t}$	A calculated deduction to the estimate of the change in soil organic removals year t, t CO_2e.
$PRS_{Adj,t}$	An adjusted estimate of project removals due to changes in soil organic carbon in year t, t CO_2e.

V.2 Acronyms

A/R	Afforestation / reforestation
CDM	Clean Development Mechanism
ABMS	Activity Baseline and Monitoring Survey
SALM	sustainable agricultural land management
SOC	soil organic carbon

Section VI: Tools

VI.1 Estimation of direct nitrous oxide emission from N-fixing species and crop residues

This tool can be used for both ex ante and ex post estimation of the nitrous oxide emissions from the use of nitrogen fixing species and crop residues within the boundary of a VCS project. For *ex post* estimation purposes, activity data (quantities of crop residues) are monitored or estimated.

It is important to note that for the project emissions, it is only the new area under N-fixing crop that is input to the formulae.

As the project proponent may use various N-fixing species, it is important to identify and record the species type and estimate the amount of inputs from each species. The direct nitrous oxide emissions from the use of nitrogen-fixing species and crop residues can be estimated using equations as follows:

$$N_2O_{direct-N,t} = F_{CR,t} \cdot EF_1 \cdot MW_{N_2O} \cdot GWP_{N_2O} \cdot 10^{-3} \quad 18$$

$$F_{CR,t} = \sum_{i=1}^{I} Crop_{i,t} \cdot \left(Area_{i,t} - Areaburnt_{i,t} \cdot C_f\right) \cdot Frac_{Renew} \cdot \left[R_{AG,i,t} \cdot N_{AG,i,t} \cdot \left(1 - Frac_{Removed}\right) + R_{BG,i,t} \cdot N_{BG,i,t}\right] \quad 19$$

Where:

$N_2O_{direct-N,t}$	Direct N_2O emission as a result of nitrogen application within the project boundary, t-CO_2-e in year t
$F_{CR,t}$	Amount of N in crop residues (above and below ground), including N-fixing crops returned to soils annually, kg N yr^{-1} in year t
EF_1	Emission Factor for emissions from N inputs, tonne-N_2O-N (tonne-N input)$^{-1}$ As noted in IPCC 2006 Guidelines (table 11.1), the default emission factor (EF_1) is 1% of applied N, and this value should be used when country-specific factors are unavailable. The project proponent may use emission factors from the peer reviewed scientific literature that are specific for the project area.
MW_{N_2O}	Ratio of molecular weights of N_2O and N (44/28), tonne-N_2O (t-N)$^{-1}$
GWP_{N2O}	Global Warming Potential for N_2O, kg-CO_2-e (kg-N_2O)$^{-1}$ (IPCC default = 310, valid for the first commitment period).
$Crop_{i,t}$	Harvested annual dry matter yield for crop i in year t, kg d.m. ha^{-1} For N-fixing trees use the above ground biomass.
$Area_{i,t}$	total annual area harvested of N-fixing crop i or trees i in year t, ha yr^{-1}
$Areaburnt_{i,t}$	annual area of N-fixing crop i or trees burnt in year t, ha yr^{-1}
C_f	combustion factor (dimensionless) (see *2006 IPCC Guidelines*, Table 2.6)
$Frac_{Renew}$	fraction of total area under crop that is renewed annually. For countries where pastures are renewed on average every X years, $Frac_{Renew}$ = 1/X. For annual crops $Frac_{Renew}$ = 1. For N-fixing trees assume that they shed their

	leaves every year are similar to annual crops
$R_{AG,i,t}$	ratio of above-ground residues dry matter ($AG_{DM,i,t}$) to harvested yield for crop i in year t ($Crop_{i,t}$), kg d.m. (kg d.m.)$^{-1}$ (see *2006 IPCC Guidelines*, Table 11.2) For NB-fixing trees use the ratio of leaf biomass to above ground biomass. For deciduous trees 0.02 is a reasonable value
$N_{AG,i,t}$	N content of above-ground residues for crop i, kg N (kg d.m.)$^{-1}$ (see *2006 IPCC Guidelines*, Table 11.2) For N-fixing trees assume 0.027 (default value for N-fixing forages) This value should be used when country-specific factors are unavailable.
$Frac_{Removed}$	Fraction of above-ground residues of crop i removed annually for purposes such as feed, bedding and construction, kg N (kg crop-N)$^{-1}$. Survey of experts in country is required to obtain data. If data for $Frac_{Removed}$ are not available, assume no removal.
$R_{BG,i,t}$	Ratio of below-ground residues to harvested yield for crop i, kg d.m. (kg d.m.)$^{-1}$. (see *2006 IPCC Guidelines*, Table 11.2) For N-fixing trees assume 0.01 (assumes that fine roots are 7% of total root biomass, that total root biomass is 25% of above ground biomass and there is a 50% fine root turnover). This value should be used when country-specific factors are unavailable.
$N_{BG,i,t}$	N content of below-ground residues for crop i, kg N (kg d.m.)$^{-1}$. (see *2006 IPCC Guidelines*, Table 11.2) For N-fixing trees assume 0.022 (default value for N-fixing forages) This value should be used when country-specific factors are unavailable.

VI.2 Estimation of emissions from the use of fossil fuels in agricultural management

The following tool is derived from the A/R Methodological Tool *Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities*[n]. The CO_2 emissions are calculated using the following equations:

$$EFF_t = \sum_{j=1J} ET_{j,t} \qquad (20)$$

Where:

EFF_t Emissions due to the use of fossil fuels in agricultural management, t CO_2e
Note: in the methodology there is a prefix B or P depending on whether they are baseline or project emissions

$ET_{j,t}$ Emission from fossil fuel combustion in vehicle/equipment type *j* during year *t*, t CO_2e/yr

j Type of vehicle/equipment

J Total number of types of vehicle/equipment used in the project activity

It is assumed that the amount of fuel combusted is available. The method may be used in estimating vehicle/equipment emission, when the vehicle/equipment is captive (i.e. controlled by the project proponent) and the entire fuel consumptions can be monitored. If this is not available, the amount of fuel combusted can be estimated using fuel efficiency (for example l/100 km, l/t-km, l/hour) of the vehicle and the appropriate unit of use for the selected fuel efficiency (for example km driven if efficiency is given in l/100 km). The equation is as follows.

$$ET_{j,t} = FC_{j,t} \cdot EF_{CO2,j}$$

Where:

$ET_{j,t}$	Emission from fossil fuel combustion in vehicle/equipment type *j* during year *t*, t CO_2e/yr
$FC_{j,t}$	Consumption of fossil fuel in vehicle/equipment type *j* during year *t*, litres/yr
$EF_{CO2,j}$	Emission factor for the type of fossil fuel combusted in vehicle or equipment, *j*
	For gasoline EF_{CO2e} = 0.002810 t per litre. For diesel EF_{CO2e} = 0.002886 t per litre[14]
j	Type of vehicle/equipment
J	Total number of types of vehicle/equipment used in the project activity

VI.3 Estimation of non-CO_2 emissions from the burning of crop residues

The CO_2 emissions from the burning of crop residues and grasslands are not included in the methodology as per IPCC convention. The non-CO_2 emissions burning this biomass, EBB_t are calculated using the following equations:

$$EBB_t = \begin{bmatrix} MB_{C,t} \bullet C_F \bullet \left(2.7 \bullet GWP_{CH4} + 0.07 \bullet GWP_{N2O}\right) \\ + MB_{G,t} \bullet C_F \bullet \left(2.3 \bullet GWP_{CH4} + 0.21 \bullet GWP_{N2O}\right) \end{bmatrix} \bullet 10^{-3} \quad (20)$$

Where:

EBB_t	Emissions due to biomass burning in year t, t CO_2e
$MB_{C,t}$	Mass of crop residues burnt in year t, tonnes
2.7, 0.07	Emissions factors for the burning of cropland, g CH_4 / kg and g N_2O / kg, respectively From Table 2.5, 2006 IPCC Guidelines for National Greenhouse Gas Inventories
$MB_{G,t}$	Mass of grasslands residues burnt in year t, tonnes
2.3, 0.21	Emissions factors for the burning of grassland, g CH_4 / kg and g N_2O / kg, respectively
	From Table 2.5, 2006 IPCC Guidelines for National Greenhouse Gas Inventories
GWP_{CH4}	Global warming potential of CH_4 (IPCC default: 21 for the first commitment period of the Kyoto Protocol); t CO_2e / t $_{CH4}$
C_F	Combustion factors that depend on vegetation type (see Table 4), unit less

[14] These values calculated from IPCC 2006 Table 3.3.1 assuming 2-stroke gasoline engine for gasoline combustion and default values for energy content of 47.1 GJ/t and 45.66 GJ/t for gasoline and diesel respectively (IEA. 2004. Energy Statistics Manual. http://www.iea.org/stats/docs/statistics_manual.pdf)

Table 4: Combustion factor values for fires in a range of vegetation types

Vegetation type	Subcategory	Mean Value
Savanna Grasslands/ Pastures (early dry season burns)	Tropical/sub-tropical grassland	0.74
	Grassland	-
All savanna grasslands (early dry season burns)		**0.74**
Savanna Grasslands/ Pastures (mid/late dry season burns)*	Tropical/sub-tropical grassland	0.92
	Tropical pasture~	0.35
	Savanna	0.86
All savanna grasslands (mid/late dry season burns)		**0.77**
Other vegetation types	Peatland	0.50
	Tropical Wetlands	0.70
Agricultural residues (Post harvest field burning)	Wheat residues	0.90
	Maize residues	0.80
	Rice residues	0.80
	Sugarcane	0.80

From Table 2.6, 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Section VII: References

[a] ABMS: Crop production and Activity baseline and Monitoring Survey Guideline for Sustainable Agricultural Land Management practices (SALM)

[b] IPCC. 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry, and Other Land Use. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

[c] A/R methodological Tool "Tool for the identification of degraded or degrading lands for consideration in implementing CDM A/R project activities" (Version 01) EB 41, Annex 15. http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-13-v1.pdf

[d] A/R Methodological Tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities (Version 02.1.0) EB 60, Annex 13. http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-14-v2.1.0.pdf

[e] AR-AMS0001 "Simplified baseline and monitoring methodologies for small-scale A/R CDM project activities implemented on grasslands or croplands with limited displacement of pre-project activities (Version 6.0)". http://cdm.unfccc.int/methodologies/DB/91OLF4XK2MEDIRIWUQ22X3ZQAOPBWY

[f] A/R Methodological tool "Estimation of direct nitrous oxide emission from nitrogen fertilization" (Version 01) EB 33, Annex 16. http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-07-v1.pdf

[g] A/R Methodological tool "Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities" (Version 01) EB 35, Annex 19. http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-02-v1.pdf

[h] K Coleman & DS Jenkinson (2008) ROTHC-26.3 - a model for the turnover of carbon in soil. http://www.rothamsted.bbsrc.ac.uk/aen/carbon/rothc.htm

[i] K Coleman & DS Jenkinson (2008) ROTHC-26.3 - a model for the turnover of carbon in soil. http://www.rothamsted.bbsrc.ac.uk/aen/carbon/rothc.htm

[j]AMS-I.E.: Switch from Non-Renewable Biomass for Thermal Applications by the User (Version 4.0). http://cdm.unfccc.int/filestorage/M/I/6/MI6Z47XJAVRTKN3BWSQ1Y8FD2E9ULG/EB60_repan20_%20AMS-I.E_ver04.pdf?t=eG58bHdnOWkyfDDxWVo4h67XHCltxDQuoxY7

[k] General guidelines for sampling and surveys for small-scale CDM project activities (Version 1) EB 50, Annex 30. http://cdm.unfccc.int/EB/050/eb50_repan30.pdf

[l] FAO/IIASA/ISRIC/ISSCAS/JRC, 2009. Harmonized World Soil Database (version 1.1). FAO, Rome, Italy and IIASA, Laxenburg, Austria http://www.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/index.html

[m] General guidelines for sampling and surveys for small-scale CDM project activities (Version 1) EB 50, Annex 30. http://cdm.unfccc.int/EB/050/eb50_repan30.pdf

[n] A/R Methodological Tool "Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities" (Version 01) EB 33 Annex 14. http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-05-v1.pdf

Approved VCS Methodology

VM0018

Version 1.0

Sectoral Scopes 3, 13

Energy Efficiency and Solid Waste Diversion Activities within a Sustainable Community

Scope

This methodology provides a procedure to determine the net CO_2, N_2O and CH_4 emissions reductions associated with grouped projects that focus on energy efficiency and solid waste diversion activities for an assortment of facilities within a set territory.

Methodology Developer

The methodology was developed by Will Solutions, Inc. (formerly Gedden Inc.), in collaboration with ICF Marbek and CertiConseil Inc.

Authors

- Methodology Process and Project Director - Martin Clermont, Eng. M.Sc. Env., B. Tech. Mec. Will Solutions, Inc. – Business Solutions
- Christophe Kaestli LEED AP, DBA - CertiConseil Inc.
- Duncan Rotherham, Chad Hamre, Braydon Boulanger – ICF Marbek

Relationship to Approved or Pending Methodologies

No approved or pending methodology under the VCS Program or an approved GHG program can reasonably be revised to meet the objective of this proposed methodology. All existing and pending VCS, CDM and CAR methodologies under sectoral scopes 3 and 13 have been reviewed. All corresponding methodologies have been grouped and listed below. None of the similar methodologies listed below could be revised without the addition of new procedures or scenarios to more than half of its sections.

Program	Sectoral Scope	Title	Similarity
CDM	3	*AM0025 - Avoided emissions from organic waste through alternative waste treatment processes*	Similar
CDM	3	*AM0041 - Mitigation of Methane Emissions in the Wood Carbonization Activity for Charcoal Production*	Not Similar
CDM	3	*AM0049 - Methodology for gas based energy generation in an industrial facility*	Not Similar
CDM	3	*AM0046 - Distribution of efficient light bulbs to households*	Not Similar
CDM	3	*AM0055 - Baseline and Monitoring Methodology for the recovery and utilization of waste gas in refinery facilities*	Not Similar
CDM	3	*AM0086- Installation of zero energy water purifier for safe drinking water application*	Not Similar
CDM	3	*AM0091- Energy efficiency technologies and fuel switching in new buildings*	Similar
CDM	3	*AM065 - Replacement of SF6 with alternate cover gas in the magnesium industry*	Not Similar
CDM	3	*AM0070 - Manufacturing of energy efficient domestic refrigerators*	Not Similar
CDM	3	*ACM003 - Emissions reduction through partial substitution of fossil fuels with alternative fuels or less carbon intensive fuels in cement manufacture*	Not Similar
CDM	3	*AM0007 - Analysis of the least-cost fuel option for seasonally-operating biomass cogeneration plants*	Not Similar
CDM	3	*AM0014 - Natural gas-based package cogeneration*	Not Similar
CDM	3	*ACM0012 - Consolidated baseline methodology for GHG emission reductions from waste energy recovery projects*	Not Similar
CDM	3	*AM0024 - Methodology for greenhouse gas reductions through waste heat recovery and utilization for power generation at cement plants*	Not Similar

Program	Sectoral Scope	Title	Similarity
CDM	4	*ACM0015 - Consolidated baseline and monitoring methodology for project activities using alternative raw materials that do not contain carbonates for clinker production in cement kilns*	Not Similar
CDM	3	*AM0020 - Baseline methodology for water pumping efficiency improvements --- Version 2.0*	Not Similar
CDM	3	*AM0044 - Energy efficiency improvement projects: boiler rehabilitation or replacement in industrial and district heating sectors --- Version 1.0*	Similar
CDM	3	*AM0060 - Power saving through replacement by energy efficient chillers --- Version 1.1*	Similar
CDM	3	*AM0068 - Methodology for improved energy efficiency by modifying ferroalloy production facility --- Version 1.0*	Not Similar
CDM	3	*AM0088 - Air separation using cryogenic energy recovered from the vaporization of LNG --- Version 1.0*	Not Similar
CDM	3	*AM0017 - Steam system efficiency improvements by replacing thermal energy traps and returning condensate --- Version 2.0*	Similar
CDM	3	*AM0018 - Baseline methodology for thermal energy optimization systems --- Version 2.2*	Similar
CDM	3	*AMS-I.I. - Biogas/biomass thermal applications for households/small users --- Version 1.0*	Not Similar
CDM	3	*AMS-II.C.- Demand-side energy efficiency activities for specific technologies --- Version 13.0*	Similar
CDM	3	*AMS-II.F. - Energy efficiency and fuel switching measures for agricultural facilities and activities --- Version 9.0*	Similar
CDM	3	*AMS-II.G. - Energy Efficiency Measures in Thermal Applications of Non-Renewable Biomass --- Version 2.0*	Not Similar
CDM	3	*ACM0005 - Consolidated Baseline Methodology for Increasing the Blend in Cement Production --- Version 5.0*	Not Similar
CDM	3	*AMS-III.B. - Switching fossil fuels --- Version 15.0*	Similar
CDM	3	*AMS-II.E. - Energy efficiency and fuel switching measures for buildings*	Similar
CDM	*3*	*AMS-II.J. - Demand-side activities for efficient lighting technologies*	Similar
CDM	*3*	*AMS-II.K. - Installation of co-generation or tri-generation systems supplying energy to commercial building*	Not Similar

Program	Sectoral Scope	Title	Similarity
CDM	3	*AMS-II.L. - Demand-side activities for efficient outdoor and street lighting technologies*	Similar
CDM	*3*	*AMS-II.M. - Demand-side energy efficiency activities for installation of low-flow hot water savings devices*	Similar
CDM	3	*AMS-III.AE. - Energy efficiency and renewable energy measures in new residential buildings*	Similar
CDM	3	*AMS-III.AL. - Conversion from single cycle to combined cycle power generation*	Similar
CDM	3	*AMS-III.AV. - Low greenhouse gas emitting water purification systems*	Similar
CDM	3	*AMS-III.X. - Energy Efficiency and HFC-134a Recovery in Residential Refrigerators*	Not Similar
CDM	13	*AM0039 - Methane emissions reduction from organic waste water and bioorganic solid waste using co-composting*	Similar
CDM	13	*AM0057 - Avoided emissions from biomass wastes through use as feed stock in pulp and paper production or in bio-oil production*	Similar
CAR	13	*CAR - Organic Waste Composting Project Protocol*	Similar
CDM	13	*AM0073 - GHG emission reductions through multi-site manure collection and treatment in a central plant*	Not Similar
CDM	13	*AM0083 - Avoidance of landfill gas emissions by in-situ aeration of landfills*	Not Similar
CDM	13	*ACM0014 - Mitigation of greenhouse gas emissions from treatment of industrial wastewater*	Not Similar
CAR	13	*CAR - Landfill Project Protocol*	Not Similar
CDM	13	*AMS-III.AJ. - Recovery and recycling of materials from solid wastes*	Similar
CDM	13	*AM0025 - Avoided emissions from organic waste through alternative waste treatment processes*	Similar
CDM	13	*AM0073 - GHG emission reductions through multi-site manure collection and treatment in a central plant*	Not Similar
CDM	13	*ACM0001 - Consolidated baseline and monitoring methodology for landfill gas project activities*	Similar
CDM	13	*ACM0010 - Consolidated baseline methodology for GHG emission reductions from manure management systems*	Not Similar

Program	Sectoral Scope	Title	Similarity
CDM	13	*ACM0014 - Mitigation of greenhouse gas emissions from treatment of industrial wastewater*	Not Similar
CDM	13	*AMS-III.G. - Landfill methane recovery*	Similar
CDM	13	*AMS-III.H. - Methane recovery in wastewater treatment*	Not Similar
CDM	13	*AMS-III.AF. - Avoidance of methane emissions through excavating and composting of partially decayed municipal solid waste (MSW)*	Not Similar
CDM	13	*AMS-III.L. - Avoidance of methane production from biomass decay through controlled pyrolysis*	Not Similar
CDM	13	*AMS-III.AO. - Methane recovery through controlled anaerobic digestion*	Not Similar
CDM	13	*AM0039 - Methane emissions reduction from organic waste water and bioorganic solid waste using co-composting*	Not Similar
CDM	13	*AM0057 - Avoided emissions from biomass wastes through use as feed stock in pulp and paper, cardboard, fiberboard or bio-oil production*	Not Similar
CDM	13	*AM0080 - Mitigation of greenhouse gases emissions with treatment of wastewater in aerobic wastewater treatment plants*	Not Similar
CDM	13	*AM0083 - Avoidance of landfill gas emissions by in-situ aeration of landfills*	Not Similar
CDM	13	*AM0093 - Avoidance of landfill gas emissions by passive aeration of landfills*	Not Similar
CDM	13	*AMS-III.E. - Avoidance of methane production from decay of biomass through controlled combustion, gasification or mechanical/ thermal treatment*	Similar
CDM	13	*AMS-III.F. - Avoidance of methane emissions through controlled biological treatment of biomass*	Not Similar
CDM	13	*AMS-III.I. - Avoidance of methane production in wastewater treatment through replacement of anaerobic systems by aerobic systems*	Not Similar
CDM	13	*AMS-III.Y. - Methane avoidance through separation of solids from wastewater or manure treatment systems*	Not Similar
CDM	13	*ACM0001 - Consolidated baseline and monitoring methodology for landfill gas project activities*	Similar
CDM	13	*ACM0010 - Consolidated baseline methodology for GHG emission reductions from manure management systems*	Not Similar

Program	**Sectoral Scope**	**Title**	**Similarity**
CDM	13	*ACM0014 - Mitigation of greenhouse gas emissions from treatment of industrial wastewater*	Not Similar
VCS	3	*Methodology for Weatherization of Single Family and Multi-family Buildings*	Similar

Table of Contents

1 SOURCES

These documents have been drawn upon heavily in the development of this methodology. Throughout the text the short form reference (PUBLISHER, YEAR) will be used to indicate areas where the sources were drawn upon most heavily.

This methodology complies with the principles of:

- *ISO 14064*: Part 2, "Specification with guidance at the project level for the quantification, monitoring and reporting of greenhouse gas emission reductions and removal enhancements*"* (ISO, 2006).
- VCS, *VCS Standard*, Version 3 (VCS, Version 3)

This methodology also draws ideas from the latest approved version of the following CDM tools:

- CDM, *Tool to Calculate the Emission Factor for an Electricity System* (Version 2.2.0) (CDM, 2011) and
- CDM, *Combined Tool to Identify the Baseline Scenario and Demonstrate Additionality* (Version 3.0.1) (CDM, 2011).

The energy efficiency approach within has been based on elements of the following methodologies:

- Direct Energy's, *GHG Quantification Protocol for Energy Efficiency in Commercial and Institutional Buildings* (Direct Energy, 2009);
- Alberta Offset System, Protocol, *GHG Quantification Protocol for Energy Efficiency in Commercial and Institutional Buildings* (AENV, 2010);
- Alberta Offset System, Protocol, *Quantification Protocol For Energy Efficiency Projects* (Version 01) (AENV, 2007);
- IPMVP - Efficiency Valuation Organization (EVO-1000-1, 2010) in its International Performance Measurement and Verification Protocol (IPMVP) (www.evo-world.org) for guidance on methods determining energy savings.[1]

This waste diversion approach within has been based on elements of the following methodologies:

- CDM, AM0039, *Methane Emissions Reduction from Organic Waste Water and Bioorganic Solid Waste using Co-composting* (Version 02) (CDM, 2007).
- CDM, *Tool to Determine Methane Emissions Avoided from Disposal of Waste at a Solid Waste Disposal Site* (Version 6.0) (CDM, 2011)
- CCX "Avoided Emissions from Organic Waste Disposal Offset Project Protocol" (CCX, 2009);

[1] IPMVP is a recognized international standard for measuring, monitoring, and verifying energy savings.

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology provides a framework for the quantification of emission reductions for grouped projects[2], where energy efficiency and solid waste diversion activities have been initiated by a Sustainable Community Service Promoter for an assortment of Client Facilities grouped in a Territory. This methodology requires that the SCSP uses a consolidated, Information and Communication Technology-enabled data monitoring and collection system to track project activity data. Even though the activities of Client Facilities vary, energy consumption and waste management are similar across many businesses and organizations. This methodology is meant to work with and support the provision of single window reporting and measurement provided by a third party to capture the information required to quantify emissions reductions.

3 DEFINITIONS

This sub-section introduces important terminology to ensure the project proponent and validation/verification bodies (VVBs) share common understandings of the various roles, parties and grouping systems involved in this methodology.

Client Facility	A large range of small companies or business units that contract the Sustainable Community Service Promoter to manage their GHG emitting services. Client Facilities may include commercial, institutional, residential and industrial buildings/facilities including but not limited to warehouses, apartment buildings, hotels, restaurants, educational buildings, shopping malls, food manufacturing plants, chemical manufacturing facilities, and light industrial plants. Client Facilities are typically located in regional or state clusters.
Sustainable Community (SC)	A Sustainable Community is as a collection of Client Facilities that have undertaken common actions (usually initiated by the SCSP) to reduce their overall GHG emissions.

[2] See *VCS Standard* for grouped project requirements.

Sustainable Community Service Promoter (SCSP)	An independent entity, which acts as the project proponent, providing essential consultation services in the fields of energy and waste to Client Facilities to stimulate greenhouse gas (GHG) reduction activities. SCSPs add value to Client Facilities by implementing Information and Communication Technology-enabled electronic tracking platforms, monitoring technologies, and emission reduction activities. In providing services to Client Facilities, SCSPs contractually maintain ownership of the environmental attributes associated with actions that reduce the Client Facilities overall GHG emissions.
Territory	A grouping of Client Facilities which belong to a common industrial or geographic cluster, where the regional conditions (i.e. electricity source, climate, waste processing schemes, etc.) and regulations (i.e. waste and emission regulations, etc.) are similar for the different facilities; where homogeneous emission factors for fossil combustibles and identifiable emission factor for the electricity grid can be applied; and where common energy efficiency activities and waste processing activities are possible. The Territory concept has been applied to facilitate VVB sampling procedures, though sampling resolutions are ultimately to be determined by the VVB based on a risk assessment of the project and project controls.

This sub-section introduces data, sampling, and conceptual terminologies that are important to how emission reductions are quantified and monitored under this methodology.

Baseline Adjustments	The non-routine adjustments arising during the monitoring period from changes in: 1) any energy governing characteristic of the facility within the measurement boundary, except the named independent variables used for routine adjustments (EVO 10000-1, 2010); or 2) any waste governing characteristic of the facility within the measurement boundary (for example, total production).
Baseline Period	The period of time chosen to represent operation of the facility or system before implementation of an Energy Conservation Measure or waste reduction/diversion activities. This period may be as short as the time required for an instantaneous measurement of a constant quantity, or long enough to reflect one full operating cycle of a system or facility with variable operations.

Confidence Interval	A confidence interval (CI) is a particular kind of interval estimate of a population parameter and is used to indicate the reliability of an estimate. It is an observed interval (i.e. it is calculated from the observations), in principle different from sample to sample, that frequently includes the parameter of interest, if the experiment is repeated. How frequently the observed interval contains the parameter is determined by the confidence interval or confidence coefficient.
Estimate	A process of determining a parameter used in a savings calculation through methods other than measuring it in the baseline and monitoring periods. These methods may be based on secondary data or engineering assumptions and estimates derived from manufacturer's rating of equipment performance. Equipment performance tests that are not made in the place where they are used during the monitoring period shall be considered as estimates.
Facility	The collection of units, excluding the Project Unit. As such, the greenhouse emissions from the facility are defined to remain constant as only the Project Unit is impacted by the project. Where the Project Unit encompasses the entire site, there may be no components defined as the Facility at the site.
Functional Equivalence	The project and the baseline shall provide the same function and quality of products or services. This type of comparison requires a common metric or unit of measurement (such as the mass of cardboard diverted from landfill for mass of finished furniture, energy use/per unit of product) for comparison between the project and baseline activity.
Information and Communication Technology (ICT)	Information and Communication Technology that is applied through an electronic tracking platform for each Client Facility. An electronic account and the effective electronic link between all Client Facilities inside a Territory to stimulate, to support and measure their GHG related activities. SCSPs employ an ICT-enabled GHG monitoring system.

Measurement Boundary	A notional boundary drawn around equipment and/or systems to segregate those which are relevant to savings determination from those which are not. All energy uses of equipment or systems within the measurement boundary must be measured or estimated, whether the energy uses are within the boundary or not (EVO 10000-1, 2010)
Non-Routine Adjustments	Calculations that account for changes in Static Factors within the measurement boundary since the baseline period. Examples of changes in Static Factors that require non-routine adjustments include the facility size, product types, building envelope characteristics, indoor environment and occupancy characteristics. Non-routine adjustments applied to the baseline are sometimes referenced as “baseline adjustments” (EVO 10000-11, 2010). For this quantification protocol, non-routine adjustments also account for changes in the “surplus” characteristics of the project.
Primary Data	Observed data from specific facilities linked to the SCSP tracking system.
Project Unit	A project activity instance wherein the equipment, processes and facilities are being serviced and impacted by the energy efficiency and waste diversion processing project. The Project Unit must be clearly defined and justified by the project proponent. All non-Project Unit items are covered under the heading of facility operation.
Routine Adjustments	The calculations made by a formula, as shown in the energy efficiency and waste diversion monitoring plans, to account for changes in selected independent variables within the measurement boundary since the baseline period (EVO 10000-11, 2010), not including any changes to Static Factors.
Secondary Data	Generic- or industry-average data from published sources that are representative of Project unit Activities and Client Facility products.
Static Factors	Those characteristics of a Client Facility which affect energy use and waste volume produced, within the chosen measurement boundary. These characteristics include fixed, environmental, operational and maintenance characteristics. They may be constant or varying (EVO 10000-11, 2010).

Standard Deviation — The standard deviation, denoted by *s* and is defined as follows:

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2},$$

where $\{x_1, x_2, \ldots, x_N\}$ are the observed values of the sample items and $\overline{x}$ is the mean value of these observations.

Suggested Sample Size — While the ultimate level of sampling must be determined by the VVB, the project proponent may provide a suggested number of Sustainable Community Project Units to be physically verified.

Unit of Productivity — The unit of productivity is to be defined by the project proponent as a basis for incorporating Functional Equivalence within the calculation methodology. Examples of units of productivity could be: energy requirements for residential buildings, per square foot of front of house commercial space, per kg/L/m2/m3 of output from manufacturing facilities, etc. The unit of productivity shall be defined to account for any non-production sensitive components. In all cases the project proponent must thoroughly justify their assessment of the appropriate unit of productivity.

Verified Data Feedback Loop — After each verification cycle, verified SCSP Client Facility data may be used to increase the confidence interval on any estimated values included in the baseline or project scenarios. Examples of such situations could include replacing regional factors for a specific facility with a more accurate waste or energy profile of the specific Client Facility based on measured data, providing it can still be related to the baseline period. This verified data feedback loop could ultimately result in adjustments that both increase or decrease emission reduction assertions in future years. The adjustments would not be retroactive to previously serialized offsets.

These definitions apply to the energy efficiency components of GHG quantification described herein.

Adjusted-baseline energy — The energy use of the baseline period, adjusted to a different set of operating conditions (EVO 10000-11, 2010).

Baseline Energy — The energy use occurring during the baseline period without adjustments (EVO 10000-11, 2010).

Cycle	The period of time between the start of successive similar operating modes of a facility or piece of equipment whose energy use varies in response to operating procedures or independent variables. For example, the cycle of most buildings is 12 months, since their energy use responds to outdoor weather which varies on an annual basis. Another example is the weekly cycle of an industrial process which operates differently on Sundays than during the rest of the week (EVO 10000-11, 2010).
Energy Conservation Measure (ECM)	An activity or set of instances designed to increase the energy efficiency of a facility, system or piece of equipment. ECMs may also conserve energy without changing efficiency. Several ECMs may be carried out in a facility at one time, each with a different thrust. An ECM may involve one or more of: physical changes to facility equipment, revisions to operating and maintenance procedures, software changes, or new means of training or managing users of the space or operations and maintenance staff. An ECM may be applied as a retrofit to an existing system or facility, or as a modification to a design before construction of a new system or facility.

These definitions apply to the waste diversion components of GHG quantification described herein.

Alternative Processing	Refers to recycling, reusing, reduction and re-processing activities which are applied as part of the project to divert waste from reaching a landfill.
Biodegradability	Biodegradability is the capability of a substance to break down into simpler substances, especially into innocuous products, by the actions of living organisms (that is, microorganisms).
Composting	The process of collecting, grinding, mixing, piling, and supplying sufficient moisture and air to organic materials to speed natural decay. The finished product of a composting operation is compost, a soil amendment suitable for incorporating into topsoil and for growing plants. Compost is different than mulch, which is a shredded or chipped organic product placed on top of soil as a protective layer.
Destinations	The ultimate destination for waste being shipped by the project. This is the location where the waste would be unloaded from a truck after having been shipped from project Origins.

Disposal	Final stage in the management of waste, which includes: treatment of waste prior to disposal, incineration of waste, with or without energy recovery, deposit of waste to land or water, discharge of liquid waste to sewer, and permanent, indefinite or long term storage of waste.
Diversion	For waste measurement purposes, diversion is any combination of waste prevention (source reduction), recycling, reuse and composting instances that reduces waste disposed at authorized landfills and transformation facilities.
Landfill Gas (LFG)	Gas generated by biological decomposition of waste material in a landfill. The gas is typically comprised of methane, carbon dioxide, other trace gases and water vapor.
Origins	Starting points for waste being shipped by the project. This is the location where the waste would be loaded onto a truck or train for ultimate delivery to Destinations.
Producer	Refers to the Client Facility that produces the waste to be disposed of.
Process Emissions	Process emissions are direct emissions from sources directly associated with production that involve chemical or physical reactions, other than combustion, and where the primary purpose of the process is not energy production.
Recycling	The process of collecting, sorting, cleansing, treating, and reconstituting materials that would otherwise become solid waste, and returning them to the economic mainstream in the form of raw material for new, reused, or reconstituted products that meet the quality standards necessary to be used in the marketplace.

Waste	All type of wastes, regulated or not regulated, hazardous or non-hazardous and generated by citizens under the municipal umbrella (Municipal Solid Waste (MSW)) or by others sources such as an Industrial, Commercial and Institutional (ICI) business unit. This definition of the wastes defined by the Basel Convention http://www.basel.int/ in the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal in the article 2 and referred to Annex I and II, shall apply for all types of wastes. Notice this UN international convention respect the full right of country to define their wastes (article 2 item 1).
Waste Transformation	Incineration, pyrolysis, distillation, gasification, or biological conversion other than composting.
Waste Management	All types of waste management operations, disposal and recycling applied for all types of wastes shall refer to the definition used by the Basel Convention http://www.basel.int/ in the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal in article 2 and referred to Annex IV. Notice this UN international convention respect the full right of country to define their management wastes operations (article 2).

4 APPLICABILITY CONDITIONS

This methodology is applicable for grouped projects for the quantification of direct and indirect reductions of GHG emissions arising from energy efficiency and waste management project activity instances at client facilities (project units).

The requirements of this methodology have been designed to meet micro energy efficiency and/or waste diversion project units where the maximum emission reductions from an individual project unit is 5,000 tCO_2e/year. Therefore, through a combination of energy efficiency and waste management activities, project units within a grouped project could have a maximum combined abatement threshold of 10,000 tCO_2e/year. While each client facility, or project unit, may only contribute a modest abatement (10,000 tCO_2e/year or less), the total sum of abatement from all project units within this entire grouped project may exceed the combined threshold of 10,000 tCO_2e/year.

This methodology is applicable for grouped projects for the quantification of direct and indirect reductions of GHG emissions arising from energy-efficiency and waste-diversion projects at client facilities. Projects can be located in residential, commercial, institutional, or industrial buildings/facilities. The project proponent must demonstrate right of use in respect of the project's GHG emission reductions, which may, for example, entail securing right of use from client facilities.

<u>Energy Efficiency</u>

This methodology is applicable to ECMs where the project activity is the construction of new facilities, the retrofit of existing facilities, or process/management changes of existing facilities that result in a reduction of energy use per unit of productivity. The ECMs must occur in conjunction with the following:

- Building envelope modifications
- Heating, ventilation and air conditioning (HVAC)
- Heat generation (including industrial thermal energy systems)
- Chilling/cooling systems
- Lighting and lighting control
- Building mechanical infrastructure
- Appliances and industrial processes (including heating and cooling requirements and process modification)
- Electric motors
- Equipment optimization

The following guidance provides further clarification on energy efficiency activities, approach and applicability:

a. The project proponent must document the useful life of the ECMs and the remaining useful life of the existing baseline equipment and ensure that the project unit(s) is not credited beyond the useful life of the ECM or remaining useful life of the existing technology in the baseline scenario. If capital stock equipment that was originally measured in the baseline for a given project crediting period is replaced during a project crediting period, it can only be considered additional, and in turn be able to generate GHG credits, if it was retired prior to its natural capital stock rotation as indicated in the initial documentation of useful life. If capital stock enters the end of its useful life prior to the end of a project crediting period and is replaced, any emission reduction attributable to this replacement technology must not be considered towards generating credits, and shall lower the facility baseline by a sum equal to the difference in emissions between the previous capital stock equipment and the replacement capital stock equipment.

b. By reducing energy consumption, applicable projects will reduce GHG emissions associated with the conversion of primary energy sources to secondary forms of energy (e.g., electricity, heat, mechanical energy, etc.).

c. This methodology is also applicable to activities generating GHG emission reductions related to improvements in combustion efficiency[3]. This applies to projects involving switching from one energy generation method to a less GHG-intensive energy generation method. In this case, this methodology only quantifies emissions reductions from fuel switching that occur within the project boundary. Fuel switching associated with large energy suppliers, which

[3] There must not be double counting between activities related to improvements in combustion efficiency and any energy efficiency activities within the project.

have emission reductions that exceed the established threshold of this methodology, are not intended to be quantified using this protocol. Only small on-site power sources, with emission reductions within the threshold limit of this methodology, are applicable for inclusion within the methodology. This separation of large offsite generation and the project removes risk of double counting. A net emission reduction and efficiency improvement would be achieved by such activities so long as a net reduction in overall greenhouse gas emissions per unit of productivity is achieved. The production of energy, particularly from fossil energy sources, has significant associated GHG emissions (typically combustion-related), including both direct and indirect sources.

d. Biological or chemical components of the operation must not yield any increase in non-biogenic greenhouse gas emissions compared to the baseline scenario, unless these are accounted for under the applicable flexibility mechanisms as indicated by an affirmation from the project proponent.

Waste Diversion

This methodology is applicable where the project activity is the diversion of waste for other productive uses and alternative disposal options. This methodology is only applicable to quantify emission reductions associated with methane avoidance. This methodology is not approved for quantifying emission reductions associated with landfill gas flaring or electricity/energy production. This methodology is applicable to the following activities:

- Card board recycling
- Organic composting
- Aerobic decomposition

5 PROJECT BOUNDARY

5.1 Project

The project proponent shall identify all GHG sources and sinks (SS) relevant to the project such as:

- Production of electricity
- Maintenance, construction and decommissioning
- Decomposition of solid waste in landfills.

The process set out in Diagram 1 identifies, illustrates and organizes SS for a typical project applicable under this methodology. Table 1 describes each SS identified in Diagram 1, discusses the SS relevance and characterizes the SS as controlled, related or affected by the project activity.

Since this methodology has been written to work for various types of project activities, one single project boundary cannot be provided. The project proponent shall use the requirements set out in this section to clearly define the most appropriate boundary for each grouping of client facilities with appropriate justifications for the inclusion or exclusion of SS. This shall include unique geo-coordinates if the projects are implemented across several dispersed locations.

For energy efficiency activities, it is important to note that the site boundaries are determined by whether the project proponent elects to quantify using “Option A – Isolation Parameter Measurement” or “Option B – Whole Facility Measurement.”

If Option A, Isolation Parameter Measurement, is selected, savings are determined by measuring the energy use of the ECM affected system, rather than the entire building. As such the boundary chosen is the ECM affected system. In this case, clear justification must be provided at the Territory level by the project proponent that the ECM affected system would have no material impact on the operation and emissions of the whole or remaining facility. Functional equivalence and unit of productivity adjustments for the ECM affected system must be made to the baseline of the system.

If Option B, Whole Facility Measurement, is selected, energy use for the entire facility is measured and any savings are calculated accordingly and therefore the boundary chosen is the entire facility. In this case, clear justification must be provided at the Territory level by the project proponent that the entire building’s baseline meets functional equivalence and has been adjusted by units of productivity.

Regardless of which option is selected, the project energy use calculations shall be done according to the methodology documents in IPMVP’s “Concepts and Options for Determining Energy and Water Savings (Volume 1)” (EVO, 2010). For waste diversion activities, the project proponent must use “Whole Facility Measurement” to determine the site boundaries. This means that if the project proponent is including waste diversion activities, then an isolated component of the facility cannot be used, the entire facility’s facility and waste stream must be included in the boundary. The project and baseline element life cycle charts are shown in Diagrams 1 and 2, respectively. Project documentation shall include diagrams that disclose the locations and processes of metering equipment used in determining the mass energy flows.

Diagram1: Project Element Life Cycle Chart

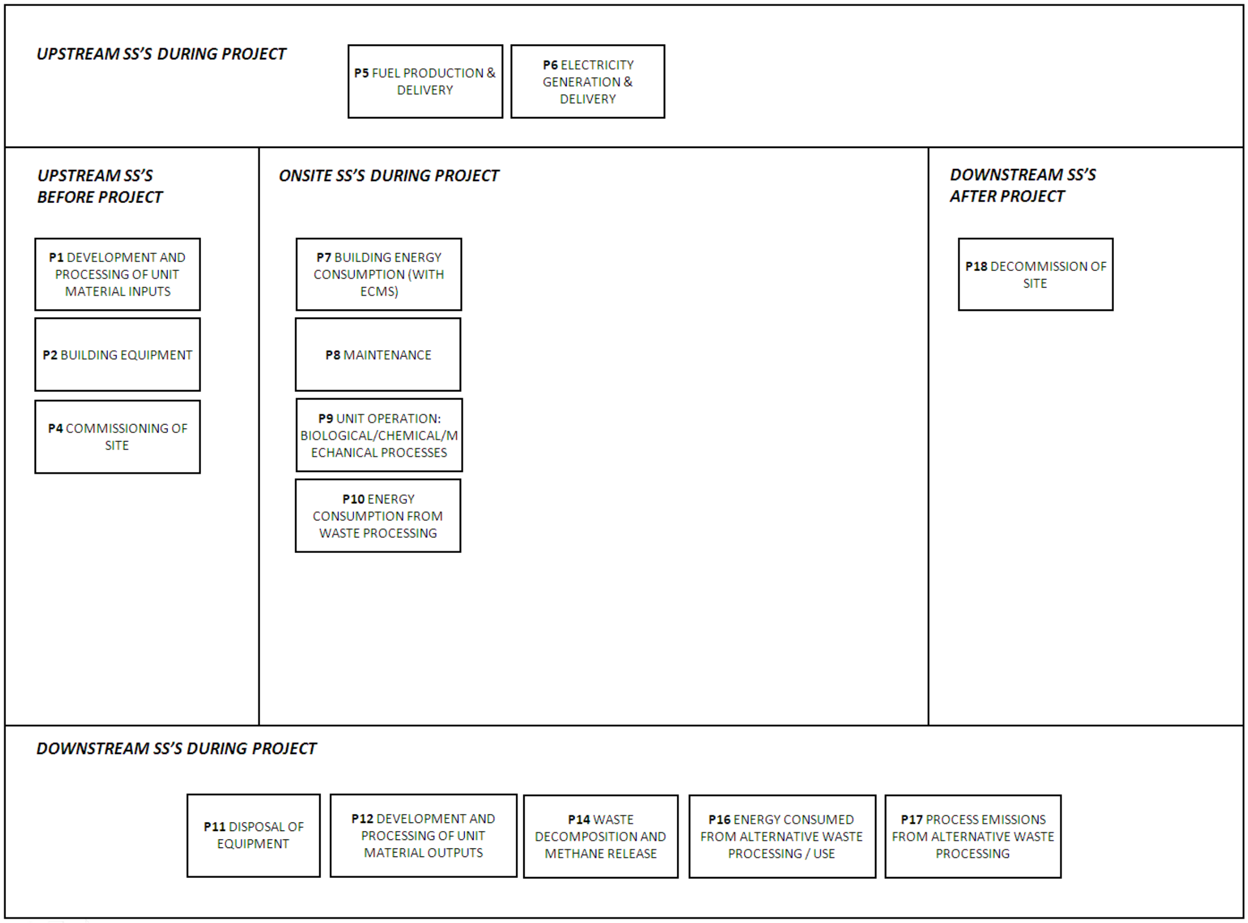

Table 1: Project Life Cycle SS Descriptions

SS	Description	Controlled, Related or Affected
Upstream Before Project		
P1 Development and Processing of Unit Material Inputs	The material inputs to the unit process need to be transported, developed and/or processed prior to the unit process. This may require any number of mechanical, chemical or biological processes. All relevant characteristics of the material inputs would need to be tracked to prove functional equivalence with the baseline scenario.	Related
P2 Building Equipment	GHG emissions arise from the manufacturing process of the equipment to implement the ECMs and conventional building/facility operation in the project. Such emissions are likely associated with the fossil fuels and electricity consumed during the manufacturing process.	Related

P4 Commissioning of Site	The development of the site (technically onsite before project) and installation of equipment result in GHG emissions, primarily from the use of fossil fuels and electricity during this process.	Related
Upstream During Project		
P5 Fuel Production & Delivery	The production and distribution of fuel used during building/facility operations result in GHG emissions. The volume and type of fuel shall be required for GHG emission calculations, as is the distribution distance.	Related
P6 Electricity Generation & Delivery	Building/facility operations could require significant amounts of electricity. The generation and distribution of electricity results in GHG emissions.	Related
Onsite During Project		
P7 Building/System Energy Consumption (with ECMs)	Energy (including fossil fuel and electricity) is likely required on-site to operate the building/facility. Equipment utilizing this energy could include boilers, lighting systems, HVAC Systems, ventilation systems, equipment, etc.	Controlled
P8 Maintenance	The facility and systems within the facility likely requires maintenance. GHG emissions arise from the use of fuels and electricity in maintenance procedures.	Controlled
P9 Unit Operation: Biological/Chemical /Mechanical Processes	Greenhouse gas emissions may occur that are associated with the operation and maintenance of the biological processes (biological, chemical, and mechanical) within the unit at the project site. All relevant characteristics of the biological processes would need to be identified.	Controlled
P10 Energy Consumption from Waste Processing	Energy may be required to power waste processing or handling equipment (i.e. compacters, etc.)	Controlled
Downstream During Project		
P11 Disposal of Equipment	The disposal of some materials/equipment which compose all or a component of the ECM or waste diversion systems may result in GHG emissions.	Related
P12 Development and Processing of Unit Material Outputs	The material outputs from the unit process need to be transported, developed, and/or processed subsequent to the unit process. This may require any number of mechanical, chemical or biological processes. All relevant characteristics of the material outputs would need to be identified to prove functional equivalence with the baseline scenario.	Related

P14 Waste Decomposition and Methane Release	Waste may decompose in the disposal facility (typically a landfill site) resulting in the production of methane. A methane collection and destruction system may be in place at the disposal site. If such a system is active in the landfill or the area of the landfill where this material is being disposed, then its characteristics must be identified and the efficiency (ie, percent of total methane generation that is capture and destroyed) must be accounted for in a reasonable manner. Disposal site characteristics, mass disposed at each site, and methane collection and destruction system characteristics may need to be identified.	Related
P16 Energy Consumed from alternative processing of waste/use	Energy may be consumed by the alternative processing waste diversion activity. The related energy inputs for fueling this equipment are identified under this SS, for the purpose of calculating the resulting GHG emissions.	Related
P17 Process Emissions from Alternative Processing of Waste	This SS encompasses any process emissions associated with the new method of handling waste. Any process emissions related to the alternative use or disposal of the solid waste must be measured or estimated. All relevant characteristics of these processes would need to be identified.	Related
Downstream After Project		
P12 Decommission of Site	Once the facility is no longer operational, the site may need to be decommissioned. This may involve the disassembly of the equipment, demolition of on-site structures, disposal of some materials, environmental restoration, re-grading, planting or seeding, and transportation of materials off-site. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site.	Related

5.2 Baseline

All SS relevant to the baseline, including on-site, upstream and downstream SS shall be identified.

The process set out in Diagram 2 identifies, illustrates and organizes SS for a typical baseline applicable under this methodology. Table 2 describes each SS identified in Diagram 2, discusses the SS relevance and characterizes the SS as controlled, related, or affected by the project activity.

Diagram 2: Baseline Life Cycle Chart

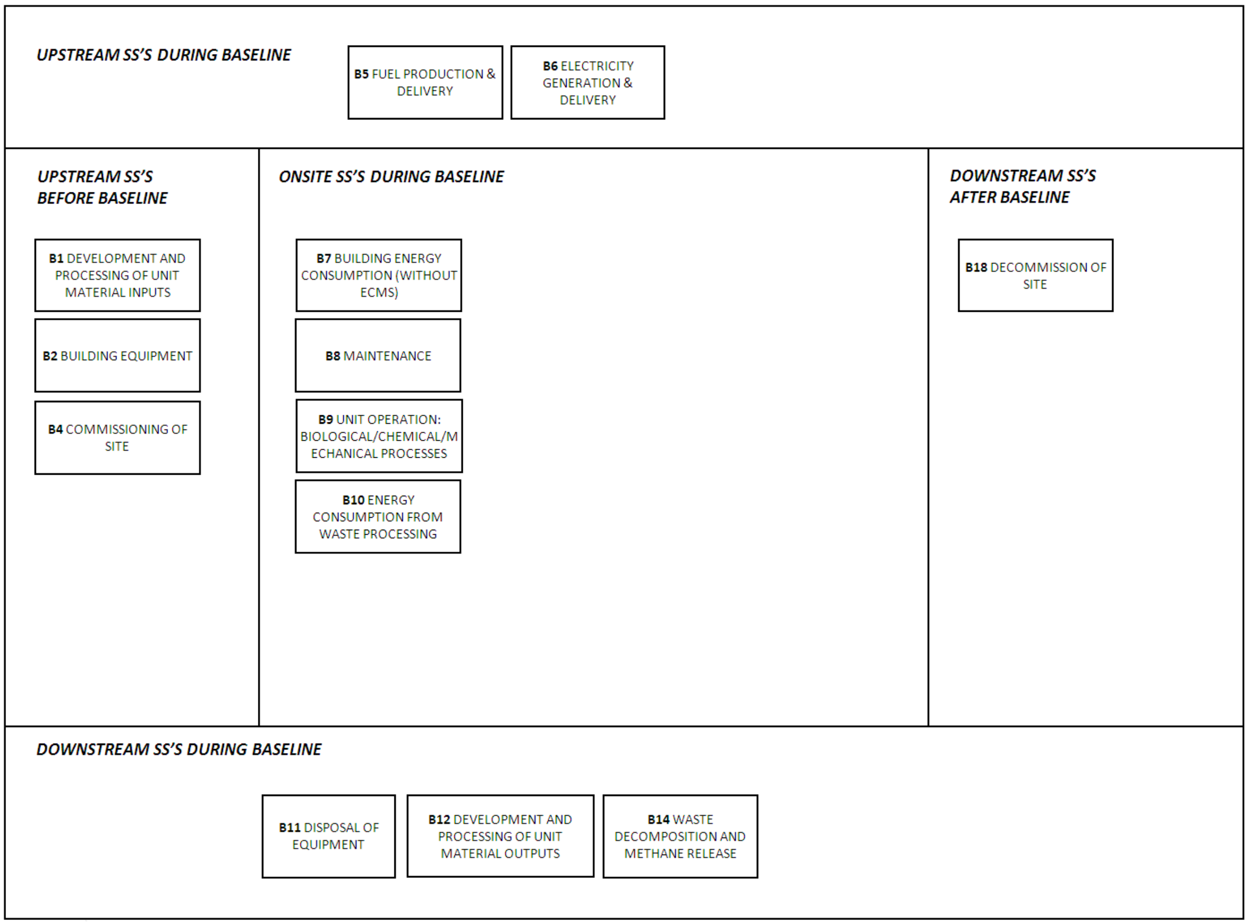

Table 2: Baseline Element Life Cycle SS Descriptions

SS	Description	Controlled, Related or Affected
	Upstream During Baseline	
B1 Development and Processing of Unit Material Inputs	The material inputs to the unit process need to be transported, developed and/or processed prior to the unit process. This may require any number of mechanical, chemical or biological processes. All relevant characteristics of the material inputs would need to be identified to prove functional equivalence with the baseline scenario.	Related
B2 Building Equipment	GHG emissions arise from the manufacturing process of the equipment to implement the ECMs and conventional building/facility operation in the project. Such emissions are likely associated with the fossil fuels and electricity consumed during the manufacturing process.	Related
B4 Commissioning of Site	The development of the site (before project) and installation of equipment results in GHG emissions, primarily from the use of fossil fuels and electricity during this process.	Related
	Upstream Before Baseline	
B5 Fuel Production & Delivery	The production and distribution of fuel used during building/facility operations results in GHG emissions. The volume and type of fuel shall be required for GHG emission calculations, as is the distribution distance.	Related
B6 Electricity Generation & Delivery	Building/facility operations could require significant amounts of electricity. The generation and distribution of electricity results in GHG emissions.	Related
	Onsite During Baseline	
B7 Building/System Energy Consumption (without ECMs)	Energy (including fossil fuel and electricity) is likely required on-site to operate the building/facility. Equipment utilizing this energy could include boilers, lighting systems, HVAC Systems, ventilation systems, equipment, etc.	Controlled
B8 Maintenance	The facility and systems within the facility likely requires maintenance. GHG emissions arise from the use of fuels and electricity in maintenance procedures.	Controlled
B9 Unit Operation: Biological/Chemical/ Mechanical Processes	GHG emissions may occur that are associated with the operation and maintenance of the biological processes (biological, chemical, and mechanical) within the unit at the project site. All relevant characteristics of the biological processes would need to be identified.	Controlled

B10 Energy Consumption from Waste Processing	Energy may be required to power waste processing or handling equipment (i.e. compacters, etc.)	Controlled
Downstream During Baseline		
B11 Disposal of Equipment	The disposal of some materials/equipment which compose all or a component of the ECM or waste diversion systems may result in GHG emissions.	Related
B12 Development and Processing of Unit Material Outputs	The material outputs from the unit process need to be transported, developed, and/or processed subsequent to the unit process. This may require any number of mechanical, chemical or biological processes. All relevant characteristics of the material outputs would need to be identified to prove functional equivalence with the baseline scenario.	Related
B14 Waste Decomposition and Methane Release	Waste may decompose in the disposal facility (typically a landfill site) resulting in the production of methane. A methane collection and destruction system may be in place at the disposal site. If such a system is active in the landfill or the area of the landfill where this material is being disposed, then its characteristics must be identified and the efficiency (ie, percent of total methane generation that is capture and destroyed) must be accounted for in a reasonable manner. Disposal site characteristics and mass disposed of at each site may need to be identified.	Related
Downstream After Baseline		
B15 Decommission of Site	Once the facility is no longer operational, the site may need to be decommissioned. This may involve the disassembly of the equipment, demolition of on-site structures, disposal of some materials, environmental restoration, re-grading, planting or seeding, and transportation of materials off-site. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment required to decommission the site.	Related

5.3 SS Selection

Each of the SS from the project and baseline scenario shall be compared and evaluated as to their relevancy. The justification for the potential exclusion or conditions upon which the SS may be excluded is provided in Table 3. Negligible emissions have been defined as being less than 1% of the project's lifetime emissions (calculated on an annual basis). Where the SS are to be excluded, they must fall below this threshold. Table 3 includes a generalized assessment that is expected to be accurate for most facilities. However, the project proponent must make an assessment for their specific project and may only exclude emissions that do not exceed the 1% threshold.

Table 3: Process for Selection of SS

Source		**Gas**	**Included?**	**Justification/Explanation**
Baseline	B1 Development and Processing of Unit Material Inputs	CO_2	[Excluded]	Expected to be excluded as they must be functionally equivalent to allow for the application of the methodology.
		CH_4	[Excluded]	
		N_2O	[Excluded]	
	B2 Building Equipment	CO_2	[Excluded]	Expected to be excluded since emissions from manufacturing of building equipment are expected to be negligible over the lifetime of the project.
		CH_4	[Excluded]	
		N_2O	[Excluded]	
	B4 Commissioning of Site	CO_2	[Excluded]	Expected to be excluded since emissions from site development are expected to be negligible given the minimal site development typically required.
		CH_4	[Excluded]	
		N_2O	[Excluded]	
	B5 Fuel Production & Delivery	CO_2	[Excluded]	Expected to be excluded since emissions from fuel production and delivery are expected to be greater under the baseline scenario.
		CH_4	[Excluded]	
		N_2O	[Excluded]	
	B6 Electricity Generation & Delivery	CO_2	[Excluded]	Expected to be excluded since emissions from electricity generation and delivery are expected to be greater under the baseline scenario.
		CH_4	[Excluded]	
		N_2O	[Excluded]	
	B7 Building/System Energy Consumption (without ECMs)	CO_2	Included	Must be included as part of baseline if energy efficiency actions are included in the project activity since this SS is fundamental to quantifying the baseline for EE emission reductions under this methodology.
		CH_4	Included	
		N_2O	Included	

Source		Gas	Included?	Justification/Explanation
	B8 Maintenance	CO_2	Included	Must be included, though can be excluded if the baseline and project scenarios would involve immaterial difference in energy consumed for maintenance activities.
		CH_4	Included	
		N_2O	Included	
	B9 Unit Operation: Biological/Chemical/ Mechanical Processes	CO_2	Included	Must be included, though can be excluded if prescribed to be functionally equivalent.
		CH_4	Included	
		N_2O	Included	
	B10 Energy Consumption from Waste Processing	CO_2	Included	Must be included, though can be excluded if the facility or group of facilities is not quantifying emission reductions associated with waste diversion activities and if the ECM activities would not affect the energy consumed for waste processing at the Territory level.
		CH_4	Included	
		N_2O	Included	
	B11 Disposal of Equipment	CO_2	[Excluded]	Expected to be excluded since emissions from disposal of equipment are expected to be negligible.
		CH_4	[Excluded]	
		N_2O	[Excluded]	
	B12 Development and Processing of Unit Material Outputs	CO_2	[Excluded]	Expected to be excluded as they must be functionally equivalent to allow for the application of the methodology.
		CH_4	[Excluded]	
		N_2O	[Excluded]	
	B14 Waste Decomposition and Methane Release	CO_2	Included	Must be included, though can be excluded if the facility or group of facilities is not quantifying emission reductions associated with waste diversion activities and if the ECM activities would not affect the amount methane emitted
		CH_4	Included	
		N_2O	Included	

Source		Gas	Included?	Justification/Explanation
				from decomposition.
	B15 Decommission of Site	CO_2	[Excluded]	Expected to be excluded since emissions from equipment disposal are expected to be negligible.
		CH_4	[Excluded]	
		N_2O	[Excluded]	
Project	P1 Development and Processing of Unit Material Inputs	CO_2	[Excluded]	Expected to be excluded as they must be functionally equivalent to allow for the application of the methodology.
		CH_4	[Excluded]	
		N_2O	[Excluded]	
	P2 Building Equipment	CO_2	[Excluded]	Expected to be excluded since emissions from the manufacture of building equipment are expected to be negligible over the lifetime of the project.
		CH_4	[Excluded]	
		N_2O	[Excluded]	
	P4 Commissioning of Site	CO_2	[Excluded]	Expected to be excluded since emissions from site development are expected to be negligible given the minimal site development typically required.
		CH_4	[Excluded]	
		N_2O	[Excluded]	
	P5 Fuel Production & Delivery	CO_2	[Excluded]	Expected to be excluded since emissions from fuel production and delivery are expected to be greater under the baseline scenario.
		CH_4	[Excluded]	
		N_2O	[Excluded]	
	P6 Electricity Generation & Delivery	CO_2	[Excluded]	Expected to be excluded since emissions from fuel production and delivery are expected to be
		CH_4	[Excluded]	

Source		Gas	Included?	Justification/Explanation
		N_2O	[Excluded]	greater under the baseline scenario.
	P7 Building/System Energy Consumption (with ECMs)	CO_2	Included	Must be included as part of baseline if energy efficiency actions are included in the project activity.
		CH_4	Included	
		N_2O	Included	
	P8 Maintenance	CO_2	Included	Must be included, though can be excluded if the baseline and project scenario operations would involve immaterial difference in energy consumed for maintenance activities. If however maintenance activities included major overhauls that would not have been included in the baseline scenario, evidence must be provided by the project proponent to show the SS is below the negligible emissions threshold.
		CH_4	Included	
		N_2O	Included	
	P9 Unit Operation: Biological/Chemical/Mechanical Processes	CO_2	Included	Must be included, though can be excluded if prescribed to be functionally equivalent.
		CH_4	Included	
		N_2O	Included	
	P10 Energy Consumption from Waste Processing	CO_2	Included	Must be included, though can be excluded if the facility or group of facilities is not quantifying emission reductions associated with waste diversion activities and if the ECM activities would not affect the energy consumed for waste processing.
		CH_4	Included	
		N_2O	Included	
	P11 Disposal of Equipment	CO_2	[Excluded]	Expected to be excluded since emissions from disposal of equipment are expected to be negligible
		CH_4	[Excluded]	
		N_2O	[Excluded]	

Source		Gas	Included?	Justification/Explanation
	P12 Development and Processing of Unit Material Outputs	CO_2	[Excluded]	Expected to be excluded as they must be functionally equivalent to allow for the application of the methodology.
		CH_4	[Excluded]	
		N_2O	[Excluded]	
	P14 Waste Decomposition and Methane Release	CO_2	Included	Must be included, though can be excluded if the facility or group of facilities is not quantifying emission reductions associated with waste diversion activities and if the ECM activities would not affect the amount methane emitted from decomposition.
		CH_4	Included	
		N_2O	Included	
	P16 Energy Consumed from Alternative Processing of Waste / Use	CO_2	Included	Must be included, though can only be excluded if the facility or group of facilities is not quantifying emission reductions associated with alternative processing of waste / use in the project scenario at the Territory level.
		CH_4	Included	
		N_2O	Included	
	P17 Process Emissions from Alternative Processing of Waste	CO_2	Included	Must be included, though can be excluded if the facility or group of facilities is not quantifying emission reductions associated with the alternative processing of waste at the Territory level.
		CH_4	Included	
		N_2O	Included	
	P18 Decommission of Site	CO_2	[Excluded]	Expected to be excluded since emissions from decommissioning are not expected to differ highly between the baseline and project scenarios.
		CH_4	[Excluded]	
		N_2O	[Excluded]	

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO AND DEMONSTRATING ADDITIONALITY

Regardless of the specific project type being proposed, the project proponent must follow the step-wise approach specified in the CDM *Combined Tool to Identify the Baseline Scenario and Demonstrate Additionality* to identify the baseline scenario and demonstrate additionality. The tool shall be applied with baseline alternatives and project scenarios categorized by project units. The cost savings associated with energy efficiency shall be included in the investment analysis.

When selecting the baseline period for waste diversion and energy efficiency activities, the appropriateness of baseline period shall be analyzed for the two activities separately. While one baseline period for both may be deemed appropriate, it is also possible that different baseline periods and approaches are required for the different activities. As one example, the best unit of productivity for the waste diversion baseline period may be different from that for the energy efficiency baseline period depending on the selected unit of productivity and the quality of data available for each.

The baseline scenario shall be determined by analyzing, at minimum, the following potential alternatives:

a. Each business owner proactively exceeds the current regulations and decreases their per unit energy consumption. Additionally, each business owner could also purchase new capital equipment prior to the natural turnover rate of their existing stock, for the purposes of energy efficiency savings, without installing the added monitoring equipment as required to quantify GHG emission reductions. This step is essentially the implementation of the energy efficiency project activity without carbon financing.

b. Each business owner proactively puts into place a system to treat waste in a manner other than anaerobic decomposition in a landfill. This step is essentially the implementation of the waste diversion project activity without carbon financing.

c. The government or industrial sector enforces minimum building codes, not only for new facilities but for the current stock of buildings. These codes could mandate certain levels of efficiency or waste handling that could achieve the anticipated results of this protocol without the use of VCUs.

d. The continuation of the current situation (ie, no project activity or other alternatives undertaken). Comparable outputs of the project – constant energy intensity per production unit and anaerobic decomposition of waste in landfill – will continue. Currently, technologies/ practices that provide outputs/services of comparable qualities, properties and application areas as the proposed project activity, are not incentivized and are not introduced to the market for dispersed client facilities. These facilities do not have the economies of scale necessary to develop and operate the necessary monitoring systems to achieve affordable gains similar to the goals of this protocol.

7 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

Quantification of the reductions, removals and reversals of relevant SS for each of the greenhouses gases must be completed by using the baseline and project emissions equations specified for energy efficiency and waste diversion activities.

If the project proponent chooses to exclude any of the sources from the SS selection (Table 3: Process for Selection of SS

), a detailed justification must be provided for each exclusion.

7.1 Baseline Emissions

$\text{Emissions}_{\text{Adjusted Baseline EE}}$	= the energy efficiency activities related baseline emissions plus any adjustments needed to adjust it to the conditions of the monitoring period
$\text{Emissions}_{\text{Adjusted Baseline EE}}$	$= \text{Emissions}_{\text{Adjusted Building/System Energy Consumption w/o ECM}} + \text{Emissions}_{\text{Adjusted Maintenance}} + \text{Emissions}_{\text{Adjusted Unit Operation}}$

$\text{Emissions}_{\text{Adjusted Building Energy Consumption w/o ECM}}$ = Emissions under SS **B7** Adjusted Building/System Energy Consumption (w/o ECMs)

$\text{Emissions}_{\text{Adjusted Maintenance}}$ = Emissions under SS **B8** Adjusted Maintenance

$\text{Emissions}_{\text{Adjusted Unit Operation}}$ = Emissions under SS **B9** Adjusted Unit Operation: Biological/Chemical/Mechanical Processes

$\text{Emissions}_{\text{Adjusted Baseline WASTE}}$	= the waste related baseline emissions plus any adjustments needed to adjust it to the conditions of the monitoring period
$\text{Emissions}_{\text{Adjusted Baseline WASTE}}$	$= \text{Emissions}_{\text{Adjusted Energy Consumption from Waste Processing}} + \text{Emissions}_{\text{Adjusted Waste Decomposition and Methane Release}}$

$\text{Emissions}_{\text{Adjusted Energy Consumption from Waste Processing}}$ = Emissions under SS **B10** Adjusted Energy Consumption from Waste Processing

$\text{Emissions}_{\text{Adjusted Waste Decomposition and Methane Release}}$ = Emissions under SS **B14** Adjusted Waste Decomposition and Methane Release

7.2 Adjustments

The project proponent may conduct emission adjustments for measuring functional equivalence as well as unit of productivity. The baseline scenario identified for the projects using this methodology may require adjustments to ensure functional equivalence with the project.

In order for this comparison between the project scenario and baseline scenario to be meaningful, the project and the baseline must provide the same function and quality of products or services. This consistency in metrics and units of production provides an ability to quantify actual emissions reductions achieved in the project scenario.

Table 4 provides SS-specific equations for the baseline component of the comparison. Table 5 provides project SS emission adjustment quantification.

In some cases, the project scenario cannot have the same units as the baseline. An example of this would be where the project seeks to displace conventional natural gas with landfill gas. In this case, the common metric would be the energy content of each fuel, reported as energy content/liter of fuel[4].

The project proponent is strongly encouraged to review IPMVP volumes for examples of how to make adjustments for functional equivalence and productivity.

The unit of productivity must be used by the project proponent as a basis for incorporating functional equivalence within the calculation methodology. Examples of units of productivity could be: energy requirements for residential buildings, per square foot of front of house commercial space, per kg/L/m^2/m^3 of output from manufacturing facilities, etc. The unit of productivity shall be defined to account for any non-production sensitive components. In all cases the project proponent must thoroughly justify their assessment of the appropriate unit of productivity.

The project proponent must also justify the selection of data used for deriving the unit of productivity.

Functional equivalence adjustments are usually performed when the energy savings are quantified. In many cases, the quantification and claims of GHG emission reductions shall occur on a yearly basis; therefore, these adjustments need to be performed according to that same schedule. Typical adjustment includes routine adjustments and non-routine adjustments as explained below:

Routine Adjustments of the Baseline

IPMVP provides the following guidance on performing routine adjustments: “For any energy governing factors expected to change routinely during the monitoring period such as weather… a variety of techniques can be used to perform the adjustments. Techniques may be as simple as a constant value (no adjustment) or as complex as a several multiple parameter non-linear equations, each correlating energy with one or more independent variables. Valid mathematical techniques must be used to derive

[4] Ibid.

the adjustment method." The quantification of routine baseline adjustments should reflect best practice set out in the latest IPMVP volume[5].

Non-Routine Adjustments of the Baseline

IPMVP provides examples of non-routine adjustments. The quantification of non-routine baseline adjustments should reflect best practice set out in the latest IPMVP volume.

Table 4: Baseline SS Emission Adjustment Quantification

[5] IPMVP contains examples of routine and non-routine adjustments.

SS	Units	Baseline SS Formula
B7 Building/System Energy Consumption (without ECMs)	kgCO2e	Emissions $_{Building/System\ Energy\ Consumption\ w/o\ ECM}$ = ∑ [(Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; (GWP_{CH4} * Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; (GWP_{N2O} * Vol. Fuel $_i$ * EF Fuel $_{i\ N20}$)] + [Electricity * EF $Grid_{CO2e}$] + [Thermal Energy * EF Thermal $Energy_{CO2e}$]
B8 Maintenance	kgCO2e	Emissions $_{Maintenance}$ = ∑ [(Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; (GWP_{CH4} * Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; (GWP_{N2O} * Vol. Fuel $_i$ * EF Fuel $_{i\ N20}$)] + [Electricity * EF $Grid_{CO2e}$] + [Thermal Energy * EF Thermal $Energy_{CO2e}$]
B9 Unit Operation: Biological / Chemical / Mechanical Processes	kgCO2e	Emissions $_{Unit\ Operation}$ = ∑ [(Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; (GWP_{CH4} * Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; (GWP_{N2O} * Vol. Fuel $_i$ * EF Fuel $_{i\ N20}$)] + [Electricity * EF $Grid_{CO2e}$] + [Thermal Energy * EF Thermal $Energy_{CO2e}$]
B10 Energy Consumption from Waste Processing	kgCO2e	Emissions $_{Energy\ Consumption\ from\ Waste\ Processing}$ = ∑ [(Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; (GWP_{CH4} * Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; (GWP_{N2O} * Vol. Fuel $_i$ * EF Fuel $_{i\ N20}$)] + [Electricity * EF $Grid_{CO2e}$] + [Thermal Energy * EF Thermal $Energy_{CO2e}$]
B13 Energy Consumption from Waste Processing	kgCO2e	Emissions $_{Energy\ Consumption\ from\ Waste\ Processing}$ = ∑ [(Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; (GWP_{CH4} * Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; (GWP_{N2O} * Vol. Fuel $_i$ * EF Fuel $_{i\ N20}$)] + [Electricity * EF $Grid_{CO2e}$] + [Thermal Energy * EF Thermal $Energy_{CO2e}$]

B14 Waste Decomposition and Methane Release	kgCO2e	Emissions $_{\text{Waste Decomposition and Methane Release}}$ $= 1000 * \phi * (1-f) * GWP_{CH4} * (1-OX) * \left(\frac{16}{12}\right) * F * DOC_f * MCF * \sum_{x=1}^{y} \sum_{j} W_{j,x} * DOC_j * e^{-k_j(y-x)} * (1 - e^{-k_j})$ aste Decomposition and Methane Release = Methane emissions avoided during the year y from preventing waste disposal at the solid waste disposal site during the period from the start of the project activity to the end of the year y Model correction factor to account for model uncertainties (0.9) Fraction of methane captured at the solid waste disposal sites (SWDS) and flared, combusted or used in another manner Global Warming Potential (GWP) of methane, valid for the relevant commitment period Oxidation factor (reflecting the amount of methane from SWDS that is oxidised in the soil or other material covering the waste) Fraction of methane in the SWDS gas (volume fraction) (0.5) Fraction of degradable organic carbon (DOC) that can decompose Methane correction factor Mass of Waste Material type j Sent to Landfill in the year x (tons) Fraction of degradable organic carbon (by weight) in the waste type j Decay rate for the waste type j Waste type category (index) Year during the crediting period: x runs from the first year of the first crediting period (x = 1) to the year y for which avoided emissions a re-calculated (x = y) Year for which methane emissions are calculated

7.3 Project Emissions

$$\text{Emissions}_{\text{Project EE}} = \text{sum of the energy efficiency related emissions under the project scenario}$$

$$\text{Emissions}_{\text{Project EE}} = \text{Emissions}_{\text{Building/System Energy Consumption with ECM}} + \text{Emissions}_{\text{Maintenance}} + \text{Emissions}_{\text{Unit Operation}}$$

$\text{Emissions}_{\text{Building Energy Consumption with ECM}}$ = Emissions under SS **P7** Building/System Energy Consumption (with ECMs)

$\text{Emissions}_{\text{Maintenance}}$ = Emissions under SS **P8** Maintenance

$\text{Emissions}_{\text{Unit Operation}}$ = Emissions under SS **P9** Unit Operation: Biological/Chemical/Mechanical Processes

$$\text{Emissions}_{\text{Project WASTE}} = \text{sum of the waste related emissions under the project scenario}$$

$$\text{Emissions}_{\text{Project WASTE}} = \text{Emissions}_{\text{Energy Consumption from Waste Processing}} + \text{Emissions}_{\text{Waste Decomposition and Methane Release}} + \text{Emissions}_{\text{Energy Consumed from Alternative Processing of Waste Use}} + \text{Emissions}_{\text{Process Emissions from Alternative Processing of Waste}}$$

$\text{Emissions}_{\text{Energy Consumption from Waste Processing}}$ = Emissions under SS **P10** Energy Consumption from Waste Processing

$\text{Emissions}_{\text{Waste Decomposition and Methane Release}}$ = Emissions under SS **P14** Waste Decomposition and Methane Release

$\text{Emissions}_{\text{Energy Consumed from alternative processing of waste / use}}$ = Emissions under SS **P16** Energy Consumed from alternative processing of waste / use

$\text{Emissions}_{\text{Process Emissions from Alternative Processing of Waste}}$ = Emissions under SS **P17** Process Emissions from Alternative Processing of Waste

Table 5 provides SS-specific equations for comparisons of the project SS.

Table 5: Project SS Emission Adjustment Quantification

SS	Units	Project SS Formula
P7 Building/System Energy Consumption (with ECMs)	kgCO2e	Emissions $_{\text{Building/System Energy Consumption with ECM}}$ = ∑ [(Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; (GWP_{CH4} * Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; (GWP_{N2O} * Vol. Fuel $_i$ * EF Fuel $_{i\ N20}$)]
P8 Maintenance	kgCO2e	Emissions $_{\text{Maintenance}}$ = ∑ [(Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; (GWP_{CH4} * Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; (GWP_{N2O} * Vol. Fuel $_i$ * EF Fuel $_{i\ N20}$)] + [Electricity * EF $Grid_{CO2e}$] + [Thermal Energy * EF Thermal $Energy_{CO2e}$]
P9 Unit Operation: Biological / Chemical / Mechanical Processes	kgCO2e	Emissions $_{\text{Unit Operation}}$ = ∑ [(Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; (GWP_{CH4} * Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; (GWP_{N2O} * Vol. Fuel $_i$ * EF Fuel $_{i\ N20}$)] + [Electricity * EF $Grid_{CO2e}$] + [Thermal Energy * EF Thermal $Energy_{CO2e}$]
P10 Energy Consumption from Waste Processing	kgCO2e	Emissions $_{\text{Energy Consumption from Waste Processing}}$ = ∑ [(Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; (GWP_{CH4} * Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; (GWP_{N2O} * Vol. Fuel $_i$ * EF Fuel $_{i\ N20}$)] + [Electricity * EF $Grid_{CO2e}$] + [Thermal Energy * EF Thermal $Energy_{CO2e}$]
P14 Waste Decomposition and Methane Release	kgCO2e	Emissions $_{\text{Waste Decomposition and Methane Release}}$ $= 1000 * \phi * (1-f) * GWP_{CH4} * (1-OX) * \left(\frac{16}{12}\right) * F * DOC_f * MCF * \sum_{x=1}^{y}\sum_{j} W_{j,x} * DOC_j * e^{-k_j(y-x)} * \left(1-e^{-k_j}\right)$
P16 Energy Consumed from alternative processing of waste / use	kgCO2e	Emissions $_{\text{Energy Consumed from alternative processing of waste / use}}$ = ∑ [(Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; (GWP_{CH4} * Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; (Vol. Fuel $_i$ * EF Fuel $_{i\ N20}$)] + [Electricity * EF $Grid_{CO2e}$] + [Thermal Energy * EF Thermal $Energy_{CO2e}$]
P17 Process Emissions from Alternative Processing of Waste	kgCO2e	Emissions $_{\text{Process Emissions from Alternative Processing of Waste}}$ = ∑ [(Mass $_{CO2}$) ; (Mass $_{N2O}$) ; (Mass $_{CH4}$)]

7.4 Leakage

The project proponent must assess the likelihood of leakage based on the specific project activities. If it cannot be shown that no plausible material leakage would occur based on the specific project activities, then this methodology shall not be applied.

The project proponent must quantify GHG emissions sources occurring outside the project boundary as a result of implementation of the project activities, which are expected to contribute more than 1% of the overall average emission reductions.

7.5 Summary of GHG Emission Reduction and/or Removals

Quantification of the net GHG reductions must be calculated using the equation set out below.

Emission Reductions = [Emission $_{\text{Adjusted Baseline EE}}$ – Emissions $_{\text{Project EE}}$] + [Emission $_{\text{Adjusted Baseline WASTE}}$ – Emissions $_{\text{Project WASTE}}$]

Where:

Emissions $_{\text{Adjusted Baseline EE}}$ = the energy efficiency related baseline emissions plus any adjustments needed to adjust it to the conditions of the monitoring period

Emissions $_{\text{Adjusted Baseline WASTE}}$ = the waste related baseline emissions plus any adjustments needed to adjust it to the conditions of the monitoring period

Emissions $_{\text{Project EE}}$ = sum of the energy efficiency related emissions under the project scenario

Emissions $_{\text{Project WASTE}}$ = sum of the waste related emissions under the project scenario

8 Monitoring

8.1 Parameters Available at Validation

The following data units/parameters are referred to numerous times in the formulas presented in Section 6. Actual measured or local data are to be used when available. If not available, regional data must be used. The data sources for each parameter are offered below, however; in their absence, IPCC defaults can be used from the most recent version of the IPCC Guidelines for National Greenhouse Gas Inventories.

Parameter:	EF Thermal Energy$_{CO2e}$
Data unit:	Kg CO_2e per GJ
Description:	CO_2e emissions factor for local generation of thermal energy
Source of data:	For the Territory of interest, the project proponent must identify the most appropriate CO2e emission factor for the source of thermal energy used under the project scenario. Regional data (for example: US Department of Energy's Form EIA-1605 Appendix N. Emission factors for Steam and Chilled/Hot Water) shall be used. In its absence, IPCC defaults must be used from the most recent version of *IPCC Guidelines for National Greenhouse Gas Inventories* providing they are deemed to reasonably represent local circumstances. The project proponent must choose the values in a conservative manner and justify the choice.
Justification of choice of data or description of measurement methods and procedures applied:	Thermal Energy generation characteristics are likely to remain relatively stable over a year's time.

Parameter:	EF Fuel $_{i\ N20}$
Data unit:	Kg N_2O per L, m^3, or other
Description:	N_2O emissions factor for combustion of each type of fuel (EF Fuel $_{i\ N2O}$)
Source of data:	For both mobile and stationary fuel combustion for the Territory of interest, the project proponent must identify the most appropriate emission factors for the source of thermal energy used under the project condition. Regional data (for example: EPA's AP 42, *Compilation of Air Pollutant Emission Factors*) shall be used. In its absence, IPCC defaults must be used from the most recent version of *IPCC Guidelines for National Greenhouse Gas Inventories* providing they are deemed to reasonably represent local circumstances. The project proponent must choose the values in a conservative manner and justify the choice.
Justification of choice of data or description of measurement methods and procedures applied:	This is one of the most comprehensive fuel emission factor databases available.

Parameter:	EF Fuel $_{i\ CH4}$
Data unit:	Kg CH_4 per L, m^3, or other
Description:	CH_4 emissions factor for combustion of each type of fuel (EF Fuel $_{i\ CH4}$)
Source of data:	For both mobile and stationary fuel combustion for the Territory of interest, the project proponent must identify the most appropriate emission factors for the source of thermal energy used under the project scenario. Regional data (for example: EPA's AP 42, *Compilation of Air Pollutant Emission Factors*) shall be used. In its absence, IPCC defaults can be used from the most recent version of *IPCC Guidelines for National Greenhouse Gas Inventories* providing they are deemed to reasonably represent local circumstances. The project proponent must choose the values in a conservative manner and justify the choice.
Justification of choice of data or description of measurement methods and procedures applied:	This is one of the most comprehensive fuel emission factor databases available.

Parameter:	EF Fuel $_{i\ CO2}$
Data unit:	Kg CO_2 per L, m^3, or other
Description:	CO_2 Emissions Factor for combustion of each type of fuel (EF Fuel $_{i\ CO2}$)
Source of data:	For both mobile and stationary fuel combustion for the Territory of interest, the project proponent must identify the most appropriate emission factors for the source of thermal energy used under the project scenario. Regional data (for example: EPA's AP 42, *Compilation of Air Pollutant Emission Factors*) shall be used. In its absence, IPCC defaults can be used from the most recent version of *IPCC Guidelines for National Greenhouse Gas Inventories* providing they are deemed to reasonably represent local circumstances. The project proponent must choose the values in a conservative manner and justify the choice.
Justification of choice of data or description of measurement methods and procedures applied:	This is one of the most comprehensive fuel emission factor databases available.

Parameter:	ϕ
Data unit:	-
Description:	Model correction factor to account for model uncertainties (0.9)
Source of data:	This factor is determined using the CDM's "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site (Version 05.1.0)" (CDM, 2011).
Justification of choice of data or description of measurement methods and procedures applied:	The most used tool for calculation landfill gas emission reductions.

Parameter:	OX
Data unit:	-
Description:	Oxidation factor (reflecting the amount of soil or other material covering the waste)
Source of data:	This factor is determined using the CDM's "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site (Version 05.1.0)" (CDM, 2011).
Justification of choice of data or description of measurement methods and procedures applied:	The most used tool for calculation landfill gas emission reductions.

Parameter:	DOC_f
Data unit:	-
Description:	Fraction of degradable organic carbon (DOC) that can decompose
Source of data:	This factor is determined using the CDM's "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site (Version 05.1.0)" (CDM, 2011).
Justification of choice of data or description of measurement methods and procedures applied:	The most used tool for calculation landfill gas emission reductions.

Parameter:	DOC_j
Data unit:	-
Description:	Fraction of degradable organic carbon (by weight)
Source of data:	This factor is determined using the CDM’s “Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site (Version 05.1.0)” (CDM, 2011).
Justification of choice of data or description of measurement methods and procedures applied:	The most used tool for calculation landfill gas emission reductions.

Parameter:	MCF
Data unit:	-
Description:	Methane correction factor
Source of data:	This factor is determined using the CDM’s “Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site (Version 05.1.0)” (CDM, 2011).
Justification of choice of data or description of measurement methods and procedures applied:	The most used tool for calculation landfill gas emission reductions.

Parameter:	k_j
Data unit:	-
Description:	Decay rate for the waste type j
Source of data:	IPCC 2006 Guidelines for National Greenhouse Gas Inventories (adapted from Volume 5, Table 3.3)
Justification of choice of data or description of measurement methods and procedures applied:	Apply the following default values for the different waste types j

Waste type *j*		**Boreal and Temperate (MAT≤20°C)**		**Tropical (MAT>20°C)**	
		Dry (MAP/PET <1)	Wet (MAP/PET >1)	Dry (MAP< 1000mm)	Wet (MAP> 1000mm)
Slowly degrading	Pulp, paper, cardboard (other than sludge), textiles	0.04	0.06	0.045	0.07
Slowly degrading	Wood, wood products and straw	0.02	0.03	0.025	0.035
Moderately degrading	Other (non-food) organic putrescible garden and park waste	0.05	0.10	0.065	0.17
Rapidly degrading	Food, food waste, beverages and tobacco (other than sludge)	0.06	0.185	0.085	0.40

NB: MAT – mean annual temperature, MAP – Mean annual precipitation, PET – potential evapotranspiration. MAP/PET is the ratio between the mean annual precipitation and the potential evapotranspiration.

If a waste type, prevented from disposal by the proposed CDM project activity, cannot clearly be attributed to one of the waste types in the table above, project participants choose among the waste types that have similar characteristics that waste type where the values of *DOCj* and *kj* result in a conservative estimate (lowest emissions), or request a revision of / deviation from this methodology.

Document in the CDM-PDD the climatic conditions at the SWDS site (temperature, precipitation and, where applicable, evapotranspiration). Use long-term averages based on statistical data, where available. Provide references.

8.2 Data and Parameters Monitored

The specific data and parameters associated with each SS are identified below.

Data Unit / Parameter:	Vol. $Fuel_i$
Data unit:	L, m^3, or other
Description:	Volume of each type of fuel combusted. This volume of fuel is adjusted for both functional equivalence and units of productivity.
Source of data:	The volume of fuel is determined by third party custody invoices, consolidated monthly. Un-calibrated internal meters cannot be used.
Description of measurement methods and procedures to be applied:	Monthly invoices filed for verification.
Frequency of monitoring/recording:	Monthly.
QA/QC procedures to be applied:	Manual transcription is avoided where possible.

Data Unit / Parameter:	Electricity
Data unit:	kWh
Description:	The amount of electricity consumed from the grid.
Source of data:	The amount of electricity consumed from the grid is determined by third party custody invoices, consolidated monthly. If internal meters are required for the Isolation Parameter Measurement option, calibration records is provided as per the manufacturer's schedule.
Description of measurement methods and procedures to be applied:	Monthly.
Frequency of monitoring/recording:	Manual transcription is avoided where possible.
QA/QC procedures to be applied:	Cross reference when possible.

Data Unit / Parameter:	EF $Grid_{CO2e}$
Data unit:	Kg CO2e per kWh
Description:	CO_2e Emissions Factor for electricity from the grid.
Source of data:	For the Territory of interest, the project proponent must calculate the emission factor for the appropriate emission factor using the CDM's "Tool to calculate the emission factor for an electricity system (Version 2.2.1)" (CDM, 2011).
Justification of choice of data or description of measurement methods and procedures applied:	Refer to the latest version of the CDM tool.

Data Unit / Parameter:	Thermal Energy
Data unit:	GJ
Description:	Thermal Energy consumed at the facility. This amount is adjusted for both functional equivalence and units of productivity.
Source of data:	Thermal energy crossing the boundary is measured with monthly invoices. If the thermal energy crosses the boundary without a custody caliber meter, only calibrated internal meters is relied upon. Calibration records must be made available during verification.
Description of measurement methods and procedures to be applied:	Continuous Metering or invoice reconciliation
Frequency of monitoring/recording:	Frequency of metering and reconciliation is most frequent as possible.
QA/QC procedures to be applied:	Cross-checked with the quantity of heat invoiced if relevant

Data Unit / Parameter:	$W_{j,x}$
Data unit:	kg
Description:	Mass of Waste Material Sent to Landfill
Source of data:	Direct measurement of mass of waste sent for disposal.
Description of measurement methods and procedures to be applied:	Continuous metering or invoice reconciliation. The mass of material diverted from conventional landfill disposal may be measured by invoice reconciliation from a sight appropriate for no anaerobic disposal of waste. The mass of organic material sent to landfill may be measured upon departure from the composting site or at the waste disposal site. Care must be taken to ensure no material is then diverted to landfill without being accounted for.
Frequency of monitoring/recording:	Both methods are standard practice. Frequency of metering is highest level possible.
QA/QC procedures to be applied:	As per the latest version of the "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site (Version 05.1.0)" (CDM, 2011).

Data Unit / Parameter:	f
Data unit:	-
Description:	Fraction of methane captured in the SWDS gas
Source of data:	This factor is determined using the CDM's "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site (Version 05.1.0)" (CDM, 2011).
Justification of choice of data or description of measurement methods and procedures applied:	The most used tool for calculation landfill gas emission reductions.

Data Unit / Parameter:	Mass $_{CO2}$
Data unit:	Kg
Description:	Mass of CO_2 emitted as a process emissions
Source of data:	Measured or Estimated
Description of measurement methods and procedures to be applied:	This variable can be either measured or estimated. Measured process emissions would be conducted via a continuous monitoring system that records both the flow rate of the gas and the percent composition of CO_2. This would allow a mass to be accurately determined. If measurement is in place, calibration schedules and records must be provided in the project document. If estimation is used in absence of a continuous monitoring system, the details of the mass balance must be provided in the project document. The mass balance must include the justification around an average waste composition used in the mass balance.
Frequency of monitoring/recording:	Continuous measurement or hourly estimations
QA/QC procedures to be applied:	If the measurement results differ significantly from previous measurements or other relevant data sources, conduct additional measurements or cross checking with other reported values.

Data Unit / Parameter:	Mass $_{N2O}$
Data unit:	Kg
Description:	Mass of N_2O emitted as a process emissions
Source of data:	Measured or Estimated
Description of measurement methods and procedures to be applied:	This variable can be either measured or estimated. Measured process emissions would be conducted via a continuous monitoring system that records both the flow rate of the gas and the percent composition of N_2O. This would allow a mass to be accurately determined. If measurement is in place, calibration schedules and records must be provided in the project document. If estimation is used in absence of a continuous monitoring system, the details of the mass balance must be provided in the project document. The mass balance must include the justification around an average waste composition used in the mass balance.
Frequency of monitoring/recording:	Continuous measurement or hourly estimations
QA/QC procedures to be applied:	If the measurement results differ significantly from previous measurements or other relevant data sources, conduct additional measurements or cross checking with other reported values.

Data Unit / Parameter:	Mass $_{CH4}$
Data unit:	Kg
Description:	Mass of CH_4 emitted as a process emissions
Source of data:	Measured or Estimated
Description of measurement methods and procedures to be applied:	This variable can be either measured or estimated. Measured process emissions would be conducted via a continuous monitoring system that records both the flow rate of the gas and the percent composition of CH_4. This would allow a mass to be accurately determined. If measurement is in place, calibration schedules and records must be provided in the project document. If estimation is used in absence of a continuous monitoring system, the details of the mass balance must be provided in the project document. The mass balance must include the justification around an average waste composition used in the mass balance.
Frequency of monitoring/recording:	Continuous measurement or hourly estimations
QA/QC procedures to be applied:	If the measurement results differ significantly from previous measurements or other relevant data sources, conduct additional measurements or cross checking with other reported values.

8.3 Description of the Monitoring Plan

Data quality management must include sufficient data capture such that the mass and energy balances may be easily performed with the need for minimal assumptions and use of contingency procedures. The data shall be of sufficient quality to fulfill the quantification requirements and be substantiated by company records for the purpose of verification.

The project proponent shall establish and apply quality management procedures to manage data and information. Written procedures must be established for each measurement task outlining responsibility, timing and record location requirements. The greater the rigor of the management system for the data, the easier it will be to conduct an audit for the project.

In case of doubt regarding appropriateness of the proposed sample, the project proponent shall refer to the latest version of the CDM *General Guidelines for Sampling and Surveys for Small-Scale Project Activities and Programme of Activities (PoAs)*.

Record keeping practices shall include the following procedures:

- Electronic recording of values of logged primary parameters for each measurement interval;
- Offsite electronic back-up of all logged data;

- Written logs of operations and maintenance of the project system including notation of all shut-downs, start-ups and process adjustments; and
- Storage of all documents and records in a secure and retrievable manner for at least two years after the end of the project crediting period.

Quality assurance/Quality control (QA/QC) shall also be applied to add confidence that all measurements and calculations have been made correctly. These include, but are not limited to:

- Protecting monitoring equipment (sealed meters and data loggers);
- Protecting records of monitored data (hard copy and electronic storage);
- Checking data integrity on a regular and periodic basis (manual assessment, comparing redundant metered data, and detection of outstanding data/records);
- Comparing current estimates with previous estimates as a ‘reality check’;
- Provide sufficient training to operators to perform maintenance and calibration of monitoring devices;
- Establish minimum experience and requirements for operators in charge of project and monitoring; and
- Performing recalculations to make sure no mathematical errors have been made.

Requirements for sampling eligibility of a Territory within a Sustainable Community[6]:

- Project Units in the Territory, connected to the Sustainable Community and which apply all or part of the Sustainable Community activities (identified as ECM and/or waste diversion) are applicable for sampling as long the Sustainable Community data are collected and stored in the project proponent system.
- The project proponent’s data collection and storage shall be centrally controlled and administered.
- The project proponent shall demonstrate its capacity to identify project units with data that inappropriately[7] affects the confidence interval of the Sustainable Community; these project units shall either be audited or excluded from the Sustainable Community.

Confidence Interval requirements:

- The Confidence Interval shall be set to 95%.

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[6] Sampling requirements follow guidance provided in *ANSI/ASQC Z1.4-2008* “Sampling Procedures and Tables for Inspection*” by Attributes* and *IAF MD 1:2007* “IAF Mandatory Document for the Certification of Multiple Sites Based on Sampling.”

[7] Inappropriate in this context means data collected which, when compared to regional conditions, are outside the acceptable range (defect).

Sampling size requirements:

- The sample shall be partly selective based on factors, such as importance of activities and GHG reduction volume, range of activities being conducted, exceptional performance (beyond Territory and sectoral performance).
- The sample shall be partly nonselective, with at least 20% of the sample being selected at random.
- The project proponent shall have a documented procedure for determining the sample to be taken when verifying project sites and submit to the validation/verification body.
- When necessary, stratified random sampling shall be conducted on homogeneous sub-populations. The criteria for sub-population grouping are based on appropriate economic sectors. The criteria are based on an official territory authority classification or an internationally recognized equivalent (examples include the North American Industry Classification System (NAICS) or Statistical Classification of Economic Activities in the European Community (NACE[8]).

For a Territory, there are three different levels of sampling:

- Normal: the size of the sample shall be the square root of the number of project units connected to the project proponent, rounded to the upper whole number.
- Reduced: the size of the sample shall be the square root of the number of project units connected to the project proponent reduced by a coefficient (max. 0.6) when the overall confidence interval of the Sustainable Community data exceeds the target value[9].
- Reinforced: the size of the sample shall be the square root of the number of project units connected to the project proponent increased by a coefficient (max. 1.3) when the overall confidence interval of the Sustainable Community data is below the target value.

Sample Defect requirements:

- The sample size shall be enlarged to a maximum of 160% of the initial size if the reported values for one or more GHG reduction activities is beyond the acceptable range (defect) and the number of defects exceeds the acceptable quality level.
- The sample size shall be reduced to a maximum of 60% of the initial size if all client facility reported values are within the acceptable range (no defects) for five consecutive samplings.

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[8] The Statistical Classification of Economic Activities in the European Community (in French: *Nomenclature Statistique des Activités économiques dans la Communauté Européenne (NACE*)) is a pan-European classification system which groups organizations according to their business activities.

[9] The target value corresponds to a confidence interval of 95%.

REFERENCES AND OTHER INFORMATION

Acronyms

AENV	Alberta Environment
CCX	Chicago Climate Exchange
CDM	Clean Development Mechanism
CI	Confidence Interval
DOC	Degradable Organic Carbon
ECM	Energy Conservation Measure
EF	Emission Factor
EE	Energy Efficiency
EPA	Environmental Protection Agency
EVO	Efficiency Valuation Organization
f	Fraction
GHG	Greenhouse Gases
GJ	Gigajoule
GWP	Global Warming Potential
HVAC	Heating, Ventilation and Air Conditioning
ICI	Industrial, Commercial and Institutional Business Unit
IPCC	Intergovernmental Panel on Climate Change
IPMVP	International Performance Measurement and Verification Protocol
Kg	Kilograms
kWh	Kilowatt hour
/L	Per Litres
LFG	Landfill Gas
/m2	Per square metre
/m3	Per cubic metre
MAT	Mean Annual Temperature
M&V	Monitoring and Verification
MSW	Municipal Solid Waste
Mt	Metric tonnes
PET	Potential Evapotranspiration
QA/QC	Quality Assurance/ Quality Control
SC	Sustainable Community
SCSP	Sustainable Community Service Promoter
SS	Sources and Sinks

SWDS	Solid Waste Disposal Sites
UN	United Nations
VCS	Verified Carbon Standard
VCU	Verified Carbon Unit

VERIFIED CARBON STANDARD
A Global Benchmark for Carbon

Approved VCS Methodology VM0019

Version 1.0
Sectoral Scope 7

Fuel Switch from Gasoline to Ethanol in Flex-Fuel Vehicle Fleets

18 June 2012

Document Prepared by Keyassociados and Ecofrotas

Relationship to Approved or Pending Methodologies

There is no sectoral scope 7 methodology currently approved under the VCS. Also, none of the sectoral scope 7 methodologies under development in the VCS are focused on commercial fleet fossil fuel substitution, as further explained below:

Methodology for Determining GHG Emission Reductions Through Bicycle Sharing Projects – from sectoral scope 7, this methodology is applicable for project activities that reduce GHG emissions through the usage of public sharing-based bicycle projects which introduce an alternative mode of transportation to displace other, more carbon intensive modes.

Methodology for Efficiency Improvements HDV's and Mobile Machinery – from sectoral scope 7, this methodology aims to improve the efficiency of trucks and/or mobile machinery equipment. Measures to improve operating vehicle efficiency may include but are not limited to anti-idling devices, eco-drive, tire-rolling resistance improvement, air-conditioning system improvement, low viscosity oils, cab-heaters, aerodynamic drag reduction measures, transmission improvements, etc.

There is no approved or pending methodology in the UNFCCC, from sectoral scope 7, for which a revision could be requested to comprise the project activity of fossil fuel substitution in commercial fleets, as presented below:

AM0031 - Baseline methodology for bus rapid transit projects - focuses on the construction and operation of a new bus rapid transit system (BRT) for urban transport of passengers.

AM0090 - Modal shift in transportation of cargo from road transportation to water or rail transportation - focuses on the displacement of a more-carbon-intensive transportation mode.

ACM0016 - Baseline methodology for mass rapid transit projects - focuses on the establishment and operation of rail-based or bus-based mass rapid transit systems in urban or suburban regions for passenger transport by replacing a traditional urban bus-driven public transport system.

AMS-III.AA - Transportation energy efficiency activities using retrofit technologies - focuses on energy efficiency measures in transportation to reduce GHG emissions due to decreased fuel consumption.

AMS-III.AK - Biodiesel production and use for transport applications - focuses on the production of biodiesel that is used for transportation applications, where the biodiesel is produced from oilseed cultivated on dedicated plantations and from waste oil/fat.

AMS-III.AP - Transport energy efficiency activities using post-fit Idling Stop device - focuses on the demand side activities associated with the installation of post-fit type Idling Stop devices in passenger vehicles used for public transport, in order to reduce fossil fuel consumption and GHG emissions.

AMS-III.AQ - Introduction of Bio-CNG in transportation applications - focuses on the production of Biogenic Compressed Natural Gas (Bio-CNG) from renewable biomass including waste organic matters to be used in transportation applications. The crops from renewable biomass origin used for production of the Bio-CNG should be sourced from dedicated plantations.

AMS-III.AT - Transportation energy efficiency activities installing digital tachograph systems to commercial freight transport fleets - focuses on the installation of a digital tachograph system that reduces GHG emissions associated with fossil fuel combustion in freight transport by providing to the driver feedback against inefficient driving.

AMS-III.C - Emission reductions by electric and hybrid vehicles - comprises emission reductions from electric and hybrid vehicle use only.

AMS-III.S - Introduction of low-emission vehicles/technologies to commercial vehicle fleets - focuses on introducing low-greenhouse gas emitting vehicles for commercial passenger (including public transportation), material and freight transport, operating on a number of routes with comparable conditions. Retrofitting of existing vehicles is also included in the methodology.

AMS-III.T - Plant oil production and use for transport applications - covers project activities involving the cultivation of oilseeds, the production of plant oil and the use of plant oil for transportation applications.

AMS-III.U - Cable Cars for Mass Rapid Transit System (MRTS) - focuses on cable cars substituting traditional road based transport trips.

NM0360 - Use of lower energy-intensive intermodal transportation method to transport freight (use of pipeline rather than over-the-road truck) - assumes that switching from truck transportation to an alternative transport method of lower energy intensity will result in reduction of fossil fuel consumption.

NM0357 - Methodology for Rail Projects - applicable for rail projects investing in new infrastructure for passenger and cargo transport. Emission reductions are due to mode shift basically from road to rail.

SSC-NM074 - Emission Reductions through Improved Efficiency of Vehicle Fleets - for project activities that improve the efficiency of vehicle fleets through improvement of the operational efficiency, i.e. a reduction of fuel usage.

Among all assessed methodologies from sectoral scope 7, four have been considered more similar to the present one (AMS-III.T, AMS-III.AK, AMS-III.AQ and AM0090) and deserved a better evaluation regarding its applicability. In the case of AM0090, the present methodology does not involve a modal shift. Flex-fuel vehicles both in the baseline and project scenarios compose the commercial fleets, and it also does not refer to cargo transportation, it refers only to the choice between two types of fuel. The approved methodologies AMS-III.T, AMS-III.AK and AMS-III.AQ are related to the biofuel production, while the present methodology is focused on the option to consume fuels available in the market (ethanol instead of gasoline); and the present methodology refers to ethanol, not biodiesel or Bio-CNG.

As demonstrated for each UNFCCC sectoral scope 7 methodology presented above, none are applicable to the proposed project activity of commercial fleet fossil fuel substitution or presents the possibility of requesting a revision.

Regarding the Climate Action Reserve, there is no protocol from the sectoral scope of transport.

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1 SOURCES

This methodology is not based on any approved baseline and/or monitoring methodologies.

It refers to the latest approved versions of the following tools:

- *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion* (UNFCCC);
- *Combined tool to identify the baseline scenario and demonstrate additionality* (UNFCCC).

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology is applicable to project activities that aim at complete substitution of gasoline or gasoline blends by ethanol in commercial fleets of flex-fuel vehicles. The monitoring plan must guarantee exclusive consumption of ethanol by vehicles from the project boundary. This should be done using a fuel monitoring system (direct or indirect measurement) with continuous registration of place (gas station), date, type and quantity of fuel used in the project activity.

In order to calculate the baseline emissions, historical fuel consumption pattern shall be analysed and a factor that shows the ratio of gasoline to ethanol in the total consumption of fuel by commercial fleet shall be calculated. In cases where the project area is not homogenous in terms of availability and prices of fuels, it should be stratified into project regions. The fuel consumption pattern should be calculated for each project region. Historical fuel consumption pattern is based on historical data of the project proponent. In cases when no credible historical data is available or in the case of a Greenfield project activity instance, the historical average pattern of the same regional group shall be used.

Additionality shall be demonstrated by applying the latest version of CDM *Combined tool to identify the baseline scenario and demonstrate additionality*.

The baseline emissions are calculated by applying the determined fuel consumption pattern (ratio of gasoline to ethanol in the total fuel consumption during the historical reference period), corrected by a fuel conversion factor, to the total quantity of ethanol consumed in the year *y* of the project activity. The fuel conversion factor determines a quantity of ethanol needed to substitute one liter of gasoline in the type of vehicles used in the project activity.

Project emissions are calculated by applying the emission factor to the quantity of gasoline consumed in the project activity and monitored in liters.

The emissions reductions are calculated as the difference between the baseline emissions and the project emissions. No leakage emissions are attributed to this project type.

Additionality	Project Method
Crediting Baseline	Project Method

3 DEFINITIONS

For the purpose of this methodology, the following definitions apply:

Commercial fleet - 10 or more vehicles owned by a single company and used for business purposes.

Direct measurement – Direct measurement of fuel consumption in the project activity corresponds to a measurement that registers the data that will be utilized in the emission reduction calculation with no treatment (i.e., no statistical estimation or conversion can be used to find the fuel consumption in liters).

Emergency gasoline - gasoline consumed in cases of ethanol temporary unavailability in specific gas stations.

Ethanol - fuel produced from renewable biological resources such as plant biomass.

Flex-fuel vehicle - a flexible-fuel vehicle (FFV) is an automobile that can alternate between at least two sources of fuel, such as gasoline or ethanol blends in any proportion.

Fuel consumption pattern - proportion of gasoline to ethanol used in the flex-fuel vehicles of the project proponent commercial fleets in the baseline scenario.

Greenfield – any new project activity instance, corresponding to an existent flex-fuel vehicles fleet, with insufficient history under the monitoring conditions specified by the project activity.

I**ndirect measurement** – Indirect measurement of fuel consumption in the project activity corresponds to a measurement of a data registry that needs to be converted to the unit that will be used for the emission reduction calculation, or the measurement of a sample group that will be used to estimate the consumption of the whole fleet.

Lifecycle emissions - The aggregate quantity of greenhouse gas emissions (including direct and significant indirect emissions such as land use changes), related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through the distribution, delivery and use of the finished fuel by the final consumer.[1]

Opportunity cost - The cost of an alternative that must be forgotten when the fleet owner decides to adhere the project activity (e.g., the benefits from the flexible alternative (the choice for the cheapest fuel type) that the fleet owner is giving up when opting for the exclusive consumption of ethanol).

Regional Grouping - is a multivariable method that aims at classifying a sample of subjects (or objects) on the basis of a set of measured variables.

Renewable materials - any natural resources of economic value that can be replaced or replenished fast enough so that the supply continues to be available in time. In the case of fuels, renewable materials are those whose source can be cultivated and/or replaced by human activity (e.g. wheat, corn, sugar beets, sugar cane and molasses).

[1] The definition of lifecycle emissions was adapted from the United States Energy Independence and Security Act of 2007 (EISA), retrieved from the United States Environmental Protection Agency (EPA), available at: http://www.epa.gov/oms/renewablefuels/420f10006.htm#footnotes

Start-up Gasoline - gasoline reserved for the ignition of ethanol engines at low temperatures in flex-fuel technologies, located in a separate reservoir of around 1 liter.

Vehicle owner - company responsible for the operational control of the vehicle.

4 APPLICABILITY CONDITIONS

This methodology applies to project activities that aim at complete substitution of fossil fuels or blends of gasoline by ethanol in commercial fleets of the project proponent. The methodology is applicable under the following conditions:

- Project boundary contains commercial fleets that consist exclusively of flex-fuel vehicles (i.e. only flex-fuel vehicles are used both in baseline scenario and in the project activity);
- Only existent fleets of flex-fuel vehicles are eligible (i.e. flex-fuel vehicle acquisition is not acceptable under this methodology);
- In the baseline scenario, the vehicles use gasoline or blend of any proportion of ethanol and gasoline (0-99%);
- Fuel consumed in the project activity is exclusively ethanol (E100); up to 5% of total fuel consumed per fleet and per year can be gasoline, for emergency cases and for the start-up mechanism as required by the flex-fuel motor technology. Where a fleet consumes more than 5% of gasoline in a given year, it shall be permanently excluded from the project activity, with no possibility to be reinserted and no right to receive credits for the reductions achieved in that year and all subsequent ones;
- The project activity fuel (ethanol) is available at the same gas stations as the baseline fuel (gasoline or blend of ethanol and gasoline) for at least 50% of the gas stations available in the project region;
- Gasoline, ethanol and their blends comply with relevant regulations (national or regional market);
- Ethanol used in the project is produced from renewable resources[2];
- Ethanol used in the project shall have lower lifecycle emissions than the gasoline used in the baseline. The onus is upon the project proponent to clearly demonstrate this, failing which the project shall not be eligible for crediting.[3]

[2] In order to demonstrate that the ethanol used in the project activity is produced from renewable materials, the project proponent shall evaluate the production of the ethanol available in the project region and the Validation/Verification Body must evaluate such assessment and issue its favorable opinion on the renewable characteristic of ethanol for the project region.

[3] Several lifecycle analyses have concluded that ethanol can have lower lifecycle emissions than gasoline. Such studies have been performed by the U.S. EPA, UNEP and FAO. In order to demonstrate compliance with this applicability condition, project proponents may also reference other studies, as relevant to their project, available from a recognized, credible source, and reviewed for publication by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency.

- The monitoring system is designed to allow measurement of the fuel consumption for each vehicle in each fleet within the project boundaries continuously (on each fueling operation), over the whole project crediting period and during the period to which the historical consumption pattern refers;

- The system of measurement (direct and indirect) shall guarantee that 95% of the fuel consumed per fleet and per year under the project activity is ethanol. When direct measurement is used, the Validation/Verification Body has the authority to decide when the measurement method adopted by the project activity is robust enough to ensure that the data (type and quantity of fuel consumed) obtained, processed and registered is reliable. When indirect measurement is used, the project activity must guarantee that the width of a 95% confidence interval does not exceed 30% of the estimated value, in order to ensure that the uncertainty range is not significant. If the data does not satisfy this criteria, it cannot be used in the project activity;

- No legal requirement exists to use exclusively ethanol fuel in commercial fleets in the relevant market (national or regional);

- Where the project proponent is not the owner of the commercial fleet vehicles (e.g., the project proponent is a fleet manager with many clients, each client being the owner of its respective commercial fleet vehicles), there shall exist a contract between the project proponent and each fleet owner to establish clear ownership of the emission reductions;

- As in the CDM baseline and monitoring methodologies related to the biofuel production (i.e., AMS.III-T, AMS.III-AK, and AMS.III-AQ discussed above), "*the retailer, the final users, and the producer are bound by a contract that states that the final consumers and retailers shall not claim emission reductions resulting from its consumption"*, the contract between the project proponent and the fleet owner shall include a clause stating that, to avoid double counting in the supply chain, the commercial fleet owner must not participate in any other emission reduction project associated with a biofuel producer or retailer. Only the commercial fleet owner or manager can claim emissions reductions under this methodology.

5 PROJECT BOUNDARY

The project boundary encompasses flex-fuel vehicles from the project commercial fleets. The project area includes all the gas stations used by the project commercial fleets as a part of the project activity.

The only emission source included in both the baseline and project scenario is the gasoline consumption by the commercial fleets within the project boundary[4]:

[4] This approach is the same used in AM0090.

Source		Gas	Included?	Justification/Explanation
Baseline	Gasoline Consumption	CO_2	Yes	Main emission source.
		CH_4	No	Excluded for simplification. This is conservative.
		N_2O	No	Excluded for simplification. This is conservative.
Project	Gasoline Consumption	CO_2	Yes	Main emission source.
		CH_4	No	Excluded for simplification. This is conservative.
		N_2O	No	Excluded for simplification. This is conservative.

Stratification of the project area into the project regions

In order to guarantee the accuracy and precision of the baseline emissions calculation, a stratification of the project region shall be carried out. Stratification is conducted *ex ante* and remains fixed for the whole project crediting period. It shall be based on publicly available data.

Stratification of the project area is conducted through a multivariable method that aims at classifying a sample of subjects (or objects) on the basis of a set of measured variables. The subjects are classified into a number of different groups in a way that similar subjects are placed in the same group. The obligatory variables that shall be included in the regional grouping of the project are fuel availability, prices and regulatory framework. Additional optional variables can be proposed by the project proponent and shall be justified.

The use of hierarchical methods (agglomerative or divisive) is suggested as the most suitable option for regional grouping of the project, considering the obligatory variables. Such methods include different approaches to define the distance that is used to establish the regional groups, such as Ward method (which minimizes the variance inside each group), single linkage (where the distance between two groups is the minimum of the distances of all pairs of patterns drawn from the two groups), complete linkage (where the distance between two groups is the maximum of all pairwise distances between patterns in the two groups), etc. Still, the project proponent can suggest application of non-hierarchical methods[5] (also known as k-means grouping methods) along with justification of the choice.

The project proponent shall select a distance measure (e.g., Euclidean distance) and justify why it is the most appropriate to determine similarity between regions in the project activity.

For both definition of the regional grouping method and distance measure to be applied by a project activity, the Validation/Verification Body has the authority to decide whether they are the most suitable and proper for the regional grouping process.

Therefore, a regional group is a subdivision of the project activity region, defined by its features of fuel availability, price, regulatory framework and other additional optional variables. The baseline and additionality assessments shall be conducted for each of the regional groups separately.

[5] In these methods the desired number of regional groups is specified in advance and the ’best’ solution is chosen.

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

The project proponent shall apply the latest version of the CDM *Combined tool to identify the baseline scenario and demonstrate additionality* to identify the baseline scenario for every regional group and for every commercial fleet in the project boundary, including Greenfield instances.

When applying Step 1 of the CDM *Combined tool to identify the baseline scenario and demonstrate additionality*, the project proponent shall consider as alternative scenarios, at least the following alternatives:

S1: The proposed project activity undertaken without being registered as a VCS project activity;

S3: The continuation of the current situation, not requiring any investment or expenses to maintain the current situation.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

Additionality shall be demonstrated for each regional group by applying the latest version of the CDM *Combined tool to identify the baseline scenario and demonstrate additionality*.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

The baseline emissions include exclusively the emissions from fossil fuel combustion by the commercial fleet that would have occurred in the baseline scenario.

The baseline emissions are calculated as follows:

$$BE_y = \sum_{i=x_1}^{x_n} BE_{FF,i,y} \quad (1)$$

Where:

BE_y	Baseline emissions in the year *y* (tCO_2);
$BE_{FF,i,y}$	Baseline emissions from gasoline combustion by commercial fleet *i* in year *y* (tCO_2e);
i	$x_1, x_2, \ldots, x_n$ commercial fleets in the project activity.

The baseline emissions from fossil fuel combustion by a commercial fleet are calculated as follows:

$$BE_{FF,i,y} = COEF_{gas,y} \bullet \sum_{R=r_1}^{r_m} FC_{gas,i,R,y} \quad (2)$$

Where:

$BE_{FF,i,y}$	Baseline emissions from gasoline combustion by commercial fleet *i* in year *y* (tCO_2e);

$FC_{gas,i,R,y}$	Gasoline consumption by the commercial fleet *i* in the baseline scenario, in regional group *R* in year *y* (L);
$COEF_{gas,y}$	CO_2 emission coefficient of gasoline in year *y* (tCO_2/L)
R	r_1, r_2, ... , r_m regional groups where a fleet *i* has fueled during the year *y*.

The gasoline consumption by fleets in the baseline scenario is calculated as follows:

$$FC_{gas,i,R,y} = FC_{ethanol,i,R,y} \bullet P_{i,R,BSL} \bullet T_{ff,y} \quad \textbf{(3)}$$

Where:

$FC_{gas,i,R,y}$	Gasoline consumption by the commercial fleet *i* in the baseline scenario, in regional group *R* in year *y* (L);
$FC_{ethanol,i,R,y}$	Ethanol consumption by the commercial fleet *i* in the project activity in regional group *R* in year *y* (L);
$P_{i,R,BSL}$	Baseline fuel consumption pattern of commercial fleet *i* in regional group *R* in the baseline scenario (adimensional);
$T_{ff,y}$	Conversion factor between gasoline and ethanol in year *y* (dimensionless);

8.1.1. Procedure to calculate the CO_2 emission coefficient ($COEF_{gas,y}$)

The CO_2 emission coefficient $COEF_{gas,y}$ is calculated through the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion*. It can be calculated using one of the following two options depending on the availability of data on gasoline as follows:

Option A: The CO_2 emission coefficient $COEF_{gas,y}$ is calculated based on the chemical composition of gasoline, using the following approach:

$$COEF_{gas,y} = w_{C,gas,y} \bullet \rho_{gas,y} \bullet 44/12 \quad \textbf{(4)}$$

Where:

$COEF_{gas,y}$	CO_2 emission coefficient of gasoline in year *y* (tCO_2/L);
$w_{C,gas,y}$	weighted average mass fraction of carbon in gasoline in year *y* (tC/mass unit);
$\rho_{gas,y}$	weighted average density of gasoline in year *y* (mass unit/L).

Option B: The CO_2 emission coefficient $COEF_{gas,y}$ is calculated based on net calorific value and CO_2 emission factor of gasoline, as follows:

$$COEF_{gas,y} = NCV_{gas,y} \bullet EF_{CO2,gas,y} \quad \textbf{(5)}$$

Where:

$COEF_{gas,y}$	CO_2 emission coefficient of gasoline in year *y* (tCO_2/L);
$NCV_{gas,y}$	weighted average net calorific value of gasoline in year *y* (GJ/L);
$EF_{CO2,gas,y}$	weighted average CO_2 emission factor of gasoline (tCO_2/GJ).

Option A is the preferred approach, if the necessary data is available.

8.1.2. Procedure to determine the baseline fuel consumption pattern of a commercial fleet ($P_{i,R,BSL}$)

Proportion between the use of gasoline and the use of ethanol in the annual fuel consumption in the baseline scenario in a regional group characterizes the baseline fuel consumption pattern of a fleet in this regional group. The historical values of the fuel consumption patterns of the project proponent's commercial fleets shall be adopted. For this purpose it is acceptable that a minimum reference period of three years and a maximum period that is consistent with the ethanol availability in the project region be used (i.e., it shall take into account national circumstances, including policies and market conditions). The Validation/Verification Body has the authority to decide whether the maximum historical period is suitable or not.

In the case of a Greenfield project activity instance, or if insufficient historical data is available, the historical average consumption pattern from the same regional group shall be adopted.

Baseline fuel consumption pattern in a regional group is determined as follows:

$$P_{i,R,BSL} = \frac{FC_{gas,i,R,BSL}}{FC_{gas,i,R,BSL} + FC_{ethanol,i,R,BSL}} \quad \textbf{(6)}$$

Where:

$P_{i,R,BSL}$	Baseline fuel consumption pattern of a commercial fleet *i* in regional group *R* in the baseline scenario (adimensional);
$FC_{gas,i,R,BSL}$	Total quantity of gasoline consumed by commercial fleet *i* in regional group *R* during the reference period (L);
$FC_{ethanol,i,R,BSL}$	Total quantity of ethanol consumed by commercial fleet *i* in regional group *R* during the reference period (L).

8.1.3. Procedure to determine the conversion factor between gasoline and ethanol ($T_{ff,y}$)

The conversion factor between gasoline and ethanol is calculated as a relationship between net calorific values (NCV) of these fuels. It shows the equivalent volume of ethanol necessary to substitute one liter of gasoline in the project activity.

The conversion factor between gasoline and ethanol is calculated as follows:

$$T_{ff,y} = \frac{NCV_{ethanol,y}}{NCV_{gas,y}} \quad \textbf{(7)}$$

Where:

$T_{ff,y}$	conversion factor between gasoline and ethanol in year *y*;
$NCV_{ethanol,y}$	weighted average net calorific value of ethanol in year *y* (GJ/L);
$NCV_{gas,y}$	weighted average net calorific value of gasoline in year *y* (GJ/L).

8.2 Project Emissions

Project emissions include start-up and emergency consumption of gasoline in the project activity, for which the sum shall not exceed 5% of the total fuel consumption under the project activity per each fleet per year. The project emissions from ethanol consumption that is renewable fuel are considered zero.

Project emissions are calculated as follows:

$$PE_y = \sum_{i=x_1}^{x_n} PE_{FC,i,y} \quad (8)$$

Where:

PE_y	Project emissions in year *y* (t CO_2/yr)
$PE_{FC,i,y}$	Project emissions from gasoline combustion by commercial fleet *i* in year *y* (t CO_2/yr)
i	x_1, x_2,..., x_n commercial fleets in the project activity.

Project emissions from gasoline combustion are calculated as follows:

$$PE_{FC,i,y} = FC_{gas,i,y} \bullet COEF_{gas,y} \quad (9)$$

Where:

$PE_{FC,i,y}$	Project emissions from gasoline combustion in year y (tCO_2);
$FC_{gas,i,y}$	Gasoline consumption by commercial fleet *i* in the project scenario in year *y* (L);
$COEF_{gas,y}$	CO_2 emission coefficient of gasoline in year *y* (tCO_2/L), according to Procedure 8.1.1.

8.3 Leakage

No leakage emissions are considered in this methodology.

8.4 Summary of GHG Emission Reduction and/or Removals

Emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y - LE_y \quad (10)$$

Where:

ER_y	Emission reductions in year *y* (tCO_2e/yr)
BE_y	Baseline emissions in year *y* (tCO_2e/yr)
PE_y	Project emissions in year *y* (tCO_2/yr)
LE_y	Leakage emissions in year *y* (tCO_2/yr)

9 MONITORING

9.1 Data and Parameters Available at Validation

In addition to the parameters listed in the tables below, the provisions on data and parameters not monitored in the tools referred to in this methodology apply.

Data Unit / Parameter:	$P_{i,R,BSL}$
Data unit:	adimensional
Description:	Fuel consumption pattern of fleet *i* in project region *R*, in the baseline scenario
Source of data:	Calculated *ex ante*
Justification of choice of data or description of measurement methods and procedures applied:	Calculated according to Procedure 8.1.2.
Any comment:	

Data Unit / Parameter:	$FC_{gas,i,R,BSL}$
Data unit:	liters
Description:	Total quantity of gasoline consumed by commercial fleet *i* in project region *R* during the reference period before the start of the project activity
Source of data:	Historical values
Justification of choice of data or description of measurement methods and procedures applied:	The historical fuel consumption of the project proponent's commercial fleets, obtained through direct or indirect measurement of fuel quantity and type, shall be adopted. If direct measurement was used, the respective equipment shall have been regularly calibrated following the manufacture specification. If indirect measurement was used, the Validation/Verification Body has the authority to decide when the measure method adopted by the project activity is robust enough to ensure that the data (type and quantity of fuel consumed) obtained, processed and registered is reliable. In the case of a Greenfield project activity instance or if no sufficient historical data is available, the historical average consumption pattern from the same regional group shall be adopted.
Any comment:	

Data Unit / Parameter:	$FC_{ethanol,i,R,BSL}$
Data unit:	liters
Description:	Total quantity of ethanol consumed by commercial fleet *i* in

	project region *R* during the reference period before the start of the project activity
Source of data:	Historical values
Justification of choice of data or description of measurement methods and procedures applied:	The historical fuel consumption of the project proponent's commercial fleets, obtained through direct or indirect measurement of fuel quantity and type, shall be adopted. If direct measurement was used, the respective equipment shall have been regularly calibrated following the manufacture specification. If indirect measurement was used, the Validation/Verification Body has the authority to decide when the measure method adopted by the project activity is robust enough to ensure that the data (type and quantity of fuel consumed) obtained, processed and registered is reliable. In the case of a Greenfield project activity instance or if no sufficient historical data is available, the historical average consumption pattern from the same regional group shall be adopted.
Any comment:	

9.2 Data and Parameters Monitored

Data Unit / Parameter:	$NCV_{gas,y}$
Data unit:	GJ/L
Description:	Weighted average net calorific value of gasoline in year *y*
Source of data:	The following data sources may be used if the relevant conditions apply:

Data source	Conditions for using the data source
a) Values provided by the fuel supplier in invoices	This is the preferred source
b) Measurements by the project proponent	If a) is not available
c) Regional or national default values	If a) and b) are not available. These sources should be based on well documented, reliable sources (such as national energy balances)
d) IPCC default values at the upper limit of the uncertainty at a 95% confidence interval as provided in Table 1.2 of Chapter 1 of Vol.2 (Energy) of the 2006 IPCC Guidelines on National	If a), b) and c) are not available

	GHG Inventories
Description of measurement methods and procedures to be applied:	For a) and b): Measurements should be undertaken in line with national or international fuel standards.
Frequency of monitoring/recording:	For a) and b): The NCV should be obtained for each fuel delivery, from which weighted average annual values should be calculated. For c): Review appropriateness of the values annually For d): Any future revision of the IPCC Guidelines should be taken into account
QA/QC procedures to be applied:	Verify if the values under a), b) and c) are within the uncertainty range of the IPCC default values as provided in Table 1.2, Vol. 2 of the 2006 IPCC Guidelines. If the values fall below this range collect additional information from the testing laboratory to justify the outcome or conduct additional measurements. The project proponent must justify the value according to such conditions and the Validation/Verification Body has the authority to decide when the justification is appropriate. The laboratories in a), b) or c) should have ISO 17025 accreditation or justify that they can comply with similar quality standards.
Any comment:	

Data Unit / Parameter:	$NCV_{ethanol,y}$
Data unit:	GJ/L
Description:	Weighted average net calorific value of ethanol in year *y*.
Source of data:	The following data sources may be used if the relevant conditions apply:

Data source	Conditions for using the data source
a) Values provided by the fuel supplier in invoices	This is the preferred source
b) Measurements by the project proponent	If a) is not available
c) Regional or national default values	If a) and b) are not available. These sources should be based on well documented, reliable sources (such as national energy balances)
d) IPCC default values at the upper limit of the uncertainty at a 95% confidence interval as provided in Table 1.2 of Chapter 1 of Vol.2 (Energy) of the 2006 IPCC Guidelines on National	If a), b) and c) are not available

	GHG Inventories
Description of measurement methods and procedures to be applied:	For a) and b): Measurements should be undertaken in line with national or international fuel standards
Frequency of monitoring/recording:	For a) and b): The NCV should be obtained for each fuel delivery from which weighted average annual values should be calculated. For c): Review appropriateness of the values annually. For d): Any future revision of the IPCC Guidelines should be taken into account
QA/QC procedures to be applied:	Verify if the values under a), b) and c) are within the uncertainty range of the IPCC default values as provided in Table 1.2, Vol. 2 of the 2006 IPCC Guidelines. If the values fall below this range collect additional information from the testing laboratory to justify the outcome or conduct additional measurements. The project proponent must justify the value according to such conditions and the Validation/Verification Body has the authority to decide when the justification is appropriate. The laboratories in a), b) or c) should have ISO 17025 accreditation or justify that they can comply with similar quality standards.
Any comment:	

Data Unit / Parameter:	$FC_{ethanol,i,R,y}$
Data unit:	liters
Description:	Ethanol consumption by the commercial fleet *i* in the project scenario in project region *R* in year *y*
Source of data:	Refueling transactions database
Description of measurement methods and procedures to be applied:	Direct or indirect measurement of place (gas station), date, type and quantity of fuel used in the project activity.
Frequency of monitoring/recording:	Every transaction
QA/QC procedures to be applied:	If direct measurement is used, the respective equipment shall be regularly calibrated following the manufacture specification. If indirect measurement is used, the Validation/Verification Body has the authority to decide when the measure method adopted by the project activity is robust enough to ensure that the data (type and quantity of fuel consumed) obtained, processed and registered is reliable.
Any comment:	

Data Unit / Parameter:	$w_{C,gas,y}$
Data unit:	tC/mass unit of gasoline
Description:	Weighted average mass fraction of carbon in gasoline in year *y*.
Source of data:	The following data sources may be used if the relevant conditions apply: **Data source** — **Conditions for using the data source** a) Values provided by the fuel supplier in invoices — This is the preferred source b) Measurements by the project proponent — If a) is not available
Description of measurement methods and procedures to be applied:	Measurements should be undertaken in line with national or international fuel standards
Frequency of monitoring/recording:	The mass fraction of carbon should be obtained for each fuel delivery, from which weighted average annual values should be calculated.
QA/QC procedures to be applied:	Verify if the values under a) and b) are within the uncertainty range of the IPCC default values as provided in Table 1.3, Vol. 2 of the 2006 IPCC Guidelines. If the values fall below this range collect additional information from the testing laboratory to justify the outcome or conduct additional measurements. The project proponent must justify the value according to such conditions and the Validation/Verification Body has the authority to decide when the justification is appropriate. The laboratories in b) should have ISO 17025 accreditation or justify that they can comply with similar quality standards.
Any comment:	Applicable where Option A is used. Preferably the same data source should be used for $w_{C,gas,y}$ and $\rho_{gas,y}$.

Data Unit / Parameter:	$\rho_{gas,y}$
Data unit:	mass unit of gasoline/L
Description:	Weighted average density of gasoline in year *y* (mass unit/L)
Source of data:	The following data sources may be used if the relevant conditions apply: **Data source** — **Conditions for using the data source** a) Values provided by the fuel — This is the preferred source

	<table><tr><td>supplier in invoices</td><td></td></tr><tr><td>b) Measurements by the project proponent</td><td>If a) is not available</td></tr><tr><td>c) Regional or national default values</td><td>If a) and b) are not available. These sources should be based on well documented, reliable sources (such as national energy balances)</td></tr></table>
Description of measurement methods and procedures to be applied:	Measurements should be undertaken in line with national or international fuel standards
Frequency of monitoring/recording:	The density of the fuel should be obtained for each fuel delivery, from which weighted average annual values should be calculated.
QA/QC procedures to be applied:	
Any comment:	Applicable where Option A is used. Preferably the same data source should be used for $w_{C,gas,y}$ and $\rho_{gas,y}$.

Data Unit / Parameter:	$EF_{CO2,gas,y}$
Data unit:	tCO_2/GJ
Description:	Weighted average CO_2 emission factor of gasoline
Source of data:	The following data sources may be used if the relevant conditions apply: <table><tr><th>Data source</th><th>Conditions for using the data source</th></tr><tr><td>a) Values provided by the fuel supplier in invoices</td><td>This is the preferred source</td></tr><tr><td>b) Measurements by the project proponent</td><td>If a) is not available</td></tr><tr><td>c) Regional or national default values</td><td>If a) and b) are not available. These sources should be based on well documented, reliable sources (such as national energy balances)</td></tr><tr><td>d) IPCC default values at the upper limit of the uncertainty at a 95% confidence interval as provided in Table 1.4 of Chapter 1 of Vol.2 (Energy) of</td><td>If a), b) and c) are not available</td></tr></table>

	the 2006 IPCC Guidelines on National GHG Inventories
Description of measurement methods and procedures to be applied:	For a) and b): Measurements should be undertaken in line with national or international fuel standards
Frequency of monitoring/recording:	For a) and b): The CO_2 emission factor should be obtained for each fuel delivery, from which weighted average annual values should be calculated. For c): Review appropriateness of the values annually. For d): Any future revision of the IPCC Guidelines should be taken into account.
QA/QC procedures to be applied:	
Any comment:	Applicable where option B is used. For a): If the fuel supplier does provide the NCV value and the CO_2 emission factor on the invoice and these two values are based on measurements for this specific fuel, this CO_2 factor should be used. If another source for the CO_2 emission factor is used or no CO_2 emission factor is provided, Options b), c) or d) should be used.

Data Unit / Parameter:	$COEF_{gas,y}$
Data unit:	tCO_2/L
Description:	CO_2 emission coefficient of gasoline in year *y*.
Source of data:	Calculated
Description of measurement methods and procedures to be applied:	Calculated according to Procedure 8.1.
Frequency of monitoring/recording:	
QA/QC procedures to be applied:	
Any comment:	

Data Unit / Parameter:	$T_{ff,y}$
Data unit:	dimensionless
Description:	Conversion factor between gasoline and ethanol in year *y*

Source of data:	Calculated
Description of measurement methods and procedures to be applied:	Calculated according to Procedure 8.3.
Frequency of monitoring/recording:	
QA/QC procedures to be applied:	
Any comment:	

Data Unit / Parameter:	$FC_{gas,\ i,\ y}$
Data unit:	L
Description:	Gasoline consumption by commercial fleet *i* in the project scenario in year *y*
Source of data:	Refueling transactions database
Description of measurement methods and procedures to be applied:	Direct or indirect measurement of place (gas station), date, type and quantity of fuel used in the project activity.
Frequency of monitoring/recording:	Every transaction
QA/QC procedures to be applied:	If direct measurement is used, the respective equipment shall be regularly calibrated following the manufacture specification. If indirect measurement is used, the Validation/Verification Body has the authority to decide when the measure method adopted by the project activity is robust enough to ensure that the data (type and quantity of fuel consumed) obtained, processed and registered is reliable.
Any comment:	When the $FC_{gas,\ i,\ y}$ represents more than 5% of the sum of $FC_{ethanol,i,R,y}$ and $FC_{gas,\ i,\ y}$ for an individual fleet and year, the project activity instance corresponding to this fleet shall be definitely excluded from the project activity, with no possibility to be reinserted and no right to reduction credits derived from such transgression year.

9.3 Description of the Monitoring Plan

All data collected as a part of monitoring process should be archived electronically and be kept at least for 2 years after the end of the last project crediting period. 100% of the data should be monitored if not indicated otherwise in the tables above. All direct measurements should be conducted with calibrated measurement equipment according to relevant industry standards.

10 REFERENCES AND OTHER INFORMATION

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VCS | VERIFIED CARBON STANDARD
A Global Benchmark for Carbon

Approved VCS Methodology VM0020

Version 1.0

Sectoral Scopes 3 and 7

Transport Energy Efficiency from Lightweight Pallets

6 November 2012

Document prepared by Axios Mobile Assets Corporation with the support of PE INTERNATIONAL & Five Winds Strategic Consulting.

Relationship to Approved or Pending Methodologies

Justification for a new methodology is provided below according to the procedure and requirements of the VCS document "Methodology Approval Process".

List of Approved or Pending Methodologies under Same Sectoral Scopes:

GHG Program	Sectoral Scope	Reference Number	Name	Status
VCS	3	VM0008	Methodology for Weatherization of Single and Multi-Family Buildings	Approved
VCS	3	VM0013	Baseline and Monitoring Methodology for the Reduction of Jet Engine Emissions through the Use of Engine Washing Technology	Approved
VCS	7	N/A	Methodology for Efficiency Improvements HDV's and Mobile Machinery	First Assessment
VCS	7	N/A	Methodology for Determining GHG Emission Reductions Through Bicycle Sharing Projects	Second Assessment
VCS	7	VM0019	Methodology for fuel switching from gasoline to ethanol in flex-fuel vehicle fleets	Approved
VCS	4, 6, 7, 13	VM0018	Energy Efficiency and Solid Waste Diversion Activities within a Sustainable Community	Approved
CDM	3	AM0017	Steam System Efficiency Improvements by Replacing Steam Traps and Returning Condensate	Approved
CDM	3	AM0018	Baseline Methodology for Steam Optimization Systems	Approved
CDM	3	AM0020	Baseline Methodology for Water Pumping Efficiency Improvements	Approved
CDM	3	AM0046	Distribution of Efficient Light Bulbs to Households	Approved
CDM	3	AM0060	Power Saving through Replacement by Energy Efficient Chillers	Approved
CDM	3,9	AM0068	Methodology for Improved Energy Efficiency by Modifying Ferroalloy Production Facility	Approved
CDM	3	AM0086	Installation of Zero Energy Water Purifier for Safe Drinking Water Application	Approved
CDM	3	AM0088	Air Separation using Cryogenic Energy Recovered from the Vaporization of LNG	Approved
CDM	3	AM0091	Energy efficiency and fuel switching measures in new buildings	Approved
CDM	3	AMS-II.C.	Demand-Side Energy Efficiency Activities for Specific Technologies	Approved
CDM	3	AMS-II.E.	Energy Efficiency and Fuel Switching Measures for Buildings	Approved

GHG Program	Sectoral Scope	Reference Number	Name	Status
CDM	3	AMS-II.F.	Energy Efficiency and Fuel Switching Measures for Agricultural Facilities and Activities	Approved
CDM	3	AMS-II.G.	Energy Efficiency Measures in Thermal Applications of Non-Renewable Biomass	Approved
CDM	3	AMS-II.J.	Demand-Side Activities for Efficient Lighting Technologies	Approved
CDM	3	AMS-II.K.	Installation of Co-generation or Tri-generation Systems Supplying Energy to Commercial Building	Approved
CDM	3	AMS-II.L.	Demand-side activities for efficient outdoor and street lighting technologies	Approved
CDM	3	AMS-II.M.	Demand-side energy efficiency activities for installation of low-flow hot water savings devices	Approved
CDM	3,11	AMS-III.X.	Energy Efficiency and HFC-134a Recovery in Residential Refrigerators	Approved
CDM	3	AMS-III.AE.	Energy Efficiency and Renewable Energy Measures in New Residential Buildings	Approved
CDM	3	AMS-III.AL.	Conversion from Single Cycle to Combined Cycle Power Generation	Approved
CDM	3	AMS-III.AV.	Low greenhouse gas emitting water purification systems	Approved
CDM	7	AM0031	Baseline Methodology for Bus Rapid Transit Projects	Approved
CDM	7	AM0090	Modal Shift in Transportation of Cargo from Road Transportation to Water or Rail Transportation	Approved
CDM	7	ACM0016	Baseline Methodology for Mass Rapid Transit Projects	Approved
CDM	7	AMS-III.C.	Emission Reductions by Electric and Hybrid Vehicles	Approved
CDM	7	AMS-III.S.	Introduction of Low-Emission Vehicles/Technologies to Commercial Vehicle Fleets	Approved
CDM	7	AMS-III.T.	Plant Oil Production and Use for Transport Applications	Approved
CDM	7	AMS-III.U.	Cable Cars for Mass Rapid Transit System (MRTS)	Approved
CDM	7	AMS-III.AA.	Transportation Energy Efficiency Activities Using Retrofit Technologies	Approved
CDM	7	AMS-III.AK.	Biodiesel Production and Use for Transport Applications	Approved
CDM	7	AMS-III.AP.	Transport Energy Efficiency Activities Using Post-Fit Idling Stop Device	Approved

GHG Program	Sectoral Scope	Reference Number	Name	Status
CDM	7	AMS-III.AQ.	Introduction of Bio-CNG in Transportation Activities	Approved
CDM	7	AMS-III.AT.	Transportation energy efficiency activities installing digital tachograph systems to commercial freight transport fleets	Approved

This methodology applies to project activities that are not broadly similar to an activity or measure covered by an existing approved or pending methodology.

None of the similar methodologies identified above could be revised without substantial changes to the section on project boundary.

None of the similar methodologies identified above could be revised without the addition of new procedures or scenarios to more than half of its sections.

Table of Contents

1 SOURCES

The VCS Methodology Template was used to develop this methodology.

This Methodology is based on elements of the following CDM methodologies:

- AMS-III.AA. "Transportation Energy Efficiency Activities using Retrofit Technologies" (Section 4)
- AMS-III.S. "Introduction of Low Emission Vehicles/Technologies to Commercial Vehicle Fleets" (Sections 4 and 8)
- ACM0017 "Production of Biodiesel for Use as Fuel" (Sections 6, 8.3, and 9.2)
- AM0090 "Modal Shift in Transportation of Cargo from Road Transportation to Water or Rail Transportation" (Sections 6 and 8)

This methodology refers to the latest approved version of the following CDM tool:

- *Combined tool to identify the baseline scenario and demonstrate additionality* (Section 6 Procedure for Determining the Baseline Scenario)[1]

This methodology refers to elements of the latest approved version of the following CDM tool:

- *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion* (Section 9.2 Data and Parameters Monitored, including: "Source of data", "Description of measurement methods and procedures to be applied", "QA/QC procedures to be applied")[2]

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Pallets are flat, portable structures that support goods during handling, transportation and storage. This methodology outlines procedures to estimate the avoided net greenhouse gas (GHG) emissions resulting from project activities involving the use of pallets that are lighter in weight than their conventional alternatives for freight transport. Typical GHG reduction projects with lightweight pallets involve:

a) Replacing an existing fleet of conventional wood pallets with lightweight pallets, or
b) Setting up a new fleet of pallets using lightweight pallets.

In both cases, the baseline would be the same fleet of conventional pallets. Projects achieve GHG emission reductions through reducing the total weight of goods transported, hence reducing fuel consumption and associated GHG emissions.

This methodology provides procedures to select the baseline from amongst plausible scenarios and provides methods to transparently estimate the baseline GHG emissions. Project emissions are

[1] http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-02-v4.0.0.pdf

[2] http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-03-v2.pdf

quantified by monitoring the fuel consumption by captive truck fleets transporting freight using lightweight pallets.

Baseline emissions are quantified by assuming the same routes, vehicles, fuel, and driving behavior as the project, and modifying GHG emissions associated with fuel consumption to take account of increased weight transported.

Relevant GHG sources not included in the project boundary (ie, production of raw materials and pallet manufacturing) are considered as leakage.

Additionality	Project Method
Crediting Baseline	Project Method

3 DEFINITIONS

Captive Fleet: A collection of vehicles with clearly defined boundaries, typically owned or managed by one party.

Conventional pallet: A pallet composed mainly of either wood or plastic. Currently, wood pallets dominate the market, representing 90-95% of all pallets produced across the globe.[3]

Freight: Goods transported by commercial fleets.

Lightweight pallet: A pallet that is lighter in weight than its conventional alternative.

Pallet: A flat, portable structure that supports goods during handling, transport and storage.

Trip: A journey where the weight transported remains constant. A new trip begins each time there is a change in the transported weight.

4 APPLICABILITY CONDITIONS

This methodology applies to project activities that reduce GHG emissions from the transportation of freight on truck fleets by reducing the weight of pallets transported, hence reducing fuel consumption. Emission reductions claimed under this methodology are only related to increased fuel efficiency due to the use of lightweight pallets.

[3] FP Innovations: PalletTrends 2009. http://www.valuetowood.ca/imports/pdf/en/market_profiles/2009/Palette-Trends2009.pdf

The following conditions apply to this methodology:

Pallet Performance Requirements

a) Lightweight pallets deployed in the project must offer the same or better technical performance compared to the baseline pallets. This must be demonstrated via certified conformance with ISO 8611-2.

Pallet Identification

a) Lightweight pallets deployed in the project must each have a unique ID (e.g., Radio-Frequency Identification (RFID) tags, Universal Product Code (UPC), etc.) to facilitate monitoring.

Fleet, Truck and Fuel Characteristics

a) Vehicles are part of a captive fleet.
b) If project proponent is not the captive fleet operator, a contract addressing ownership of emission reduction credits with the captive fleet operator is required.
c) When freight is transported, the freight must be transported on pallets in both the project and baseline scenarios.
d) If biofuel blends are used, the blending ratio in the project and baseline must be the same.

If any of these conditions are violated during a single trip, the trip must not be included in the project and no emission reduction credits can be claimed from the trip.

This methodology is not applicable to emission reductions from the following scenarios:

a) Introduction of low-emission vehicles (eg, compressed natural gas vehicles, electric vehicles, liquid petroleum gas vehicles, and hybrid vehicles with electrical and internal combustion motive systems);
b) Fuel switch in existing vehicles (eg, fossil fuel to plant oil use);
c) Retrofitting of existing vehicles (eg, switching from high greenhouse gas intensive to low greenhouse gas intensive fossil fuel);
d) Modal shift in transportation; and
e) Changes in truck freight capacity enabled by use of lightweight pallets.

5 PROJECT BOUNDARY

The project boundary encompasses truck fleets while carrying lightweight pallets as part of their cargo and consuming fossil fuel.

Emission sources are summarized in Table 1 below.

Source		Gas	Included?	Justification/Explanation
Baseline	Vehicles consuming fossil fuel	CO_2	Yes	Main emission source in the combustion of fossil fuel.
		CH_4	No	Excluded for simplification.
		N_2O	No	Excluded for simplification.
Project	Vehicles consuming fossil fuel	CO_2	Yes	Main emission source in the combustion of fossil fuel.
		CH_4	No	Excluded for simplification.
		N_2O	No	Excluded for simplification.

Project and baseline emissions from loading and unloading of trucks are excluded because they would not be significant.

Return trips (i.e., empty pallets only) can be included as a trip as part of the "Vehicles consuming fossil fuel" source if all requirements, including monitoring requirements, are met.

For simplification and conservativeness, production of raw materials used to manufacture conventional pallets and manufacturing of conventional pallets are not included in the baseline boundary.

Production of raw materials used to manufacture lightweight pallets and manufacturing of lightweight pallets are not included in the project boundary, but are included under leakage.

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

Project participants must use the most recent version of the CDM's *Combined tool to identify the baseline scenario and demonstrate additionality* to identify alternative baseline scenarios and determine the most plausible scenario.

The following must be adhered to when applying each of the steps in the CDM tool:

Step 1: Identify all realistic and credible alternatives to using lightweight pallets

When applying Sub-step 1a of the tool, alternative scenarios for pallet types must include all realistic and credible alternatives to the project activity that are available in the relevant market.

The following likely scenarios for pallet types must be assessed, *inter alia*:

- Wood pallets, and
- Petroleum-based plastic pallets.

All considered scenarios must provide the same type and level of service, ie, they must be able to transport the same amount of freight as transported under the project activity.

Step 2: Barrier Analysis

Barrier analysis must be used to assess which of these alternatives is to be excluded from further consideration (i.e. alternatives where barriers are prohibitive or which are clearly economically unattractive) and Step 3 must be applied for all remaining alternatives.

Step 3: Investment Analysis

In applying Step 3, the following must be followed:

- The investment analysis must be carried out from the perspective of the project participants, i.e. the owner or operator of the truck fleet.
- At a minimum, project participants must take into account the following costs in the investment analysis:
    a. Costs of acquiring and maintaining pallets
    b. Fuel costs
    c. Costs of disposing of pallets at the end of their useful life

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

Project participants must use the most recent version of the CDM's "Combined tool to identify the baseline scenario and demonstrate additionality" to demonstrate additionality. The additional procedures described above in Section 6 must be used when applying this tool.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

The first step to determine the baseline emissions is to calculate the fleet's project emission factor per tonne of freight carried 1 kilometer. The project emission factor is determined by dividing total fleet-wide, fuel consumption-related emissions for eligible trips during the project by the sum of freight weight and distance travelled for each vehicle and trip in the fleet. The weight transported must stay constant during each trip. Each time the weight changes, a trip must be declared and the project proponent monitors the weight of freight, distance travelled, and number of pallets for each trip. Only trips where there is complete substitution of the baseline pallets must be quantified using the following equations (i.e., no partial substitution at the trip level is allowed).

$$PEF_y = \sum_{j,k,y}\left(FC_{j,k,y} \times EF_{j,y}\right) \div \sum_{i,k,y}\left(W_{i,k,y} \times D_{i,k,y}\right) \qquad (1)$$

Where:

PEF_y Project emission factor in year y per weight-distance of freight (t CO_2/t km)
$FC_{j,k,y}$ Quantity of fuel type j combusted by the fleet for eligible trips k in year y (volume of fuel)
$EF_{j,y}$ GHG emission factor of fuel j in year y (t CO_2/unit volume of fuel consumed)
$W_{i,k,y}$ Weight of freight (including project pallets) transported by vehicle i for trip k in year y (metric tonnes)
$D_{i,k,y}$ Distance travelled by vehicle i for trip k in year y (km)

The total baseline emissions are then calculated using the project emission factor applied to the same fleet and distance travelled, assuming increased freight weight transported due to use of conventional pallets.

$$BE_y = PEF_y \times \sum_{i,k,y}\left(D_{i,k,y} \times \left(W_{i,k,y} + \left(P_B - P_P\right) \times N_{i,k,y}\right)\right) \qquad (2)$$

Where:

BE_y Total baseline emissions in year y (t CO_2/year)
PEF_y Project emission factor in year y per weight-distance of freight (t CO_2/t km)
$D_{i,k,y}$ Distance travelled by vehicle i for trip k in year y (km)
$W_{i,k,y}$ Weight of freight (including project pallets) transported by vehicle i for trip k in year y (metric tonnes)
P_B Weight of each baseline pallet (metric tonnes)
P_P Weight of each project pallet (metric tonnes)
$N_{i,k,y}$ Number of pallets carried by vehicle i for trip k in year y

8.1.1 Baseline Emissions (Alternative Approach)

This alternative approach can only be used if the data for the approach described in 8.1 is not available and must be used with the approach described in section 8.2.1. The approaches described in sections

8.1 and 8.2 are more accurate and preferred. If the data to determine the baseline emissions using the approach described in 8.1 is not available (eg, no fuel consumption or freight weight data), the following alternative approach using default emission factors from recognized sources is acceptable.

$$BE_y = DEF_{j,y} \times \sum_{i,k,y} \left(D_{i,k,y} \times \left(W_{i,k,y} + \left(P_B - P_P \right) \times N_{i,k,y} \right) \right) \quad (3)$$

Where:

BE_y Total baseline emissions in year y (t CO_2/year)
$DEF_{j,y}$ Default emission factor for fuel type j in year y per weight-distance of freight (t CO_2/t km)
$D_{i,k,y}$ Distance travelled by vehicle i for trip k in year y (km)
$W_{i,k,y}$ Weight of freight (including project pallets) transported by vehicle i for trip k in year y (metric tonnes)
P_B Weight of each baseline pallet (metric tonnes)
P_P Weight of each project pallet (metric tonnes)
$N_{i,k,y}$ Number of pallets carried by vehicle i for trip k in year y

8.2 Project Emissions

Project emissions are determined by monitoring the consumption of fuel for eligible trips (as defined above in section 8.1) for the entire fleet transporting freight using lightweight pallets, according to the following formula:

$$PE_y = \sum_{j,y} \left(FC_{j,k,y} \times EF_{j,y} \right) \quad (4)$$

Where:

PE_y Total project emissions in year y (t CO_2/year)
$FC_{j,k,y}$ Quantity of fuel type j combusted by the fleet for eligible trips k in year y (volume of fuel)
$EF_{j,y}$ GHG emission factor of fuel j in year y (t CO_2/unit volume of fuel consumed)

8.2.1 Project Emissions (Alternative Approach)

This alternative approach can only be used if the data for the approach described in 8.2 is not available and must be used with the approach described in section 8.1.1. The approaches described in sections 8.2 and 8.1 are more accurate and preferred. If the data to determine the project emissions using the approach described in 8.2 is not available (ie, no fuel consumption data), the following alternative approach using default emission factors from recognized sources is acceptable.

$$PE_y = DEF_{j,y} \times \sum_{i,k,y}(D_{i,k,y} \times W_{i,k,y}) \quad (5)$$

Where:

PE_y Total project emissions in year y (t CO_2/year)
$DEF_{j,y}$ Default emission factor for fuel type j in year y per weight-distance of freight (t CO_2/t km)
$D_{i,k,y}$ Distance travelled by vehicle i for trip k in year y (km)
$W_{i,k,y}$ Weight of freight (including project pallets) transported by vehicle i for trip k in year y (metric tonnes)

Note that using this alternative approach allows emission reductions to be calculated using a default emission factor, distance travelled, weight reduction per pallet, and the number of pallets carried. The total weight transported is the same in equations (3) and (5), and cancels out when project emissions are subtracted from baseline emissions. Baseline and project emissions can be quantified separately by using actual weight of freight transported data (if available), or by making reasonable assumptions about the weight of freight transported and justifying those assumptions. Any uncertainty in these assumptions will be eliminated when project emissions are subtracted from baseline emissions to quantify emission reductions.

8.3 Leakage

This methodology estimates the following sources of leakage:

- Production of raw materials used to manufacture lightweight pallets; and
- Manufacturing of lightweight pallets.

Positive leakage from baseline sources (e.g., production of raw materials used to manufacture conventional pallets, manufacturing of conventional pallets) is not included, which is conservative. Leakage associated with transportation of raw materials used to manufacture pallets, transportation of manufactured pallets (before first use) and end of life treatment for pallets is considered insignificant and is not included.

Leakage is calculated as follows:

$$LE_y = LE_{RM,y} + LE_{M,y} \quad (6)$$

Where:

LE_y Leakage emissions in year y (t CO_2)
$LE_{RM,y}$ Leakage emissions associated with production of raw materials used to manufacture lightweight pallets in year y (t CO_2)
$LE_{M,y}$ Leakage emissions associated with manufacturing of lightweight pallets

8.3.1 Production of raw materials used to manufacture lightweight pallets

Emissions from production of raw materials used to manufacture lightweight pallets are estimated by listing all raw materials that account for a total of at least 95% of the lightweight pallet mass, then estimating the upstream emissions for their production, as follows:

$$LE_{RM,y} = \Sigma_x (N \times M_x \times EF_x) \quad (7)$$

Where:

$LE_{RM,y}$	Leakage emissions associated with production of raw materials used to manufacture lightweight pallets in year y (t CO_2)
N	Number of pallets consumed per year
M_x	Mass of raw material x consumed per pallet manufactured (tonnes)
EF_x	Upstream emission factor for production of raw material x (t CO_2/t raw material x)

8.3.2 Manufacturing of lightweight pallets

Emissions from manufacturing of lightweight pallets are estimated by listing all GHG sources from manufacturing lightweight pallets, then estimating manufacturing emissions as follows:

$$LE_{M,y} = \Sigma_a(N \times A_a \times EF_a) \quad (8)$$

Where:

$LE_{M,y}$	Leakage emissions associated with manufacturing of lightweight pallets in year y (t CO_2)
N	Number of pallets consumed per year
A_a	Activity level from GHG source a per pallet manufactured (energy consumption or fuel volume units)
EF_a	Emission factor for GHG source a (t CO_2 /unit energy consumption or fuel volume)

If primary energy consumption data from manufacturing lightweight pallets is not available, the project proponent may use other primary or secondary data sources to estimate emissions from manufacturing of lightweight pallets. These sources of data must be justified (ie, alternative sources of data must be listed and the reasons for selecting the data used must be given) using criteria that include data source (recognized and authoritative sources are preferred); geographic, temporal and technology specificity; conservativeness (ie, does not overestimate emission reduction); and if the data is peer reviewed (preferred).

8.4 Summary of GHG Emission Reduction and/or Removals

Emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y - LE_y \tag{9}$$

Where:

ER_Y Net GHG emissions reductions in year y
BE_Y Baseline emissions in year y
PE_y Project emissions in year y
LE_y Leakage in year y

9 MONITORING

9.1 Data and Parameters Available at Validation

Data Unit / Parameter:	P_B
Data unit:	Weight unit (e.g. metric tonnes)
Description:	Weight of each individual baseline pallet
Source of data:	Measurements using weight scales Manufacturer specifications
Justification of choice of data or description of measurement methods and procedures applied:	Obtain the weight of one baseline pallet by consulting with the specifications provided by the manufacturer. Cross check using properly calibrated weight scales and a statistically significant sample of baseline pallets.
Any comment:	-

Data Unit / Parameter:	$DEF_{j,y}$
Data unit:	t CO_2/t km
Description:	Default GHG emission factor for fuel type j per unit weight-distance of freight in year y
Source of data:	Statistics published by recognized sources such as US government or industry associations. For example, EPA Climate Leaders publication "Optional Emissions from Commuting, Business Travel & Product Transport, EPA43-R-08-006" or WRI/WBCSD GHG Protocol Mobile Combustion tool
Justification of choice of data or description of measurement methods and procedures applied:	The range of appropriate data must be documented and the chosen data must be justified, using criteria that include data source (recognized and authoritative sources); geographic, temporal and technology specificity; conservativeness (i.e., does not overestimate emission reduction); and if the data is peer reviewed (preferred).
Any comment:	The above justification is required to manage the uncertainty associated with this parameter.

9.2 Data and Parameters Monitored

Data Unit / Parameter:	$FC_{j,y}$
Data unit:	Volume units per year (e.g. gallons/year)
Description:	Quantity of fuel type *j* combusted by the fleet during the year *y*
Source of data:	Onsite and offsite sources a) Purchasing records b) Metering c) Logs
Description of measurement methods and procedures to be applied:	Purchasing records • For centralized purchases, use invoices from suppliers and adjust for inventory of fuel at beginning and end of year • For offsite purchases, use electronic records from cardlock or similar system Metering • Use fuel flow meters to measure volume of fuel transferred to vehicles at central facilities or offsite filling stations Logs • Record volume of fuel consumed per vehicle per refill in electronic or manual logs
Frequency of monitoring/recording:	Continuously
QA/QC procedures to be applied:	Purchasing records must be cross checked against metered fuel transferred to vehicles. Fuel flow meters must be calibrated according to current good practice (e.g., relevant industry standards). The consistency of metered fuel consumption quantities must be cross-checked by an annual reconciliation based on purchased quantities and stock changes. Metered fuel consumption quantities must also be cross-checked with available purchase invoices from financial records (e.g., cardlock system)
Any comment:	-

Data Unit / Parameter:	$EF_{j,y}$
Data unit:	t CO_2/unit volume of fuel consumed

Description:	GHG emission factor of fuel type *j* consumed by the fleet in year *y*
Source of data:	The following data sources may be used if the relevant conditions apply: **Data source** — **Conditions for using data source** a) Regional or national default values from recognized sources — These values must be based on well-documented, reliable sources (e.g., national energy balances, government publications, industry associations, WRI/WBCSD GHG Protocol) b) IPCC default values at the upper limit of the uncertainty at a 95% confidence interval as provided in table 1.4 of Chapter 1 of Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories — If a) is not available
Description of measurement methods and procedures to be applied:	If more than one recognized source is available, the most appropriate source must be selected, based on data quality indicators including technological appropriateness, regional specificity, and vintage of the data.
Frequency of monitoring/recording:	Review appropriateness of the values annually
QA/QC procedures to be applied:	Fuel type *j* must be recorded for each refill, transfer or other transaction, including the fraction of biofuel present (if applicable).
Any comment:	-

Nested table (Source of data):

Data source	Conditions for using data source
a) Regional or national default values from recognized sources	These values must be based on well-documented, reliable sources (e.g., national energy balances, government publications, industry associations, WRI/WBCSD GHG Protocol)
b) IPCC default values at the upper limit of the uncertainty at a 95% confidence interval as provided in table 1.4 of Chapter 1 of Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories	If a) is not available

Data Unit / Parameter:	$W_{i,k,y}$
Data unit:	Weight unit (e.g. metric tonnes)

Description:	Weight of freight (including pallets) transported by vehicle *i* for trip *k* in year *y*
Source of data:	Onsite measurements by project participants, or Shipping records
Description of measurement methods and procedures to be applied:	The weight of freight transported under the VCS project by the project vehicles must be measured at the point of origin using weight scales. The amount must be cross-checked with the freight received at destination. If direct weight measurement is not feasible, shipping records must be used to estimate weight of freight transported.
Frequency of monitoring/recording:	Continuously
QA/QC procedures to be applied:	Weight scales must be calibrated according to current good practice (e.g., relevant industry standards). If measurements used, cross check measurements against shipping records. If shipping records used, cross check shipping records against billing or other information systems.
Any comment:	-

Data Unit / Parameter:	$D_{i,k,y}$
Data unit:	Distance unit (e.g. kilometers)
Description:	Total distance travelled by vehicle *i* for trip *k* in year *y* (kilometers)
Source of data:	a) Odometer readings; b) Tracking solution; and/or c) Electronic Data Interchange (EDI) / Advanced Shipping Notice (ASN) system
Description of measurement methods and procedures to be applied:	For a): Monitor odometer readings of all trucks in fleet at beginning and end of each trip. For b): Use a tracking solution (e.g. GPS vehicle tracking) to monitor routes and distances travelled by each vehicle. For c): Use transactional data from the fleet operator's EDI/ASN system, in conjunction with a tracking software solution to provide an audit trail of where the vehicles have travelled.
Frequency of monitoring/recording:	Continuously
QA/QC procedures to be applied:	Check consistency of distance records provided by the fleet operator by comparing recorded distances from odometer readings or tracking solution with information from other sources (e.g. driver logs and/or route maps).

Any comment:	-

Data Unit / Parameter:	P_P
Data unit:	Weight unit (e.g. metric tonnes)
Description:	Weight of each individual project pallet
Source of data:	Measurements using weight scales Manufacturer specifications
Description of measurement methods and procedures to be applied:	Obtain the weight of one project pallet by consulting with the specifications provided by the manufacturer.
Frequency of monitoring/recording:	Annually or more frequently if pallet specifications change.
QA/QC procedures to be applied:	Cross check using properly calibrated weight scales and a statistically significant sample of project pallets
Any comment:	-

Data Unit / Parameter:	$N_{i,k,y}$
Data unit:	Number
Description:	Number of pallets carried by vehicle *i* for trip *k*
Source of data:	Shipping records Unique ID for each pallet (e.g., Radio-Frequency Identification (RFID) tags, Universal Product Code (UPC), etc.)
Description of measurement methods and procedures to be applied:	EDI/ASN information system to make use of unique ID for each pallet so that the number of pallets carried by each vehicle for each trip is recorded automatically.
Frequency of monitoring/recording:	Continuously
QA/QC procedures to be applied:	Project participants must cross-check the total number of pallets recorded by the EDI/ASN information system with onsite shipping records. Cross check the average weight carried per pallet against pallet capacity for reasonableness and potential inconsistencies.
Any comment:	-

Leakage Data and Parameters

Data Unit / Parameter:	N
Data unit:	–
Description:	Number of pallets consumed by fleet operator per year
Source of data:	Average number of pallets in use and average lifetime of pallets
Description of measurement methods and procedures to be applied:	The number of pallets consumed per year is determined by monitoring the average number of pallets used by the fleet operator each year (e.g., average of beginning and ending inventory, or average of 12 monthly inventories), and dividing it by the average lifetime of each pallet. Average lifetime (i.e. number of years the average pallet lasts before its final disposal) is determined from internal records, manufacturer specifications and/or industry standard testing procedures.
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	Cross check against purchasing records for reasonableness. Note that annual purchases will vary depending on a number of factors, but will, over time, converge to the overall number of pallets consumed. The average lifetime from manufacturer specification or industry standards must be compared against internal records to account for project specific conditions.
Any comment:	-

Data Unit / Parameter:	M_x
Data unit:	Weight unit (e.g. metric tonnes)
Description:	Mass of raw material x consumed per pallet manufactured
Source of data:	Manufacturer specifications
Description of measurement methods and procedures to be applied:	The mass of each type of raw material consumed per pallet must be determined from manufacturer specifications and include the mass of raw material consumed as waste in the process.
Frequency of monitoring/recording:	Annually or more frequently if pallet specifications change

QA/QC procedures to be applied:	Cross check manufacturer specification against current version of pallet to ensure current pallet specifications are being used. Cross check against total weight of pallet to ensure at least 95% of the total pallet weight is accounted for.
Any comment:	-

Data Unit / Parameter:	EF_x
Data unit:	t CO_2 / t of raw material x
Description:	Upstream emission factor for production of raw materials for pallets
Source of data:	The following data sources may be used: a) Primary data from suppliers b) Industry data c) National Life Cycle Inventory (LCI) databases d) Commercial LCI databases
Description of measurement methods and procedures to be applied:	For secondary data, emission factors for each raw material must be determined from recognized sources for each raw material consumed. For raw materials with no secondary data available from a recognized source, proxy data must be used for a similar material that is likely to have a similar upstream emission factor. If more than one recognized source is available, the most appropriate source must be selected, based on data quality indicators including technological appropriateness, regional specificity, and vintage of the data.
Frequency of monitoring/recording:	Annually

QA/QC procedures to be applied:	For primary data from suppliers, request documentation of methodologies used and compare to good practices. Identify and correct any major deficiencies. For secondary data from publications or databases, compare multiple sources if available. The range of appropriate data must be documented and the chosen data must be justified, using criteria that include data source (recognized and authoritative sources are preferred); geographic, temporal and technology specificity; conservativeness (i.e., does not overestimate emission reduction); and if the data is peer reviewed (preferred).
Any comment:	The above justification is required to manage the uncertainty associated with this parameter.

Data Unit / Parameter:	A_a
Data unit:	Energy consumption or fuel volume units
Description:	Activity level from GHG source a per pallet during manufacturing of pallet
Source of data:	Manufacturer's records • Invoices from suppliers • Metered data
Description of measurement methods and procedures to be applied:	The activity level of each GHG emission source per pallet must be determined by monitoring the total amount of each energy consuming activity at the manufacturer's facility per year and dividing by the number of pallets produced by the manufacturer's facility per year. If more than one product is produced at the facility, allocation rules consistent with ISO 14040/44 must be applied.
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	-
Any comment:	-

Data Unit / Parameter:	EF_a
Data unit:	(t CO_2 /unit energy consumption or fuel volume units)
Description:	Emission factor for GHG source a

<table>
<tr><td>Source of data:</td><td>The following data sources may be used:

<table><tr><th>Data source</th><th>Conditions for using data source</th></tr><tr><td>a) Regional or national default values from recognized sources</td><td>This is the preferred source.

These values must be based on well-documented, reliable sources (e.g., national energy balances, government publications, WRI/WBCSD GHG Protocol)</td></tr><tr><td>b) IPCC default values at the upper limit of the uncertainty at a 95% confidence interval as provided in table 1.4 of Chapter 1 of Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories</td><td>If a) is not available.</td></tr></table></td></tr>
<tr><td>Description of measurement methods and procedures to be applied:</td><td>Emission factors for each GHG emission source must be determined from regional, national or international default values for each raw material consumed per pallet.

For a): Review appropriateness of the values annually.
For b): Any future revision of the IPCC Guidelines must be taken into account.</td></tr>
<tr><td>Frequency of monitoring/recording:</td><td>For a): Review appropriateness of the values annually.
For b): Any future revision of the IPCC Guidelines must be taken into account.</td></tr>
<tr><td>QA/QC procedures to be applied:</td><td>-</td></tr>
<tr><td>Any comment:</td><td>-</td></tr>
</table>

9.3 Description of the Monitoring Plan

The project proponent must establish, maintain and apply a monitoring plan and GHG information system that includes criteria and procedures for obtaining, recording, compiling and analyzing data, parameters and other information important for quantifying and reporting GHG emissions relevant for the project and baseline scenario. Monitoring procedures must address the following:

a) Types of data and information to be reported;
b) Units of measurement;
c) Origin of the data;
d) Monitoring methodologies (e.g., estimation, modeling, measurement, calculation);
e) Where options are provided in section 9 above, justification for the option selected;
f) Type of equipment used, if any;
g) Monitoring times and frequencies;
h) QA/QC procedures;
i) Monitoring roles and responsibilities, including experience and training requirements;
j) GHG information management systems, including the location, back up, and retention of stored data.

Where measurement and monitoring equipment is used, the project proponent must ensure the equipment is calibrated according to current good practice (eg, relevant industry standards).

All data collected as part of monitoring must be archived electronically and kept at least for 2 years after the end of the last project crediting period.

QA/QC procedures must include, but are not limited to:

Data Gathering, Input and Handling Measures

- Input data checked for typical errors, including inconsistent physical units, unit conversion errors, typographical errors caused by data transcription from one document to another; and missing data for specific time periods or physical units;
- Input time series data checked for large unexpected variations (eg, orders of magnitude) that could indicate input errors;
- All electronic files to use version control to ensure consistency;
- Physical protection of monitoring equipment (eg, sealed meters and data loggers); and
- Physical protection of records of monitored data (eg, hard copy and electronic records).

Data Documentation

- Input data units checked and documented;
- All sources of data, assumptions and emission factors documented;
- Changes to data, assumptions and emission factors documented; and
- Documented assumptions and algorithms validated based on best practices.

Calculations

- Units for input data and conversion factors documented;
- Units for all intermediate calculations and final results documented;

- Input data and calculated data clearly differentiated;
- Comparison to previous results to identify potential inconsistencies; and
- Results aggregated in various ways to identify potential inconsistencies.

10 REFERENCES AND OTHER INFORMATION

The latest approved versions of CDM tools referenced above are available at:

http://cdm.unfccc.int/Reference/tools/index.html

Approved VCS Methodology
VM0021

Version 1.0, 16 November 2012
Sectoral Scope 14

Soil Carbon Quantification Methodology

Methodology developed by:

The Earth Partners LLC.

RELATIONSHIP TO APPROVED OR PENDING METHODOLOGIES

To date no similar methodologies have been approved under the VCS Program.

Four related methodologies are currently under development or approved under the VCS Program:

- *ALM Adoption of Sustainable Grassland Management through Adjustment of Fire and Grazing* (methodology under development)- This methodology is limited to activities on uncultivated grasslands where fire is a potential occurrence.
- *Agricultural Land Management – Improved Grassland Management* (methodology under development) – This methodology is dependent on the existence of applicable, tested soil models for determining soil carbon.
- *VM0017 Adoption of Sustainable Agricultural Land Management (SALM)* – This methodology focuses on a specific set of management practices
- *Methodology for Sustainable Grassland Management (SGM)* (methodology under development) – This methodology is specific to sustainable grassland management projects where ongoing degradation is occurring and is expected to continue
- *Calculating Emission Reductions in Rice Management Systems* (methodology under development) – This methodology is specific to reducing emissions from rice cultivation.

All of these existing proposed methodologies focus on specific elements of the ALM continuum. The use of soil carbon prediction models such as Century and DNDC are widely applied in these methodologies. This methodology is much more general, and is designed to be applicable to projects where a wide variety of activities may occur under the baseline or project scenario, such as timber harvesting, and fertilization. Soil carbon is measured in both the baseline and project scenarios and the DNDC model is used only for quantifying the methane and nitrous oxide emissions.

Table of Contents

1 SOURCES

This methodology and its modules have been developed on the accounting principles as set out in: IPCC 2003 Good Practice Guidance for Land Use, Land-Use Change and Forestry.

The modules used in this methodology are:

- *VMD0018 Methods to Determine Stratification*
- *VMD0019 Methods to Project Future Conditions*
- *VMD0020 Methods to Determine the Project Boundary*
- *VMD0021 Estimation of Stocks in the Soil Carbon Pool*
- *VMD0022 Estimation of Carbon Stocks in Living Plant Biomass*
- *VMD0023 Estimation of Carbon Stocks in the Litter Pool*
- *VMD0024 Estimation of Carbon Stocks in the Dead Wood Pool*
- *VMD0025 Estimation of Woody Biomass Harvesting and Utilization*
- *VMD0026 Estimation of Carbon Stocks in the Long Lived Wood Products Pool*
- *VMD0027 Estimation of Domesticated Animal Populations*
- *VMD0028 Estimation of Emissions from Domesticated Animals*
- *VMD0029 Estimation of Emissions of Non-CO_2 GHG from Soils*
- *VMD0030 Estimation of Emissions from Power Equipment*
- *VMD0031 Estimation of Emissions from Biomass Burning*
- *VMD0032 Estimation of Emissions from Activity Shifting Leakage*
- *VMD0033 Estimation of Emissions from Market Leakage*
- *VMD0034 Methods for Developing a Monitoring Plan*
- *VMD0035 Methods to Determine the Net Change in Atmospheric GHG Resulting from Project Activities*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology describes methods for quantifying and monitoring changes in carbon accrual in, and emissions from, soils, as well as from other GHG pools and sources which may be impacted by soil focused activities. The methodology is designed based on guidance provided in the IPCC 2003 Good Practice Guidance for Land Use, Land-Use Change and Forestry. This methodology has been designed to be applicable to conservation, ecosystem restoration and agricultural projects, as well as other projects where the management of soils directly, or management of hydrology, fertility and vegetation systems, can affect changes in soils and soil carbon. The methodology is applicable to a range of project activities designed to improve soils, including changes to agricultural practices, grassland and rangeland restorations, soil carbon protection and accrual benefits from reductions in erosion, grassland protection projects, and treatments designed to improve diversity and productivity of grassland and savanna plant communities.

The intention of the developers has been to create a methodology which includes sufficient detail on methods to allow a wide range of project proponents to use the methods during the development of soil carbon projects. However, accurately estimating and projecting the values of the various ecosystem carbon pools does require a significant level of technical ability on the part of the project proponent team. It is therefore expected that in many cases landowners and farmers may need to work with people with specific technical skills to complete the development of a soil carbon project description (PD) using this methodology.

This methodology provides methods for the quantification of soil carbon, as well as methods for quantifying changes in vegetation and litter pools which can be impacted by project activities, as compared with the baseline scenario.

This methodology does not address projects designed to enhance carbon sequestration in ancient soils (paleosols) that have been buried by more recent soil formations. While the same methods presented here are applicable to characterize the buried substrates, other methods (such as drilling rigs with a deeper boring capacity and split spoon sampling equipment) are beyond the scope of this methodology, which is focused on the extant active soil surfaces and active present day rooting zones soils.

This methodology is focused on addressing the following key variables:

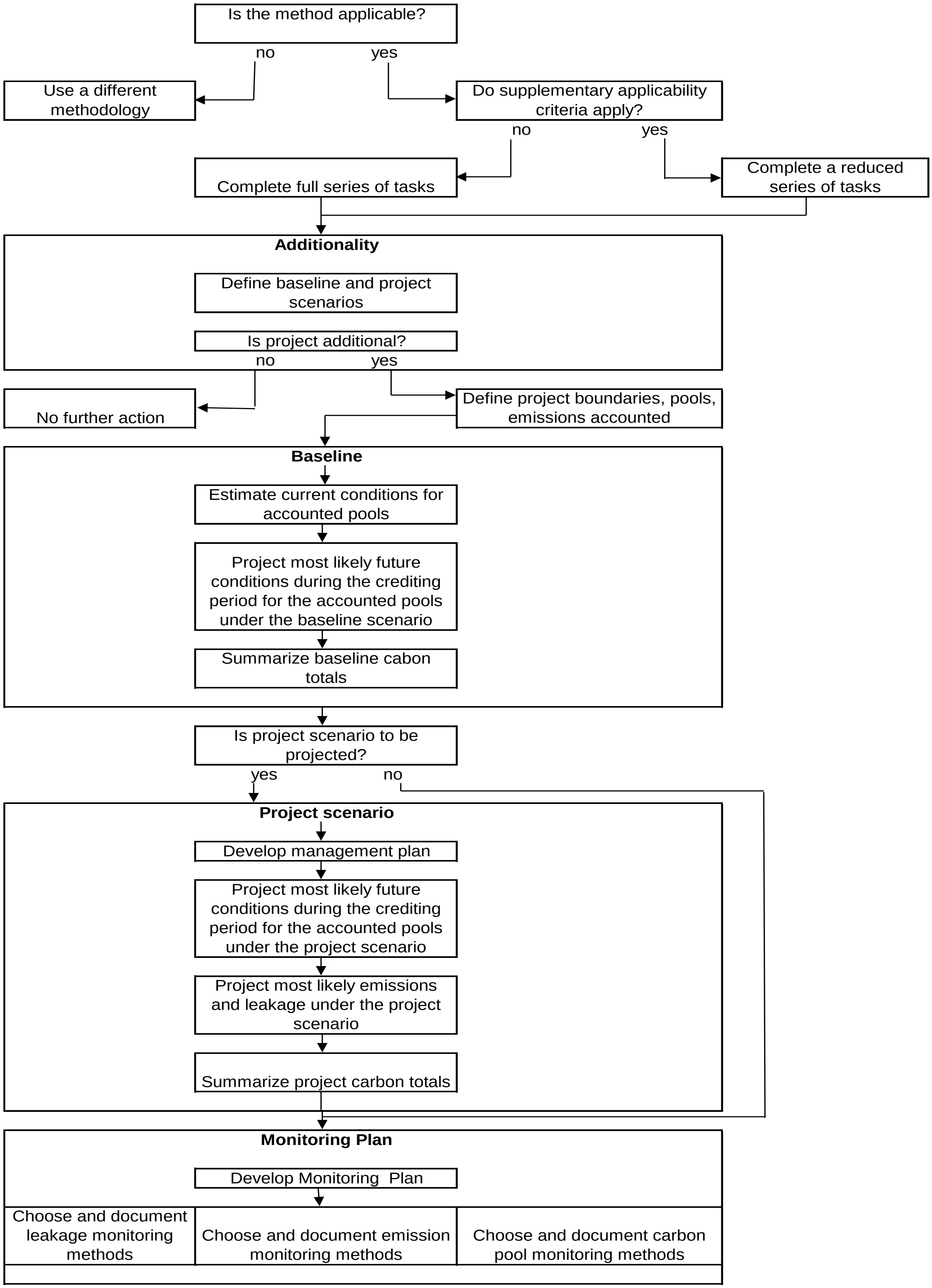
- Estimating the amount of carbon in the soil, litter, and living vegetation pools at the start of the project;
- Monitoring and documenting changes in soil carbon and the other carbon pools over time under the project scenario;
- Projecting changes in soil carbon and other pools under the baseline scenario;
- Estimating emissions of nitrous oxides and methane from soils, and,
- Estimating project leakage.

The methodology has been designed using a modular approach. This methodology document lays out the steps required to fulfill estimation, projection and quantification requirements for projects wishing to register credits under the VCS. The methodology calls on the associated modules for specific techniques and options for estimating or projecting the GHG impacts of changes in specific pools and emissions.

The methodology requires the completion of four main tasks, each of which is comprised of a number of sub-tasks:

1. Task 1: Identification of project boundary, demonstration of additionality and determination of the baseline scenario
2. Task 2: Ex-ante estimation and projection of carbon pools and emissions under the baseline scenario
3. Task 3: Ex-ante estimation and projection of carbon pools and emissions under the project scenario
4. Task 4: Development of a monitoring plan subsequent ex-post monitoring of pools and emissions under the project scenario as well as under the baseline scenario if a monitored baseline is used, and monitoring of leakage.

The overall process used by the methodology is shown in the following methodology map.


Is the method applicable?
no
yes
Use a different methodology
Do supplementary applicability criteria apply?
no
yes
Complete full series of tasks
Complete a reduced series of tasks
Additionality
Define baseline and project scenarios
Is project additional?
no
yes
No further action
Define project boundaries, pools, emissions accounted
Baseline
Estimate current conditions for accounted pools
Project most likely future conditions during the crediting period for the accounted pools under the baseline scenario
Summarize baseline cabon totals
Is project scenario to be projected?
yes
no
Project scenario
Develop management plan
Project most likely future conditions during the crediting period for the accounted pools under the project scenario
Project most likely emissions and leakage under the project scenario
Summarize project carbon totals
Monitoring Plan
Develop Monitoring Plan
Choose and document leakage monitoring methods
Choose and document emission monitoring methods
Choose and document carbon pool monitoring methods

3 DEFINITIONS

Activity Shifting Leakage: Activities that are moved by local actors from within the project area to outside due to the project, and which result in losses of carbon in pools outside the project area.

Agent: A person or organization undertaking actions which impact the management of carbon pools and emissions.

Baseline: The total amount of carbon within the project area in absence of the project.

Baseline Scenario: The most likely sequence of events and actions which would be expected to occur within the project area in the absence of the project.

Carbon Project: See *VCS Program Definitions* for project.

Conservative: Tending to err on the side of reduced creditable carbon in cases where uncertainty exists as to the correct value of variables, or relationships among variables.

Coarse Fragments: Pieces of rock or cemented soils > 2mm in diameter, and therefore too large to pass through the screen used in the laboratory prior to laboratory analyses.

Directly Attributable: The change or effect occurs as result of a chain of causal events linking the change or effect to an event, or to the actions of an agent. Each of the causal events or conditions in the chain must be primarily and directly caused by the previous event in the chain. Analysis of the linkages in the chain should show that for each one, the previous event is at least 75% responsible for the next event. For this reason, the relationship between an event, or the actions of an agent, and the directly attributable effect, typically consist of not more than a few causal linkages.

Ex-ante: Before the fact. Projection of values or conditions in the future.

Ex-post: After the fact. Estimation of values or conditions in the present or past.

Long Lived Wood Products: Products produced from harvested timber which is expected to persist and to sequester carbon for an extended period of time – typically 100 years, unless there is a specific reason for using a different time period.

Monitoring Event: The time at which monitoring of all of the relevant variables is undertaken, to determine the net change in atmospheric carbon attributable to the project.

Monitoring Period: The time period specified in a monitoring report during which GHG emission reduction or removals were generated by the project.

Monitoring Plan: Plan in which a monitoring schedule and methods will be documented.

Planned: Changes in the value of the variable are under the control of identified agents who are independent of the project proponent.

Project Area : The area or areas of land on which the project proponent will undertake the project activities.

Project Crediting Period: See *VCS Program Definitions.*

Project Scenario: The actions and events which are expected to occur as a result of implementing the project.

Significant: A pool or source is significant if it does not meet the criteria for being deemed de minimis. Specific carbon pools and GHG sources, including carbon pools and GHG sources that cause project and leakage emissions, may be deemed de minimis and do not have to be accounted for if together the omitted decrease in carbon stocks (in carbon pools) or increase in GHG emissions (from GHG sources) amounts to less than five percent of the total GHG benefit generated by the project.

Stratification: The division of an area into sub-units (strata) which are relatively homogenous for the value of the variable on which the stratification is based, which are repeatable in the landscape, and could reasonably be expected to be similarly identified and classified by different people.

Stratum (plural strata): An area of land within which the value of a variable, and the processes leading to change in that variable, are relatively homogenous.

Verification Date: A date, at which an independent verifier audits the results of monitoring.

Woody Biomass: Biomass which exists primarily in the form of lignified tissues, such as that of shrubs and trees. Typically accounting of woody biomass includes the non woody parts (leaves, etc.) of plants which contain woody biomass.

4 APPLICABILITY CONDITIONS

4.1 Mandatory Conditions

All projects using this methodology must meet the following conditions:

a. Projects must meet the most recent VCS requirements for one of the following three Agricultural Land Management activities:

- Improved Cropland Management (ICM)
- Improved Grassland Management (IGM)
- Cropland and Grassland Land-use Conversions (CGLC)

b. As of the project start date all of the project area consists of grasslands or croplands. Crops may include woody species grown for food products, fuel products or timber, providing that the densities of these crops do not meet the requirements for definition of these lands as forest lands. The project area must not consist of forest, wetlands, or peatlands, as such terms are defined under the VCS.

c. The only baseline activities that could be displaced by the project activities are grazing and fodder production, crop production and timber production.

d. Project activities must not include changes in surface and shallow (<1m) soil water regimes through flood irrigation, drainage or other significant anthropogenic changes in the ground water table.

e. The project activity must not cause a significant change in termite populations, as compared with the baseline scenario.

4.2 Optional Conditions

The following conditions do not need to be met to utilize the methodology. However, each of these conditions allows the simplification of the methodology through the elimination of the requirement for the completion of specific tasks.

a. The activities and agents which have caused the degradation of the croplands, grasslands or rangelands are expected to continue to impact the area in the absence of the project activity. On that basis, it can be demonstrated that the total carbon content of the soil organic and inorganic carbon pools within the project area is highly unlikely to increase under the baseline scenario during the project crediting period.

   Consequence if met: Project proponent may conservatively assume that soil carbon content for all future dates under the baseline scenario shall be accounted as equal to the current soil carbon content, subject to re-assessment at year 10, as required under the VCS rules.

b. Changes in above and below ground living biomass pools within the project area can be shown to be insignificant under either the baseline or project scenarios.

   Consequence if met: Project proponent is not required to complete Tasks 2.4, 2.5, 2.6, 3.3, 3.4, 4.3 and 4.4 of this document.

c. Woody biomass is found within the project area, but amounts of current and projected wood harvest under the baseline and project scenarios are not significant.

   Consequence if met: Project proponent is not required to complete Tasks 2.7, 2.8, 2.9, 3.5, 3.6, 4.5, and 4.6 of this document.

d. GHG emissions from populations of domesticated animals are expected to remain the same or decline under the project scenario as compared with the baseline scenario.

Consequence if met: Project proponent is not required to complete Tasks 2.12, 2.13, 2.14, 3.8, 3.9, 4.8, and 4.9 of this document.

e. No significant change is expected to occur in the amounts or locations of any of the following conditions or activities between the baseline scenario and the project scenario:

- Amount or location of application of organic or inorganic fertilizers.
- Amount or location of domesticated animal grazing and deposition of manure or urine.
- Amount or location of areas subject to flooding, and duration of flooding.
- Amount or location of nitrogen fixing species.

Consequence if met: Project proponent is not required to complete Tasks 2.15, 2.16, 3.10, and 4.12 of this document.

5 PROJECT BOUNDARY

Task 1: Identification of project boundary, demonstration of additionality and determination of the baseline scenario

Task 1.1 Project boundary determination
Requirement: For all projects
Goal: To determine the project boundary for baseline scenario and additionality purposes.
Method: Determine the project boundary using the module *VMD0020 Methods to Determine Project Boundary*

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

Task 1: Identification of project boundary, demonstration of additionality and determination of the baseline scenario (continued)

Task 1.2 Baseline scenario determination

Requirement: Required for all projects.

Goal: To determine the most plausible baseline scenario.

Method: Determine the baseline scenario(s) for the project area using the latest version of the CDM *Combined tool to identify the baseline scenario and demonstrate additionality for A/R CDM project activities.*

The tool has been designed for A/R CDM project activities, but is used for the purposes of this methodology in an ALM context. As such, the following applies:

- Where the tool refers to A/R it must be understood as referring to ALM activities.

- Where the tool refers to forestation, it must be understood as referring to the project agricultural land management activities, and where the tool refers to forest, it must be understood as referring to agricultural land.
- Where the tool refers to CDM, it must be understood as referring to VCS.
- Where the tool refers to tCERs or lCERs, it must be understood as referring to VCUs.
- In case there is a conflict between the CDM tool requirements and the VCS rules, then the VCS rules must be followed.
- Where the tool makes reference to events occurring before or after December 31 1989, it must be understood as referring to events occurring before or after 10 years prior to the project start date.

Use of the tool is subject to the following:

- Applicability conditions: The tool is applicable for all VCS ALM project types that comply with the VCS eligibility rules as set out by AFOLU Requirements v3.2 section 4.2.2, or updated version
- Step 0: Start Date: Must follow most up to date VCS rules.
- Step 1 Point 9: Identify the alternative land management scenario in absence of the VCS ALM project

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

Task 1: Identification of project boundary, demonstration of additionality and determination of the baseline scenario (continued)

Task 1.3 Demonstration of additionality

Requirement: Required for all projects

Goal: to determine the additionality of the project.

Method: The project proponent must demonstrate whether or not the proposed project activity is additional using the latest version of the CDM *Combined tool to identify the baseline scenario and demonstrate additionality for A/R CDM project activities*, following the same guidance given in section 6 above, or use the latest version of the VCS *Tool for Demonstration and Assessment of Additionality in VCS AFOLU Project Activities*.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

Estimation of the carbon content of current pools, and projection of carbon pools and emissions under the baseline scenario is undertaken using the following the steps:

Task 2: Ex-ante estimation and projection of carbon pools and emissions under the baseline scenario

Task 2.1 Project area stratification for soil carbon

Requirement: Required for all projects.

Goal: To divide the project area into one or more strata within which the existing soil carbon pools and soil carbon dynamics are relatively uniform.

Methods: Use module *VMD0018 Methods to Determine Stratification*, with soil carbon as the relevant variable *X.*

Task 2.2 Estimation of the current carbon content of the soil carbon pool per unit of area, for each stratum

Requirement: Required for all projects.

Goal: To sample the organic and inorganic soil carbon content in each stratum with a sampling intensity sufficient to estimate, at the required levels of statistical precision and accuracy, the amount of soil carbon per unit area.

Methods: Use module *VMD0022 Estimation of Stocks in the Soil Carbon Pool*.

Task 2.3 Projection of the future carbon content of the soil carbon pool per unit of area, for each stratum

Requirement: Required for all projects.

Goal: To project the future organic and inorganic soil carbon content per unit area in each stratum for each projected verification date within the project crediting period under the baseline scenario.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, and *VMD0021 Estimation of Stocks in the Soil Carbon Pool*, unless optional applicability condition (a) (See Section 4) is met.

Task Notes: If optional applicability condition (a) of this methodology is met, soils within the project area are demonstrated to be subject to continued degradation. Therefore, gains in soil carbon under the baseline scenario do not need to be projected. If this applicability condition is met, the methodology allows the project proponent to conservatively assume that the current carbon content of the soils will continue to be the carbon content of the soils throughout the project crediting period under the baseline scenario. In this case, no further work need be done on this task. This approach follows the simplifying precedent set in *CDM AR-AM0001*, now part of the consolidated methodology *CDM AR-ACM0002*.

Task 2.4 Project area stratification for biomass

Requirement: Required for all projects where the difference in total above and below ground biomass carbon between the project scenario and the baseline scenario at any time after the project start date is expected to be significant. Optional for all other projects.

Goal: To divide the project area into one or more strata within which the existing vegetation carbon pools and vegetation dynamics are relatively uniform.

Methods: Use module *VMD0018 Methods to Determine Stratification*, with above and below ground biomass stocks per unit area as the relevant variable *X*.

Task 2.5 Estimation of the carbon content of current aboveground woody and non-woody biomass and below ground living biomass pools

Requirement: Same criteria as Task 2.4.

Goal: To sample the aboveground biomass pools and derive the belowground biomass pool in each stratum with a sampling intensity sufficient to estimate, at the required levels of statistical precision and accuracy, the amount of biomass carbon per unit area.

Methods: Use module *VMD0022 Estimation of Carbon Stocks in Living Plant Biomass*.

Task 2.6 Projection of future biomass pools under the baseline scenario

Requirement: Same criteria as Task 2.4.

Goal: To determine the most likely future changes in total biomass within the project area under the baseline scenario.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, with biomass pools as the relevant variable *X*.

Task 2.7 Estimation of the amount of current wood harvest from within the project area used for production of long lived wood products

Requirement: Required where the harvest of significant amounts of woody biomass currently occurs within the project area, or is expected to occur in the future under the baseline scenario, and some or all of that woody biomass is used for the production of long lived wood products. Optional and not recommended in all other cases.

Goal: To estimate the current amount of woody biomass harvesting taking place within the project area.

Methods: Use module *VMD0025 Estimation of Woody Biomass Harvesting and Utilization*.

Task 2.8 Projection of future wood harvest outputs

Requirement: Same criteria as Task 2.7.

Goal: To project the most probable amount of woody biomass harvesting, and utilization of that harvest for the production of long lived wood products, that is expected to occur under the baseline scenario.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, with wood harvest and utilization for long lived wood products as the relevant variable *X*.

Task 2.9 Long Lived Wood Products

Requirement: Same criteria as Task 2.7.

Goal: To project the amount of carbon which will be sequestered in long lived wood products under the baseline scenario.

Methods: Use module *VMD0026 Estimation of Carbon Stocks in the Long Lived Wood Products Pool*, with the outputs from Tasks 2.7 and 2.8 as the inputs.

Task 2.10 Estimation of current dead wood pools within the project area

Requirement: Required where there are significant amounts of dead wood in the project area at the project start date, and removals of dead wood through utilization, reduced inputs or accelerated burning as part of a management activity are expected to occur under the project scenario. Optional under all other circumstances.

Goal: To estimate the current amount of biomass contained in dead wood pools.

Methods: Use module *VMD0024 Estimation of Carbon Stocks in the Dead Wood Pool*.

Task 2.11 Projection of future dead wood pools within the project area

Requirement: Same as Task 2.10.

Goal: To project the amount of biomass which will be contained in dead wood pools under the baseline scenario.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, with dead wood pools as the relevant variable *X*.

Task 2.12 Estimation of current average domesticated animal populations within the project area

Requirement: Required where GHG emissions from domesticated animal populations within the project area are expected to be significantly greater under the project scenario as compared with the baseline scenario at any time during the project crediting period. Optional under all other circumstances

Goal: To estimate the average current populations of domesticated animals within the project area.

Methods: Use the module *VMD0027 Estimation of Emissions from Domesticated Animals*.

Task 2.13 Projection of future domesticated animal populations under the baseline scenario

Requirement: Same as Task 2.12.

Goal: To project the future populations of domesticated animals under the baseline scenario.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, with domesticated animal populations as the relevant variable *X.*

Task Notes: If at any time within the project crediting period the populations of domesticated animals under the baseline scenario are projected to be greater than those found at the project start date, populations at that time must be accounted as being equal to current levels. Conservatively, this methodology does not account for projected increases in animal populations and resulting emissions under the baseline scenario.

Task 2.14 Estimation of emissions of GHGs from domesticated animals within the project area under the baseline scenario

Requirement: Same as Task 2.11.

Goal: To estimate GHG emissions from current and projected future domesticated animal populations under the baseline scenario.

Methods: Use module *VMD0028 Estimation of Emissions from Domesticated Animals*, with the outputs from Tasks 2.9 and 2.10 as the inputs.

Task 2.15 Estimation of current soil emissions of N_2O or CH_4 from within the project area

Requirement: Required where emissions of N_2O or CH_4 from the soils within the project area are expected to be significantly greater under the project scenario as compared with the baseline scenario at any time within the project crediting period. Optional under all other circumstances.

Goal: To estimate the current emissions of N_2O or CH_4 from within the project area.

Methods: Use module *VMD0029 Emissions of Non-CO_2 GHGs from Soils*.

Task 2.16 Projection of future emissions of N_2O or CH_4 from the soils within the project area

Requirement: Required if at any time within the project crediting period the emissions of N_2O or CH_4 from the soils within the project area under the baseline scenario are projected to be greater than those found under the project scenario. Optional under all other circumstances.

Goal: To project future emissions from soils under the baseline scenario, in the case that these emissions are expected to decline.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, with relevant input variable(s) from the module *VMD0029 Estimation of Emissions of Non CO2 GHG from Soils*, as the relevant variable(s) *X.* Then, based on the outputs from this module, use the module *VMD0029 Estimation of Emissions of Non-*CO_2 *GHG from Soils* to estimate the projected future emissions.

Task 2.17 Projected emissions from use of power equipment

Requirement: Required for all projects where emissions from power equipment directly attributable to activities within the project area are expected to be significantly greater under the project scenario as compared with the baseline scenario. Not to be used in all other circumstances. Conservatively, this methodology does not account for emission reductions arising from reductions in the use of power equipment under the project scenario as compared with the baseline scenario.

Goal: To project GHG emissions for the monitoring period from the use of power equipment under the baseline scenario. Note that in this methodology emissions of GHGs due to the use of power equipment directly attributable to activities within the project area are all accounted as baseline or project emissions, whether or not the actual emissions occur within the project area.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, with fuel uses in power equipment as the relevant variable(s) *X.* Then, based on the outputs from this module, use the module *VMD0030 Estimation of Emissions from Power Equipment* to estimate the projected future emissions.

Task 2.18 Estimation of current litter pools.

Requirement: Required where significant decreases in litter pools within the project area are expected under the project scenario as compared with the baseline scenario at any time within the project crediting period. Optional under all other circumstances.

Goal: To estimate the carbon content of the litter pool within the project area.

Methods: Use module *VMD0023 Estimation of Carbon Stocks in the Litter Pool.*

Task 2.19 Projection of future litter pools

Requirement: Same as Task 2.18.

Goal: To project emissions from future litter pools under the baseline scenario where these emissions are expected to decline under the baseline scenario.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, with relevant input variable(s) from the module *VMD0023 Estimation of Carbon Stocks in the Litter Pool*, as the relevant variable(s) *X.*

Task Notes: If at any time in the project crediting period the litter pools within the project area under the baseline scenario are projected to be less than those at the project start date, litter pools for that time period must be accounted as being equal to levels at the project start date. Conservatively, this methodology does not account for projected decreases in litter pools under the baseline scenario.

Task 2.20 Summation of estimates and projections under the baseline scenario

Requirement: Required for all projects.

Goal: To sum current and future carbon sequestration and emissions under the baseline scenario.

Methods: Use module: *VMD0035 Methods to Determine the Net Change in Atmospheric GHG Resulting from Project Activities*.

8.2 Project Emissions

Task 3: (A) Ex-Ante Projection of GHG Pools and Emissions In the Project Scenario (Project Emissions)

Estimation of the carbon content of current pools and projection of carbon pools and emissions under the project scenario is undertaken using the following the steps:

Task 3.1 Ex-ante soil restratification

Requirement: Required for all projects.

Goal: To divide the project area into one or more strata within which the projected soil carbon pools and soil carbon dynamics are expected to be relatively uniform under the project scenario, given the stratification determined in Task 2.1, and the proposed treatment under the project scenario.

Methods: Use module *VMD0018 Methods to Determine Stratification*, with soil carbon as the relevant variable *X.*

Task 3.2 Projection of treatment impacts per stratum, and effects on soil C pools

Requirement: Required for all projects.

Goal: To project, for the time within the project crediting period, the changes in soil carbon pools which are expected to occur in each stratum within the project area, given the planned treatments for the stratum.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, with soil carbon as the relevant variable *X*, and module *VMD0021 Estimation of Stocks in the Soil Carbon Pool.*

Task 3.3 Ex-ante biomass re-stratification

Requirement: Required for all projects where significant decreases in living biomass pools are expected to occur under the project scenario, as compared with the baseline scenario. Optional in all other circumstances.

Goal: To divide the project area into one or more strata within which treatments are expected to result in living vegetation carbon pools and living vegetation dynamics which are relatively uniform for the full project crediting period.

Methods: Use module *VMD0018 Methods to Determine Stratification*, with living biomass as the relevant variable *X.*

Task 3.4 Projection of future aboveground woody and non-woody and below ground living biomass pools under the project scenario

Requirement: Same as Task 3.3.

Goal: To project for the monitoring period the aboveground woody and non-woody biomass and belowground living biomass pools in each stratum based on expected treatment regimes, and to estimate the amount of living biomass carbon per unit area based on those projections.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, with live biomass as the relevant variable *X* and the module *VMD0022 Estimation of Carbon Stocks in Living Plant Biomass*.

Task 3.5 Projection of future wood harvest outputs under the project scenario

Requirement: Required for all projects where the harvest of woody biomass within the project area is expected to be significantly lower under the project scenario as compared with the baseline scenario at any time within the project crediting period and some or all of that woody biomass is used for the production of long lived wood products. Optional but recommended in the case that harvests of woody biomass under the project scenario are expected to be significantly greater than those under the baseline scenario. Optional, but not recommended, where no significant wood harvest takes place under either the baseline or project scenario, or where no significant change in levels of wood harvest are expected under the project scenario as compared with the baseline scenario.

Goal: To project for the monitoring period the amount of woody biomass harvesting which is expected to take place within the project area under the project scenario, and the percentage of that harvest which is expected to be used for the production of long lived wood products.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, with wood harvest and wood utilization as the relevant variable *X.*

Task 3.6 Projection of C sequestration in long lived wood products

Requirement: Same as Task 3.5.

Goal: To estimate the amount of carbon which will be sequestered in long lived wood products under the project scenario, based on the projections prepared in Task 3.5.

Methods: Use module *VMD0026 Estimation of Carbon Stocks in the Long Lived Wood Products Pool*, with the outputs from Task 3.5 as the inputs.

Task 3.7 Projection of future dead wood pools within the project area under the project scenario

Requirement: Required where significant amounts of dead wood are found on the site at the project start date, and removals of dead wood through utilization, reduced inputs, or accelerated burning as part of a management activity, are expected to occur under the project scenario. Optional in all other circumstances.

Goal: To estimate the amount of biomass which will be sequestered in dead wood pools under the project scenario.

Methods: Use the module *VMD0019 Methods to Project Future Conditions*, with dead wood pools as the relevant variable *X*.

Task 3.8 Projection of future domesticated animal populations under the project scenario

Requirement: Required where increases in the emissions of GHGs from domesticated animal populations are expected under the project scenario as compared with the baseline scenario. Not to be used in all other circumstances. Conservatively, this methodology does not account for projected decreases in emissions from domesticated animals under the project scenario as compared with the baseline scenario.

Goal: To project the future populations of domesticated animals for the monitoring period under the project scenario.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, with domesticated animal populations as the relevant variable *X.*

Task 3.9 Estimation of emissions of GHGs from domesticated animals within the project area under the project scenario

Requirement: Same as Task 2.10.

Goal: To estimate the emissions of GHGs from the current and projected future populations of domesticated animals under the project scenario the monitoring period based on the projections prepared in Task 3.7.

Methods: Use module *VMD0027 Estimation of Emissions From Domesticated Animals*, with the outputs from Task 3.7 as the inputs.

Task 3.10 Projection of future emissions of N_2O or CH_4 from the soils within the project area

Requirement: Required where significant increases in the emissions of N_2O or CH_4 from the soils within the project area are expected under the project scenario as compared with the baseline scenario. Optional under all other circumstances.

Goal: To estimate future emissions from soils under the project scenario, in the case that these emissions are expected to increase.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, with relevant input variable(s) from the module *VMD0029 Estimation of Emissions of Non CO2 GHG From Soils*, as the relevant variable(s) *X.* Then, based on the outputs from this module, use the module *VMD0029 Estimation of Emissions of Non* CO_2 *GHG from Soils*, to estimate the projected future emissions.

Task 3.11 Projected emissions from use of power equipment

Requirement: Required for all projects where emissions from power equipment directly attributable to activities within the project area are expected to be *significantly* greater under the project scenario as compared with the baseline scenario. Not for use in all other circumstances. Conservatively, this methodology does not account for emission reductions arising from reductions in the use of power equipment under the project scenario as compared with the baseline scenario.

Goal: To estimate GHG emissions for the monitoring period from the use of power equipment under the project scenario. Note that in this methodology emissions of GHGs due to the use of power equipment directly attributable to the project are all accounted for as a project emissions, whether or not they occur within the project boundary.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, with fuel use in power equipment as the relevant variable(s) *X.* Then, based on the outputs from this module, use the module *VMD0030 Estimation of Emissions from Power Equipment*, to estimate the projected future emissions.

Task 3.12 Projection of future litter pools

Requirement: Required where *significant* decreases in the carbon content of the litter carbon pool are expected under the project scenario as compared with the baseline scenario. Optional under all other circumstances.

Goal: To estimate future litter pools under the project scenario.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, with litter carbon pools as the relevant variable *X.*

Task 3.13 Projection of biomass consumption by fire

Requirement: Required where *significant* burning is expected to be used for management of the project area under the project scenario. Optional but not recommended otherwise.

Goal: To project the future amounts of biomass consumed by fire during the project crediting period under the project scenario.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, with biomass consumed by fire as the relevant variable *X.*

Task Notes: This step shall be done twice if biomass burning is to be done both within the project area, and outside of the project area as a consequence of displacement leakage. In that case, the results will be used for separate calculations during Task 3.16.

Task 3.14 Projection of non CO_2 emissions from burning

Requirement: Same as Task 3.13.

Goal: To estimate emissions of non CO2 GHGs from burning of biomass.

Methods: Use module *VMD0029 Estimation of Emissions of Non CO2 GHG from Soils.*

Task Notes: This step shall be done twice if biomass burning is done both within the project area, and outside of the project area as a consequence of activity shifting leakage. In that case, the results will be reported and accounted separately during Task 3.13 above.

Task 3.15 Summation of ex-ante estimates and projections under the project scenario

Requirement: Required for all projects.

Goal: To sum current and future carbon sequestration and emissions under the project scenario.

Methods: Use module *VMD0035 Methods to Determine the Net Change in Atmospheric GHG Resulting from Project Activities*, setting leakage variables to 0, as these will be accounted for in section 8.3 below.

Task 4: (A) Ex-Post Accounting of GHG Pools and Emissions (Project Emissions)

Ex-post accounting of GHG pools and emissions must be undertaken prior to each verification event, and at least once every 5 years during the project crediting period. Note that where leakage mitigation measures include tree planting, agricultural intensification, fertilization, fodder production, and/or other measures to enhance cropland and/or grazing land areas, then any significant increase in GHG emissions associated with these activities must be accounted for using the relevant module, whether or not they occur within the project area, unless they are deemed not significant, or can otherwise be conservatively excluded.

Task 4.1 Ex-post soil re-stratification

Requirement: Required for all projects.

Goal: To divide the project area into one or more strata within which the soil carbon pools and soil carbon dynamics are relatively uniform at the time of sampling.

Methods: Use module *VMD0018 Methods to Determine Stratification*, with soil carbon as the relevant variable *X.*

Task 4.2 Estimation of the carbon content of current soil carbon pools per unit of area, for each stratum

Requirement: Required for all projects.

Goal: To sample the organic and inorganic soil carbon content in each stratum with a sampling intensity sufficient to allow estimation, at the required levels of statistical precision and accuracy, of the amount of soil carbon per unit area.

Methods: Use module *VMD0021 Estimation of Stocks in the Soil Carbon Pool.*

Task 4.3 Ex-post living biomass re-stratification

Requirement: Required for all projects where the aboveground woody and non-woody biomass and belowground living biomass carbon under the project scenario is found to be significantly less than that projected under the baseline scenarios at any time after the project start date. Optional under all other circumstances. Typically completion of this task will be required where the project area before the project start date contains more than scattered woody vegetation, and where the project activities include clearance, site preparation, burning or other activities likely to eliminate woody vegetation, or alternatively to enhance the recruitment of woody vegetation.

Goal: To divide the project area into one or more strata within which the vegetation carbon pools at the end of the project crediting period are relatively uniform.

Methods: Use module *VMD0018 Methods to Determine Stratification*, with above- and belowground living biomass stocks per unit area as the relevant variable *X.*

Task 4.4 Estimation of the carbon content of aboveground woody and non-woody and below ground living biomass pools

Requirement: Same as Task 4.3.

Goal: To sample the aboveground woody and non-woody biomass and below ground living biomass pools in each stratum to a sampling intensity sufficient to allow estimation to the required levels of statistical precision and accuracy of the amount of living biomass carbon per unit area.

Methods: Use module *VMD0022 Estimation of Carbon Stocks in Living Plant Biomass.*

Task 4.5 Estimation of the amount of wood harvest from within the project area used for production of long lived wood products

Requirement: Required for all projects where the harvest of woody biomass within the project area is expected to be *significantly* lower under the project scenario as compared with the baseline scenario at any time within the project crediting period, and some or all of that woody biomass is used for the production of long lived wood products. Optional but recommended in the case that harvests of woody biomass under the project scenario are expected to be significantly greater than those under the baseline scenario. Optional but not recommended in the case where no significant wood harvest takes place under either the baseline or project scenario, or where no significant change in levels of wood harvest are expected under the project scenario, as compared with the baseline scenario.

Goal: To estimate the amount of woody biomass harvesting taking place within the project area during a monitoring period.

Methods: Use module *VMD0025 Estimation of Woody Biomass Harvesting and Utilization*.

Task 4.6 Long Lived Wood Products

Requirement: Same criteria as Task 4.5.

Goal: To project amount of carbon which will be sequestered in long lived wood products derived from harvesting from within the project area during the monitoring period.

Methods: Use module *VMD0026 Estimation of Carbon Stocks in the Long Lived Wood Products Pool*, with the outputs from Task 4.5 as the inputs.

Task 4.7 Estimation of dead wood pools within the project area

Requirement: Required where dead wood is found on the site at the project start date, and *significant* removals of dead wood through utilization, reduced inputs, or accelerated burning as part of a management activity, are expected to occur under the project scenario. Optional under all other circumstances.

Goal: To estimate the current amount of biomass contained in dead wood pools.

Methods: Use module *VMD0024 Estimation of Carbon Stocks in the Dead Wood Pool*.

Task 4.8 Estimation of current average domesticated animal populations within the project area

Requirement: Required where increases in emissions from domesticated animals within the project area could occur in the project scenario as compared with the baseline scenario, due either to increases in populations or changes in feeding practices., Optional under all other circumstances.

Goal: To estimate the average current populations of domesticated animals within the project area during the monitoring period.

Methods: Use module *VMD0028 Estimation of Emissions from Domesticated Animals*.

Task 4.9 Estimation of emissions of GHGs from domesticated animals within the project area

Requirement: Required where increases in emissions from domesticated animals within the project area could occur in the project scenario as compared with the baselines scenario, due either to increases in populations or changes in feeding practices. Not for use under all other circumstances, to conservatively ensure that crediting for reductions in emissions from domesticated animals does not occur.

Goal: To estimate the emissions of GHGs from the current populations of domesticated animals during the monitoring period.

Methods: Use module *VMD0028 Estimation of Emissions from Domesticated Animals*, with the outputs from Task 4.8 as inputs.

Task 4.10 Estimation of emissions from use of power equipment

Requirement: Required for all projects where emissions from power equipment directly attributable to activities within the project area could be *significantly* greater under the project scenario as compared with the baseline scenario. Not for use in all other circumstances. Conservatively, this methodology does not account for emission reductions arising from reductions in the use of power equipment under the project scenario as compared with the baseline scenario.

Goal: To estimate GHG emissions from the use of power equipment under the project scenario during the monitoring period.

Methods: Use module *VMD0030 Estimation of Emissions from Power Equipment*.

Task notes: Under this methodology emissions of GHGs due to the use of power equipment directly attributable to the project are all accounted as a project emission, whether or not they occur within the project boundary.

Task 4.11 Estimation of non CO_2 emissions from burning

Requirement: Required where *significant* burning has been used for management of the project area under the project scenario. Optional but not recommended under all other circumstances.

Goal: To estimate emissions of non CO_2 GHGs from burning of biomass.

Methods: Use module *VMD0031 Estimation of Emissions from Biomass Burning*.

Task notes: This step must be done twice if biomass burning is done both within the project area and outside of the project area as a consequence of displacement leakage. In that case, the results will be reported and accounted separately during Task 4.15 and/or Task 4.16.

Task 4.12 Monitoring and estimation of soil emissions of N_2O or CH_4 from within the project area

Requirement: Required where *significant* increases in the emissions of N_2O or CH_4 from the soils within the project area are expected under the project scenario as compared with the baseline scenario. Optional under all other circumstances.

Goal: To estimate the emissions of N_2O or CH_4 from within the project area.

Methods: Use module *VMD0029 Estimation of Emissions of Non CO_2 GHG from Soils*.

Task notes: These estimations are expected to be based on the same models as those used during the ex-ante project study, unless improvements in models have occurred in the interim. In either case, values of variables used in the models must be updated to reflect actual conditions which have occurred during the monitoring period. If an updated model is used, and if modeling of baseline emissions was done as part of the baseline study, that modeling must be redone using the improved models.

Task 4.13 Estimation of current litter pools.

Requirement: Required where *significant* decreases in the carbon content of the litter pool are expected under the project scenario as compared with the baseline scenario. Optional under all other circumstances.

Goal: To estimate the carbon content of the litter pool within the project area.

Methods: Use module *VMD0023 Estimation of Carbon Stocks in the Litter Pool*.

Task 4.14 Summation of estimates of GHG fluxes under the project scenario

Requirement: Required for all projects.

Goal: To sum carbon sequestration and emission impacts directly attributable to the project activity based on the monitoring undertaken during the monitoring period.

Methods: Use module *VMD0035 Methods to Determine the Net Change in Atmospheric GHG Resulting from Project Activities*, setting leakage variables to 0, as these will be accounted in section 8.3 below.

8.3 Leakage

Under the VCS rules GHG pools and emissions affected by leakage are projected both ex-ante and accounted ex-post. Note that projects must not account for positive leakage (ie, where GHG emissions decrease, or removals increase, outside the project area due to project activities).

Task 3: (B) Ex-Ante Projection of GHG Pools and Emissions in the Project Scenario (Leakage)

Task 3.16 Projection of leakage due to displacement of grazing, fodder and agricultural production

Requirement: Required for projects where domesticated animal grazing or fodder or agricultural production occurred within the project area at the project start date, and where these activities are projected to decline within the project area due to project activities.

Goal: To project of future emissions from agricultural production, domesticated animals or fodder production displaced under the project scenario.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, with displacement of domesticated animals or agricultural production as the relevant variable(s) *X.* Then, based on the outputs from this module, use module *VMD0032 Estimation of Emissions from Activity Shifting Leakage*, to estimate the impacts. Depending on the results from the module *VMD0032 Estimation of Emissions From Activity Shifting Leakage*, calculations of emissions may require the use of other modules.

Task 3.17 Projection of leakage due to displacement of wood harvesting

Requirement: Required for projects where displacement of wood harvest to areas outside of the project boundary is projected to occur.

Goal: To project future emissions from wood harvest displaced under the project scenario. Projection includes the reductions in emissions from these displaced wood harvest activities where they are expected to result in the production of long lived wood products.

Methods: Use module *VMD0019 Methods to Project Future Conditions*, with displacement of wood harvest as the relevant variable(s) *X*. Then, based on the outputs from this module, use module *VMD0032 Estimation of Emissions from Activity Shifting Leakage*, to estimate the impacts. Depending on the results from module *VMD0032 Estimation of Emissions from Activity Shifting Leakage*, calculations of emissions may require the use of other modules.

Task notes: Where wood harvesting occurs outside of the project boundary as a result of activity shifting leakage, and where that wood harvesting results in the production of long lived wood products, module *VMD0026 Estimation of Carbon Stocks in the Long Lived Wood Products Pool* must be used to estimate the amounts of carbon stored in wood products resulting from the wood harvesting.

Task 3.18 Projection of market leakage

Requirement: Required for projects where reductions in the production of wood, animals or agricultural products within the project area are expected under the project scenario as compared with the baseline scenario, and where Tasks 3.16 and 3.17 do not find that direct displacement of these activities to identifiable areas outside the project area fully replaces the production lost within the project area.

Goal: To project leakage caused by increases in prices or demand for products resulting from reduced production of these products within the project area under the project scenario.

Methods: Use module *VMD0033 Estimation of Emissions from Market Leakage*.

Task 4: (B) Ex-Post Accounting of Leakage from GHG Pools and Emissions (Leakage)

Task 4.15 Monitoring and estimation of emissions from grazing, fodder and agricultural production displacement

Requirement: Required for projects where domesticated animal grazing or fodder or agricultural production occurred within the project area at the project start date, and where these activities have declined within the project area due to project activities.

Goal: Estimation of emissions from domesticated animals or fodder production displaced as a result of project activities during the crediting period.

Methods: Use module *VMD0032 Estimation of Emissions from Activity Shifting Leakage*, to estimate the impacts. Depending on the results from the module, calculations of emissions may require the use of other modules.

Task 4.16 Monitoring and estimation of emissions from wood harvest displacement

Requirement: Required for projects where wood harvest occurred within the project area at the project start date, and where total wood harvest from the project area over the monitoring period will decline as compared with that projected under the baseline scenario.

Goal: Estimation of emissions from wood harvesting displaced as a result of project activities during the crediting period.

Methods: Use module *VMD0032 Estimation of Emissions from Activity Shifting Leakage*, to estimate the impacts. Depending on the results from the, calculations of emissions may require the use of other modules. Where displaced wood harvesting results in the production of long lived wood products, module *VMD0026 Estimation of Carbon Stocks in the Long Lived Wood Products Pool*, must also be used.

Task 4.17 Estimation of market leakage

Requirement: Required for projects where reductions in the production of wood, animals, or agricultural products within the project area have occurred under the project scenario, as compared with the baseline scenario, and where Tasks 4.15 and 4.16 do not find that direct displacement of these activities to identifiable areas outside the project area fully replaces the production lost within the project area.

Goal: To estimate leakage caused by increases in prices or demand for products resulting from reduced production of these products within the project area under the project scenario.

Methods: Use module *VMD0033 Estimation of Emissions from Market Leakage*.

Task notes: If market leakage has been projected in Task 3, and if the input conditions remain the same ex-post as those predicted ex-ante, the projections completed in Task 3.14 may be used to satisfy the requirements of this task.

8.4 Summary of GHG Emission Reduction and/or Removals

Task 4: Ex-Post Accounting of GHG Pools and Emissions (Net Emissions Reductions and/or Removals)

Task 4.18* Calculation *of GHG emission reductions and/or removals

Requirement: Required for all projects.

Goal: To summarize net greenhouse gas benefit of project activity.

Methods: Use module *VMD0035 Methods to Determine the Net Change in Atmospheric GHG Resulting from Project Activities*.

Task notes: Net changes in atmospheric GHG at t=z can only be calculated ex-post.

9 MONITORING

9.1 Data and Parameters Available at Validation

Data and parameters available at validation are given in the modules associated with this methodology.

9.2 Data and Parameters Monitored

Data and parameters available at validation are given in the modules associated with this methodology.

9.3 Description of the Monitoring Plan

The monitoring plan must be prepared using module *VMD0034 Methods for Developing a Monitoring Plan*. This module includes specifications on quality assurance and quality control that must be followed during development of the project description and other project documents.

10 REFERENCES AND OTHER INFORMATION

Specific references are given in the modules associated with this methodology.

DOCUMENT HISTORY

Version	Date	Comment
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VCS | VERIFIED CARBON STANDARD

A Global Benchmark for Carbon

Approved VCS Methodology VM0022

Version 1.1, 30 September 2013

Sectoral Scope 14

Quantifying N_2O Emissions Reductions in Agricultural Crops through Nitrogen Fertilizer Rate Reduction

Methodology prepared by:

MICHIGAN STATE UNIVERSITY   EPRI | ELECTRIC POWER RESEARCH INSTITUTE

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Table of Contents

1 SOURCES

VCS Standard v3.3

VCS AFOLU Requirements v3.3

VCS Program Guide v3.4

2006 IPCC Guidelines for National Greenhouse Gas Inventories

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology quantifies emissions reductions of nitrous oxide (N_2O) from agriculture in the United States (US), as brought about by reductions in the rate of nitrogen (N) fertilizer (synthetic and organic) applied to cropland. The methodology encourages the application of economically optimum N fertilizer rates that do not harm productivity, and requires the use of verifiable best management practices for N timing, placement, and type. Depending on the US state where a project is implemented, the methodology uses either a generally accepted IPCC Tier 1 emission factor or an empirically derived Tier 2 regional emission factor (applicable in the 12 state North Central Region) to aid in calculating N_2O emissions reductions. The approach is straightforward and transparent and is a practical solution to help reduce N_2O emissions and other reactive N pollutants from agriculture. The field research that underpins the methodology is publicly available in the peer-reviewed literature.

Nitrous oxide production in agricultural soil occurs predominantly through the microbial transformations of inorganic N (Robertson and Groffman 2007). The potential to produce and emit N_2O increases with the increasing availability of N (Bouwman et al. 1993). Due to the strong influence of available soil N on N_2O emissions, some emissions of N_2O are an unavoidable consequence of maintaining highly productive cropland (Mosier 2002). However, any activity or process that acts to keep available soil N low will lead to lower N_2O emissions. Anthropogenic activities that lower the input of N into cropland agriculture help to reduce emissions of N_2O (Robertson and Vitousek 2009).

To date the vast majority of evidence supports N input as the most robust and reliable default proxy for calculating N_2O emissions. It is consistent and straightforward to quantify as a metric and its use is substantiated by the IPCC, which uses annual N rate as the default method for calculating N_2O emissions from managed land in national greenhouse gas inventories. Moreover, its alteration is readily accessible to management intervention.

Table 1: Additionality and Crediting Baseline Methods

Additionality	Performance Method
Crediting Baseline	Performance Method

3 DEFINITIONS

Synthetic nitrogen fertilizer: Any synthetic fertilizer (solid, liquid, gaseous) containing nitrogen (N). This may be a single nutrient fertilizer product (only including N), or any other synthetic fertilizer containing N, such as multi–nutrient fertilizers (e.g., N–P–K fertilizers) and ‘enhanced–efficiency’ N fertilizers (e.g., slow release, controlled release and stabilized N fertilizers).

Organic nitrogen fertilizer: Any organic material containing N, including animal manure, compost and sewage sludge.

Direct N_2O emissions: Those emitted directly from the site to which fertilizer N has been applied.

Indirect N_2O emissions: Those emitted beyond the site to which fertilizer N has been applied, but as a result of the fertilizer N applied at the site

North Central Region: The North Central Region (NCR) of the USA encompasses the 12 Midwestern states of Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin.

4 APPLICABILITY CONDITIONS

4.1 The methodology applies to Agricultural Land Management (ALM) project activities) that reduce net nitrous oxide (N_2O) emissions from agricultural cropping systems by reducing the nitrogen (N) fertilizer application rate compared to the business as usual (BAU) scenario.

4.2 Implementation of project activities under this methodology must not lead to violation of any applicable law even if the law is not enforced.

4.3 Projects must not be at sites that have not be cleared of native ecosystems and where eligible cropping systems have been grown for at least ten years prior to project implementation. Eligible cropping systems are defined in the applicability condition 4.8.

4.4 The following conditions with respect to fertilizer nitrogen sources must be met:

Sources of fertilizer N eligible under this methodology must be a sub–set of those detailed in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and can include:

- Synthetic N fertilizers; and
- Organic N fertilizers.

All other N input sources (e.g., crop residue N, atmospheric N deposition (other than as an indirect N_2O emissions pathway) and soil N mineralization associated with soil management practices do not qualify for consideration.

All eligible N inputs on a mass basis are considered equal irrespective of their source.

4.5 The following conditions with respect to fertilizer nitrogen management must be met:

- Fertilizer N additions to the soil during a whole crop cycle are eligible for determination of the yearly fertilizer N rate irrespective of when N is applied during the calendar year or whether N application is split between calendar years for a single crop.

- During the project crediting period, adherence to 'Best Management Practices' (BMPs) as they relate to the application of synthetic and organic N fertilizer at the project site is required. These BMPs are related to N fertilizer formulation (or N content of organic additions) and dates and methods of application. Details of fertilizer BMPs are readily available for each US state via state departments of agriculture and from federal agencies such as the Natural Resources Conservation Service (NRCS) and the USDA Farm Service Agency. More generally these BMPs are described in the Global 4R Nutrient (Fertilizer) Stewardship Framework (Right Source–Rate–Time–Place), published by the International Plant Nutrition Institute (IPNI).

- The project proponent must demonstrate that during each cropping season included in the project crediting period the total N rate to be applied to the project area is sufficient to generate expected annual yield similar to the average annual yield of the same crop(s) grown during the baseline period. Documentation required to demonstrate that this applicability condition has been met is described in Section 9.2.

4.6 Both direct and indirect pathways of N_2O emissions as outlined by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories are eligible under this methodology. Indirect N_2O emissions can occur in the following scenarios

- Following the volatilization of the gases NH_3 and NOx produced as a result of the N input to the project site and the subsequent re–deposition of these gases and their products NH_4^+ and NO_3^- to soils and waters beyond the project site;

- After leaching and runoff of N (mainly as NO_3-) applied to the project site enters receiving waters or soils beyond the project site (only applicable to regions where leaching and runoff is considered to occur – see Appendix A).

4.7 Projects must be implemented in the US only.

4.8 The following conditions with respect to cropping systems must be met:

- Projects located in the US including all fertilized agricultural crops where the product is harvested for food, livestock fodder or for another economic purpose must use Method 1 (described in section 8) to calculate direct N_2O emissions.

- Projects located in the NCR of the US that involve corn in row–crop systems such as continuous corn and rotations of corn–soybean or corn-soybean-wheat must use Method 2 (described in section 8) to calculate direct N_2O emissions.

- Projects located in the NCR that involve crops other than corn including crops in rotation with corn must use Method 1 to calculate direct N_2O emissions.

Projects must also state and justify ex-ante in the Project Document whether they will apply Method 1 or Method 2 as determined by their geographic location and cropping system. The same method must be applied to the calculation of direct N_2O emissions in the baseline and project case and used for the demonstration of additionality.

4.9 The project crop area must be the same as or less than the baseline crop area in order to ensure that the same land area is used in emission reduction calculations.

4.10 Projects must not be on sites with 'organic' soils or Histosols, as defined by the US Soil Taxonomy. The unique properties of Histosols are a very high content of organic matter (OM) in the upper 80 cm (32 in) of the soils and no permafrost. The amount of organic matter is at least 20 to 30 percent by mass (200-300 g OM kg dry soil-1) in more than half of this thickness, or the horizon that is rich in organic matter rests on rock or rock rubble. Most Histosols are peats or mucks, which consist of more or less decomposed plant remains that accumulated in water, but some formed from forest litter or moss, or both, and are freely drained. USDA NRCS soils maps for individual fields can be used to determine whether a field is underlain by a soil series in the Histosol Order.

5 PROJECT BOUNDARY

Spatial boundary

The spatial boundary of the project encompasses both direct and indirect emissions of N_2O, and includes the project site where fertilizer N is directly applied as well as any additional soils and waters where byproducts of the fertilizer N input (such as the gases NH_3 and NOx, and their products NH_4^+ and NO_3^-) are re-deposited.

The project proponent must define the project site where fertilizer N is directly applied in the Project Document, but is not required to define the specific areas where byproducts may be re-deposited beyond the project site.

Temporal boundary

The project crediting period must follow the requirements for ALM projects focusing exclusively on emissions reductions of N_2O as set out in the most recent version of the VCS Standard.

Greenhouse gases

Table 1 summarizes the greenhouse gases accounted for in the calculations of baseline emissions and project emissions.

Table 1. Greenhouse gases and their sources

Source		Gas	Included?	Justification/Explanation
Baseline	Direct emissions synthetic fertilizer	CO_2	No	Not significant - de minimis
		CH_4	No	Not significant - de minimis
		N_2O	Yes	N_2O is the major emissions source from N fertilizer
		CO_2	No	Not significant - de minimis

Source		Gas	Included?	Justification/Explanation
	Indirect emissions synthetic fertilizer	CH_4	No	Not significant - de minimis
		N_2O	Yes	N_2O is the major emissions source from N fertilizer
	Direct emissions organic fertilizer	CO_2	No	Not significant - de minimis
		CH_4	No	Not significant - de minimis
		N_2O	Yes	N_2O is the major emissions source from fertilizer N addition
	Indirect emissions organic fertilizer	CO_2	No	Not significant - de minimis
		CH_4	No	Not significant - de minimis
		N_2O	Yes	N_2O is the major emissions source from N fertilizer
Project	Direct emissions synthetic fertilizer	CO_2	No	Not significant - de minimis
		CH_4	No	Not significant - de minimis
		N_2O	Yes	N_2O is the major emissions source from N fertilizer
	Indirect emissions synthetic fertilizer	CO_2	No	Not significant - de minimis
		CH_4	No	Not significant - de minimis
		N_2O	Yes	N_2O is the major emissions source from N fertilizer
	Direct emissions organic fertilizer	CO_2	No	Not significant - de minimis
		CH_4	No	Not significant - de minimis
		N_2O	Yes	N_2O is the major emissions source from N fertilizer
	Indirect emissions organic fertilizer	CO_2	No	Not significant - de minimis
		CH_4	No	Not significant - de minimis
		N_2O	Yes	N_2O is the major emissions source from N fertilizer

Carbon pools

Table 2 summarizes the carbon pools included in projects using this methodology.

Soil carbon is the primary pool of concern for ALM methodologies. In accordance with VCS AFOLU requirements v3.3, methodologies targeting N_2O emission reductions need to account for any significant reductions in soil C stocks.

In this methodology reductions in N fertilizer rate resulting from project implementation will not result in significant (> 5% of the total CO_2e benefits from reduction in N_2O emissions) decreases in soil C stock. Evidence presented in Appendix B in the form of peer reviewed literature details how the soil C pool is deemed de minimis. Appendix B can be used for projects using this methodology as a criterion to exclude the soil C pool.

Table 2. Carbon pools considered in the methodology

Carbon Pool	Included?	Justification/Explanation
Above ground woody biomass	No	Not relevant or subject to significant change – de minimis

Carbon Pool	Included?	Justification/Explanation
Above ground non woody biomass	No	Not relevant or subject to significant change – de minimis
Below ground biomass	No	Not relevant or subject to significant change – de minimis
Litter	No	Not relevant or subject to significant change – de minimis
Dead wood	No	Not relevant or subject to significant change – de minimis
Soil	Yes	Change is nil or positive or (reduction is de minimis)
Wood products	No	Not relevant or subject to significant change – de minimis

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

The baseline scenario is the continuation of the historical cropping practices where, in the absence of the project activity, N fertilizer rate is applied in a business as usual (BAU) manner, resulting in higher emissions of N_2O from the soil when compared to a situation where the project is implemented and the application of lower N fertilizer rate results in lower emissions of N_2O.

The baseline emissions are the amount of N_2O that would have been emitted to the atmosphere during the project crediting period under the N rate practice that would have been in place had the project not been implemented.

The determination of baseline N_2O emissions is carried out using one of two Approaches. Both Approaches use a yield-goal calculation method to generate a baseline fertilizer N application rate, from which emissions of N_2O are calculated. Approach 1 derives the baseline N rate from producer-specific N fertilizer management records, and Approach 2 derives the baseline N rate from county-level records aggregated by the USDA National Agricultural Statistics Service: USDA crop yield data in conjunction with standard state-specific University-recommended yield-goal based equations for calculating N rates from these yields for the period in question.

Due to its finer spatial resolution (site specificity), project proponents must use Approach 1 if data is available. Approach 2 (county scale data) can be used if relevant site-specific records are not available or verifiable for Approach 1. The same Approach must be applied to synthetic N fertilizer and organic N fertilizer if both kinds of fertilizers have been applied during the baseline period.

Approach 1

The baseline N fertilizer rate is determined from the project proponents' management records for at least the previous five years (monoculture) or six years (e.g., three cycles of a two crop rotation, or two cycles of a three crop rotation) prior to the proposed project implementation year.

Management records from which baseline fertilizer N rate can be directly determined is required under this Approach. Examples of these include synthetic fertilizer purchase and application rate records, as well as manure application rate and manure N content data.

Determination of the baseline N_2O emissions must be based on an average of the previous N rate applications for the specific crop(s). A worked example of a baseline N rate calculation using Approach 1 is given in Appendix C.

Approach 2

If the baseline fertilizer N rate for the specific crop(s) cannot be established from project proponent records (Approach 1), then Approach 2 can be used. With Approach 2, the baseline fertilizer N rate is calculated from crop yield data at the county level (available from the United States Department of Agriculture – National Agricultural Statistics Service (USDA – NASS)) and equations for determining fertilizer N rate recommendations based on yield goal estimates (found in e.g., state department of agriculture and university agricultural extension documents).

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

Additionality is assessed through the performance method. The performance method requires projects to meet with requirements on regulatory surplus and exceed the performance benchmark specified below.

Regulatory Surplus

Project proponents meet the requirements for regulatory surplus if:

There is no mandatory law, statute or other regulatory framework in place at the local, state, or federal level, requiring producers to reduce fertilizer N input rate below that of a BAU scenario.

Appendix D provides more information and presents a list of regulations at Federal and State level that deal with practices relating to synthetic and organic N fertilizer management in the agricultural sector. Project developers must consider and evaluate the applicability of all such regulations in the context of the proposed project in order to satisfy the regulatory surplus requirements.

Performance Benchmark

Projects proponents must exceed a performance benchmark threshold that represents BAU. The BAU value is identical to the baseline value for N fertilizer application rate. The baseline value for N fertilizer rate is equivalent to the widespread and general practice of producers to apply N fertilizer rates based upon recommendations derived from yield goal calculations known to overestimate crop needs.

Reductions in N fertilizer rate and therefore N_2O emissions below the BAU site specific value (Approach 1) or below the BAU value in the county where the project is to be conducted (Approach 2) will result in a project exceeding the performance benchmark. The benchmark is defined in terms of N_2O emissions (Mg CO_2e ha^{-1}). Detailed examples using Approach 1 and Approach 2 to determine the benchmark are shown in Appendix C. Evidence for the wide-scale, historic, and continued adoption of the yield-goal approach, and therefore its legitimacy as a performance benchmark for demonstrating additionality in US crop-based agriculture is given in Appendix E.

Further discussion on why Approach 2 is conservative and the trade-offs between false positives (the crediting of activities that are not additional) and false negatives (the exclusion of activities that are additional) is also presented in Appendix E.

The procedures described below are the requirements for determining the benchmark for a crop grown in a single project site using Approach 2.

- Identify project site
- Identify project crop
- Identify years in which crop has been harvested in project site.
- Gather data on crop yield from these years in relevant US county from USDA-NASS
- Use equation C2 (Appendix C) or other relevant equation to calculate predicted crop yield (YG_t)
- Incorporate YG_t into relevant 'yield goal' equation for calculating N rate (e.g., equation C1 in Appendix C)
- Calculate annual N rates based upon field rotation and management (e.g., incorporating N credits)
- Calculate average annual N rate (i.e., baseline N rate) from all annual N rates
- Reduce N rate below the baseline N rate during project crediting period
- Record and maintain project N rate records

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

All emissions of N_2O (baseline and project, direct and indirect) are reported in units of Megagram of carbon dioxide equivalents (Mg CO_2e). One (1) Mg is equivalent to 1×10^6g or one (1) metric Ton or one (1) tonne.

Emissions for baseline and project period are calculated on a per hectare (ha) of land basis.

In the calculations below, year t is the 12-month period following the first input of N fertilizer dedicated to a particular crop, or the period of time following this input prior to an N input dedicated to a separate and subsequent crop at the same project site,

The subscripts B (e.g., $F_{B\ SN,\ t}$) and P (e.g., $F_{P\ SN,\ t}$) are added to distinguish the terms for baseline and project emission factors, respectively. All other factors without these subscripts will be applicable for use in both project and baseline emission calculations.

In calculating direct and indirect emissions of N_2O, the methodology utilizes terminology and scientific rationale presented in the most recent 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

8.1 Baseline Emissions

Baseline emissions can be calculated by the following equation:

$$N_2O_{B\ total,\ t} = N_2O_{B\ direct,\ t} + N_2O_{B\ indirect,\ t} \quad (1)$$

Where:

$N_2O_{B\ total,\ t}$ Total baseline N_2O emissions, Mg CO_2e ha^{-1} in year t;

$N_2O_{B\ direct,\ t}$	Direct baseline N_2O emissions from the project site, Mg CO_2e ha^{-1} in year t;
$N_2O_{B\ indirect,\ t}$	Indirect baseline N_2O emissions beyond the project site, Mg CO_2e ha^{-1} in year t.

Direct emissions

Method 1

The direct baseline nitrous oxide emissions from nitrogen fertilization for Method 1 can be calculated using the following equations:

$$N_2O_{B\ direct,\ t} = (F_{B\ SN,\ t} + F_{B\ ON,\ t}) * EF_{BDM1} * N_2O_{MW} * N_2O_{GWP} \quad (2)$$

$$F_{B\ SN,\ t} = M_{B\ SF,\ t} * NC_{B\ SF} \quad (3)$$

$$F_{B\ ON,\ t} = M_{B\ OF,\ t} * NC_{B\ OF} \quad (4)$$

Where:

$F_{B\ SN,\ t}$	Baseline synthetic N fertilizer applied, Mg N ha^{-1} in year t;
$F_{B\ ON,\ t}$	Baseline organic N fertilizer applied, Mg N ha^{-1} in year t;
$M_{B\ SF,\ t}$	Mass of baseline N containing synthetic fertilizer applied, Mg ha^{-1} in year t;
$M_{B\ OF,\ t}$	Mass of baseline N containing organic fertilizer applied, Mg ha^{-1} in year t;
$NC_{B\ SF}$	N content of baseline synthetic fertilizer applied, g N $(100g\ fertilizer)^{-1}$;
$NC_{B\ OF}$	N content of baseline organic fertilizer applied g N $(100g\ fertilizer)^{-1}$;
EF_{BDM1}	Emission factor for baseline direct N_2O emissions from N inputs Mg N_2O–N $(Mg\ N\ input)^{-1}$ (IPCC default Tier 1 = 0.01. See Appendix F);
N_2O_{MW}	Ratio of molecular weights of N_2O to N (44/28), Mg N_2O $(Mg\ N)^{-1}$;
N_2O_{GWP}	Global Warming Potential for N_2O, Mg CO_2e $(Mg\ N_2O)^{-1}$ (IPCC default = 310. See Appendix F).

Method 2

Direct emissions of N_2O will be calculated using a NCR derived (IPCC Tier 2) equation for baseline and project emissions. See Appendix G. The direct baseline nitrous oxide emissions from nitrogen fertilization for Method 2 can be calculated using the following equations:

$$N_2O_{B\ direct,\ t} = (F_{B\ SN,\ t} + F_{B\ ON,\ t}) * EF_{BDM2} * N_2O_{MW} * N_2O_{GWP} \quad (5)$$

$$F_{B\ SN,\ t} = M_{B\ SF,\ t} * NC_{B\ SF} \quad (3)$$

$$F_{B\ ON,\ t} = M_{B\ OF,\ t} * NC_{B\ OF} \quad (4)$$

$$EF_{BDM2} = 6.7 * 10^{-4} * (\exp (6.7 * [F_{B\ SN,\ t} + F_{B\ ON,\ t}]) – 1) / (F_{B\ SN,\ t} + F_{B\ ON,\ t}) \quad (6)$$

Where:

EF_{BDM2} — Emission factor for baseline direct N_2O emissions from N inputs Mg N_2O–N (Mg N input)$^{-1}$. See Appendix G for details of emission factor calculation.

All other terms are as for Method 1.

For Method 1 and Method 2, the amounts of applied mineral nitrogen fertilizers ($F_{B\ SN,\ t}$) and of applied organic nitrogen fertilizers ($F_{B\ ON,\ t}$) are not adjusted for the amounts of NH_3 and NO_x volatilization after application to soil. Reasons for the removal are given in 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Volume 4, Chapter 11, Note 11).

The baseline fertilizer N rate value calculated using Approach 2 represents the product of the mass and the N content of the synthetic N containing fertilizer, i.e., $M_{B\ SF,\ t} * NC_{B\ SF}$, and as such can be used directly as the value of $F_{B\ SN,\ t}$. Approach 2 is not applicable for the calculation of the baseline organic fertilizer N rate, therefore the value of $F_{B\ ON,\ t} = 0$.

Indirect emissions

The indirect baseline nitrous oxide emissions from nitrogen fertilization can be calculated using the following equations:

$$N_2O_{B\ indirect,\ t} = N_2O_{B\ volat,\ t} + N_2O_{B\ leach,\ t} \quad (7)$$

$$N_2O_{B\ volat,\ t} = [(F_{B\ SN,\ t} * Frac_{GASF}) + (F_{B\ ON,\ t} * Frac_{GASM})] * EF_{BIV} * N_2O_{MW} * N_2O_{GWP} \quad (8)$$

$$N_2O_{B\ leach,\ t} = (F_{B\ SN,\ t} + F_{B\ ON,\ t}) * Frac_{LEACH} * EF_{BIL} * N_2O_{MW} * N_2O_{GWP} \quad (9)$$

Where:

$N_2O_{B\ indirect,\ t}$ — Indirect baseline N_2O emissions beyond the project site, Mg CO_2e ha^{-1} in year t;

$N_2O_{B\ volat,\ t}$ — Indirect baseline N_2O emissions produced from atmospheric deposition of N volatilized as a result of N application at the project site, Mg CO_2e ha^{-1} in year t;

$N_2O_{B\ leach,\ t}$ — Indirect baseline N_2O emissions produced from leaching and runoff of N in regions where leaching and runoff occurs, as a result of N application at the project site, Mg CO_2e ha^{-1} in year t;

$F_{B\ SN,\ t}$ — Baseline synthetic N fertilizer applied, Mg N ha^{-1} in year t;

$F_{B\ ON,\ t}$ — Baseline organic N fertilizer applied, Mg N ha^{-1} in year t;

$Frac_{GASF}$ — Fraction of all synthetic N added to baseline soils that volatilizes as NH_3 and NO_x, dimensionless (IPCC default Tier 1 = 0.10. See Appendix F);

$Frac_{GASM}$ — Fraction of all organic N added to baseline soils that volatilizes as NH_3 and NO_x, dimensionless (IPCC default Tier 1 = 0.20. See Appendix F);

$Frac_{LEACH}$ — Fraction of N added (synthetic or organic) to baseline soils that is lost through leaching and runoff, in regions where leaching and runoff occurs, dimensionless (IPCC default Tier 1 = 0.30. See Appendix A and F);

EF_{BIV} Emission factor for baseline N_2O emissions from atmospheric deposition of N on soils and water surfaces, [Mg N_2O–N (Mg NH_3–N + NO_x–N volatilized)$^{-1}$] (IPCC default Tier 1 = 0.01. See Appendix F);

EF_{BIL} Emission factor for baseline N_2O emissions from N leaching and runoff, Mg N_2O–N (Mg N leached and runoff)$^{-1}$ (IPCC default Tier 1 = 0.0075. See Appendix F);

N_2O_{MW} Ratio of molecular weights of N_2O to N (44/28), Mg N_2O (Mg N)$^{-1}$;

N_2O_{GWP} Global Warming Potential for N_2O, Mg CO_2e (Mg N_2O)$^{-1}$ (IPCC default = 310. See Appendix F).

At project sites where leaching and runoff do not occur (see Appendix A), indirect N_2O emissions are calculated by removing the factor $N_2O_{B\ leach,\ t}$ from equation 7.

8.2 Project Emissions

Project emissions can be calculated by the following equation:

$$N_2O_{P\ total,\ t} = N_2O_{P\ direct,\ t} + N_2O_{P\ indirect,\ t} \quad (10)$$

Where:

$N_2O_{P\ total,\ t}$ Total project N_2O emissions, Mg CO_2e ha^{-1} in year t;

$N_2O_{P\ direct,\ t}$ Direct project N_2O emissions from the project site, Mg CO_2e ha^{-1} in year t;

$N_2O_{P\ indirect,\ t}$ Indirect project N_2O emissions beyond the project site, Mg CO_2e ha^{-1} in year t.

Direct emissions

Method 1

The project direct nitrous oxide emissions from nitrogen fertilization can be calculated using equations as follows:

$$N_2O_{P\ direct,\ t} = (F_{P\ SN,\ t} + F_{P\ ON,\ t}) * EF_{PDM1} * N_2O_{MW} * N_2O_{GWP} \quad (11)$$

$$F_{P\ SN,\ t} = M_{P\ SF,\ t} * NC_{P\ SF} \quad (12)$$

$$F_{P\ ON,\ t} = M_{P\ OF,\ t} * NC_{P\ OF} \quad (13)$$

Where:

$F_{P\ SN,\ t}$ Project synthetic N fertilizer applied, Mg N ha^{-1} in year t;

$F_{P\ ON,\ t}$ Project organic N fertilizer applied, Mg N ha^{-1} in year t;

$M_{P\ SF,\ t}$ Mass of project N containing synthetic fertilizer applied, Mg ha^{-1} in year t;

$M_{P\ OF,\ t}$ Mass of project N containing organic fertilizer applied, Mg ha^{-1} in year t;

$NC_{P\ SF}$ N content of project synthetic fertilizer applied g N (100g fertilizer)$^{-1}$;

$NC_{P\ OF}$ N content of project organic fertilizer applied g N (100g fertilizer)$^{-1}$;

EF_{PDM1}	Emission factor for project N_2O emissions from N inputs, Mg N_2O–N (Mg N input)$^{-1}$ (IPCC default = 0.01. See Appendix F);
N_2O_{MW}	Ratio of molecular weights of N_2O to N (44/28), Mg N_2O (Mg N)$^{-1}$;
N_2O_{GWP}	Global Warming Potential for N_2O, Mg CO_2e (Mg N_2O)$^{-1}$ (IPCC default = 310. See Appendix F).

Method 2

The direct project nitrous oxide emissions from nitrogen fertilization for Method 2 can be calculated using the following equations:

$$N_2O_{P\ direct,\ t} = (F_{P\ SN,\ t} + F_{P\ ON,\ t}) * EF_{PDM2} * N_2O_{MW} * N_2O_{GWP} \quad (14)$$

$$F_{P\ SN,\ t} = M_{P\ SF,\ t} * NC_{P\ SF} \quad (12)$$

$$F_{P\ ON,\ t} = M_{P\ OF,\ t} * NC_{P\ OF} \quad (13)$$

$$EF_{PDM2} = 6.7 * 10^{-4} * (\exp(6.7 * [F_{P\ SN,\ t} + F_{P\ ON,\ t}]) – 1) / (F_{P\ SN,\ t} + F_{P\ ON,\ t}) \quad (15)$$

Where:

EF_{PDM2}	Emission factor for project direct N_2O emissions from N inputs Mg N_2O–N (Mg N input)$^{-1}$. See Appendix **G** for details of emission factor calculation.

All other terms are as for Method 1.

For Method 1 and Method 2, the amounts of applied mineral nitrogen fertilizers ($F_{B\ SN,\ t}$) and of applied organic nitrogen fertilizers ($F_{B\ ON,\ t}$) are not adjusted for the amounts of NH_3 and NO_x volatilization after application to soil. Reasons for the removal are given in 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Volume 4, Chapter 11, Note 11).

Indirect emissions

The indirect project nitrous oxide emissions from nitrogen fertilization can be calculated using the following equations:

$$N_2O_{P\ indirect,\ t} = N_2O_{P\ volat,\ t} + N_2O_{P\ leach,\ t} \quad (16)$$

$$N_2O_{P\ volat,\ t} = [(F_{P\ SN,\ t} * Frac_{GASF}) + (F_{P\ ON,\ t} * Frac_{GASM})] * EF_{PIV} * N_2O_{MW} * N_2O_{GWP} \quad (17)$$

$$N_2O_{P\ leach,\ t} = (F_{P\ SN,\ t} + F_{P\ ON,\ t}) * Frac_{LEACH} * EF_{PIL} * N_2O_{MW} * N_2O_{GWP} \quad (18)$$

Where:

$N_2O_{P\ indirect,\ t}$	Indirect project N_2O emissions beyond the project site, Mg CO_2e ha^{-1} in year t;
$N_2O_{P\ volat,\ t}$	Indirect project N_2O emissions produced from atmospheric deposition of N volatilized as a result of N application at the project site, Mg CO_2e ha^{-1} in year t;

$N_2O_{P\ leach,\ t}$	Indirect project N_2O emissions produced from leaching and runoff of N in regions where leaching and runoff occurs, as a result of N application at the project site, Mg CO_2e ha^{-1} in year t;
$F_{P\ SN,\ t}$	Project synthetic N fertilizer applied adjusted for volatilization as NH_3 and NO_x, and leaching and runoff where applicable, Mg N ha^{-1} in year t;
$F_{P\ ON,\ t}$	Project organic N fertilizer applied adjusted for volatilization as NH_3 and NO_x, and leaching and runoff where applicable, Mg N ha^{-1} in year t;
$Frac_{GASF}$	Fraction of all synthetic N added to project soils that volatilizes as NH_3 and NO_x, dimensionless (IPCC default Tier 1 = 0.10. See Appendix F);
$Frac_{GASM}$	Fraction of all organic N added to project soils that volatilizes as NH_3 and NO_x, dimensionless (IPCC default Tier 1 = 0.20. See Appendix F);
$Frac_{LEACH}$	Fraction of N added (synthetic or organic) to project soils that is lost through leaching and runoff, in regions where leaching and runoff occurs, dimensionless (IPCC default Tier 1 = 0.30. See Appendix A and F);
EF_{PIV}	Emission factor for project N_2O emissions from atmospheric deposition of N on soils and water surfaces, [Mg N_2O–N (Mg NH_3–N + NO_x–N volatilized)$^{-1}$] (IPCC default Tier 1 = 0.01. See Appendix F);
EF_{PIL}	Emission factor for project N_2O emissions from N leaching and runoff, Mg N_2O–N (Mg N leached and runoff)$^{-1}$ (IPCC default Tier 1 = 0.0075. See Appendix F);
N_2O_{MW}	Ratio of molecular weights of N_2O to N (44/28), Mg N_2O (Mg N)$^{-1}$;
N_2O_{GWP}	Global Warming Potential for N_2O, Mg CO_2e (Mg N_2O)$^{-1}$ (IPCC default = 310. See Appendix F).

At project sites where leaching and runoff do not occur (see Appendix A), project indirect N_2O emissions are calculated by removing the factor $N_2O_{P\ leach,\ t}$ from equation 16.

8.3 Leakage

Leakage risks from increased N_2O emissions and other greenhouse gas emissions, and decreased C pools outside the ALM project boundary are not relevant and are not included in emissions calculations due to the reasons described below:

Leakage risks are negligible for ALM projects involving cropland management activities because the land in the project scenario remains maintained for commodity production. Therefore, no production activities outside the project boundary are required to compensate for a productivity decline.

Crop producers are highly risk averse and will not intentionally suffer reduced crop yields. Reducing N rates and the adoption of N rates based on economic optimization will not result in a reduction in crop yield. Extensive historical and current data from Midwestern states at typical crop-to-fertilizer price ratios indicate that there will be no significant change in crop yield as a result of lowering N fertilizer rate from current rates to the economic optimum (ISU 2004, Sawyer et al. 2006, Hoben et al. 2011). Consequently, with no reduction in productivity at the project site there will be no associated incentive for a shift of activity or increased production outside of the project site, which might in turn result in increased N fertilizer use and N_2O emissions. With no yield reduction there will also be no decrease in soil C input and therefore no change in soil C sequestration due to project activities (see section 5 and Appendix B). The leakage potential is therefore negligible.

Moreover, although accounting for ‘positive leakage’ is not eligible, less available N in the soil will result in a reduction in other gaseous and hydrologic N pollutants (e.g., NH_3, NO_x, and NO_3^-).

8.4 Summary of GHG Emission Reduction and/or Removals

The uncertainty associated with a reduction in N_2O emissions brought about by a reduction in N rate between the baseline period and the project period is calculated as:

N_2O Emissions $_{(RED\ UNC)}$ $[1 – \{0.63 * \exp(-40 * [N_{Proj}]^2)\}] * 100$ (19)

Where:

N_2O Emissions $_{(RED\ UNC)}$ Uncertainty in N_2O emissions reductions associated with a reduction in N rate, %;

N_{Proj} = $F_{P\ SN,\ t} + F_{P\ ON,\ t}$ project N input, Mg N ha^{-1} yr^{-1}.

Equation (19) is applicable to projects that determine their baseline N rate (and therefore baseline N_2O emissions) using either Approach 1 or Approach 2 (section 6). Further details of how emissions uncertainty is derived are given in Appendix G.

Project proponents will use equation (19) to calculate emissions reductions uncertainties (%) for a project. Confidence deductions as a result of uncertainty will be applied using the conservative factors specified in the CDM Meth Panel guidance on addressing uncertainty in its Thirty Second Meeting Report, Appendix 14 (Table 3 below).

Table 3: Conservativeness factors for emissions reductions based upon uncertainty at 95% confidence level.

Uncertainty range at 95% confidence level of project emissions reductions§	Conservativeness factor	Uncertainty deduction*
< ± 15%	1.000	0.000
> ± 15% ≤ ± 30%	0.943	0.057
> ± 30% ≤ ± 50%	0.893	0.107
> ± 50% ≤ ± 100%	0.836	0.164

§ Uncertainty in emissions reductions does not exceed 100% (see Appendix G).
* Where uncertainty in emissions reductions is < ± 15%, no deductions will be applied.
Uncertainty deduction (UNC) = (1 – Conservativeness factor). See equation (20).

Emissions reductions and calculations of VCUs

Equation (20) calculates the N_2O emission reductions brought about by project implementation:

$N_2O_{PR,\ t}$ = $[(N_2O_{B\ total,\ t} - N_2O_{P\ total,\ t}) * A_P] * (1 - LK) * (1 - UNC)$ (20)

Where:

$N_2O_{PR,\,t}$	Reduction in total N_2O emissions brought about by project implementation, Mg CO_2e in year t;
$N_2O_{B\ total,\,t}$	Total baseline N_2O emissions within the project spatial boundary as a result of N application at the project site, Mg CO_2e ha^{-1} in year t;
$N_2O_{P\ total,\,t}$	Total project N_2O emissions within the project spatial boundary as a result of N application at the project site, Mg CO_2e ha^{-1} in year t;
A_P	Project area, ha;
LK	Leakage deduction (set as 0 in this methodology, as described in section 8.3);
UNC	Uncertainty deduction (set as in Table 3 [this section] in this methodology).

Equation (21) calculates the amount of VCUs issued:

$$VCU_t = N_2O_{PR,\,t} * (1 - BUF) \quad (21)$$

Where:

VCU_t	Verified Carbon Units (VCUs) at time t, Mg CO_2e;
BUF	Buffer deduction (set as 0 in this methodology).

9 MONITORING

9.1 Data and Parameters Available at Validation

Data Unit / Parameter:	$M_{B\ SF,\,t}$
Data unit:	Mg ha^{-1} yr^{-1}
Description:	Baseline synthetic N containing fertilizer applied
Source of data:	Project proponent records (Approach 1)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	Approach 2 calculates baseline fertilizer N rate = ($M_{B\ SF,\,t}$ * $NC_{B\ SF}$), and is substituted into equation 3 to calculate $F_{B\ SN,\,t}$.

Data Unit / Parameter:	$M_{B\ OF,\,t}$
Data unit:	Mg ha^{-1} yr^{-1}

Description:	Baseline organic N containing fertilizer applied
Source of data:	Project proponent records (Approach 1)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	Approach 2 is not applicable for the calculation of $M_{B\ OF,\ t}$.

Data Unit / Parameter:	$NC_{B\ SF}$
Data unit:	g N $(100g\ fertilizer)^{-1}$
Description:	Nitrogen content of baseline synthetic fertilizer applied
Source of data:	Project proponent records (Approach 1)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	Approach 2 calculates baseline fertilizer N rate = ($M_{B\ SF,\ t}$ * $NC_{B\ SF}$), and is substituted into equation 3 to calculate $F_{B\ SN,\ t}$.

Data Unit / Parameter:	$NC_{B\ OF}$
Data unit:	g N $(100g\ fertilizer)^{-1}$
Description:	Nitrogen content of baseline organic fertilizer applied
Source of data:	Project proponent records (Approach 1)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	Approach 2 is not applicable for the calculation of $NC_{B\ OF}$.

Data Unit / Parameter:	Baseline Crop yield
Data unit:	Mg $ha^{-1}\ yr^{-1}$

Description:	Crop yield (standard reporting method for particular crop, e.g., dry grain yield)
Source of data:	Project proponent records (Approach 1) or county level data (Approach 2)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	Baseline Crop area
Data unit:	Hectare (ha)
Description:	Area of crop(s) planted, from which baseline fertilizer N rate determined
Source of data:	Project proponent records (Approach 1 and 2)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	The baseline crop area must encompass the project crop area in order to ensure that the same land area is used in emission reduction calculations.

Data Unit / Parameter:	$Frac_{GASF}$
Data unit:	Dimensionless
Description:	Fraction of all synthetic N added to project soils that volatilizes as NH_3 and NO_x
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.10)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	$Frac_{GASM}$
Data unit:	Dimensionless

Description:	Fraction of all organic N added to project soils that volatilizes as NH_3 and NO_x,
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.20)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	$Frac_{LEACH}$
Data unit:	Dimensionless
Description:	Fraction of N added (synthetic or organic) to project soils that is lost through leaching and runoff, in regions where leaching and runoff occurs
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.30)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	EF_{BDM1}
Data unit:	Mg N_2O–N (Mg N input)$^{-1}$
Description:	Emission factor for baseline direct N_2O emissions from N inputs (Method 1)
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.01)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	EF_{BDM2}
Data unit:	Mg N_2O–N (Mg N input)$^{-1}$

Description:	Emission factor for baseline direct N_2O emissions from N inputs (Method 2)
Source of data:	Empirical research on producer fields throughout Michigan
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	Parameter only valid in North Central Region of the US (Appendix G; Hoben et al. 2011).

Data Unit / Parameter:	EF_{BIV}
Data unit:	Mg N_2O–N (Mg NH_3–N + NO_x–N volatilized)$^{-1}$
Description:	Emission factor for baseline N_2O emissions from atmospheric deposition of N on soils and water surfaces
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.01)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	EF_{BIL}
Data unit:	Mg N_2O–N (Mg N leached and runoff)$^{-1}$
Description:	Emission factor for baseline N_2O emissions from N leaching and runoff,
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.0075)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	EF_{PDM1}
Data unit:	Mg N_2O–N (Mg N input)$^{-1}$

Description:	Emission factor for project direct N_2O emissions from N inputs (Method 1)
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.01)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	EF_{PDM2}
Data unit:	Mg N_2O–N (Mg N input)$^{-1}$
Description:	Emission factor for project direct N_2O emissions from N inputs (Method 2)
Source of data:	Empirical research on producer fields throughout Michigan
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	EF_{PIV}
Data unit:	Mg N_2O–N (Mg NH_3–N + NO_x–N volatilized)$^{-1}$
Description:	Emission factor for project N_2O emissions from atmospheric deposition of N on soils and water surfaces
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.01)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	EF_{PIL}
Data unit:	Mg N_2O–N (Mg N leached and runoff)$^{-1}$

Description:	Emission factor for project N_2O emissions from N leaching and runoff,
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.0075)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

9.2 Data and Parameters Monitored

Data Unit / Parameter:	$M_{P\ SF,\ t}$
Data unit:	Mg N yr^{-1}
Description:	Mass of project synthetic N containing fertilizer applied
Source of data:	Project proponent records
Description of measurement methods and procedures to be applied:	Generally accepted field application methods using calibrated applicators of known capacity for fertilizer mass or volume determination
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	Verify calibration and capacity of applicators
Any comment:	

Data Unit / Parameter:	$M_{P\ OF,\ t}$
Data unit:	Mg N yr^{-1}
Description:	Mass of project organic N containing fertilizer applied
Source of data:	Project proponent records
Description of measurement methods and procedures to be applied:	Generally accepted methods using calibrated applicators of known weight/volume for liquid and solid organic material application
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	Verify calibration and capacity of applicators and number of loads applied

Any comment:	

Data Unit / Parameter:	$NC_{P\ SF}$
Data unit:	g N (100g fertilizer)$^{-1}$
Description:	Nitrogen content of project synthetic fertilizer applied
Source of data:	Project proponent records
Description of measurement methods and procedures to be applied:	Generally accepted procedures for sampling, handling and analysis of bulk fertilizer
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	Verify fertilizer is from accredited source*
Any comment:	

Data Unit / Parameter:	$NC_{P\ OF}$
Data unit:	g N (100g fertilizer)$^{-1}$
Description:	Nitrogen content of project organic fertilizer applied
Source of data:	Project proponent records
Description of measurement methods and procedures to be applied:	Generally accepted sampling and handling procedures for organic materials. Laboratory analysis for total N using total Kjeldahl Nitrogen [TKN] or total N by combustion)
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	Verify N content from laboratory analysis documentation
Any comment:	

Data Unit / Parameter:	Project Crop area
Data unit:	Hectare (ha)
Description:	Area of crop(s) planted, from which project fertilizer N rate determined
Source of data:	Project proponent records

Description of measurement methods and procedures to be applied:	As per requirements of VCS version 3 “Project location for AFOLU projects must be specified using geodetic polygons to delineate the geographic area of each AFOLU project activity and provided in a KML file.
Frequency of monitoring/recording:	Each project crediting period
QA/QC procedures to be applied:	Verify file(s) coincide with project field(s) geographic boundary
Any comment:	

*The formulation of the synthetic N containing fertilizer must also be verified. From this the N content (% of mass) can be determined. Farmers’ records must be cross-checked with records from synthetic and organic N fertilizer suppliers. In case of discrepancies between the records of the farmers and those from suppliers of synthetic and organic N containing fertilizers, the most conservative value(s) must be taken.

To demonstrate the total amount of N to be applied to the project area during a cropping season is sufficient to generate expected annual yield similar to the average annual yield of the same crop(s) during the baseline period as required in Section 4 (Fertilizer Nitrogen Management), the project proponent is required to provide one of the following two forms of evidence (1 or 2 below).

1. Demonstrate consistency with the most recent state or regional N rate recommendations provided by the University Agriculture Extension Service, state department of agriculture, or a federal agency such as the USDA Natural Resources Conservation Service (NRCS) or Farm Service Agency (FSA). In this context, “consistency” means that the total amount of N to be applied to the project area during a cropping season must be equal to or greater than 80% of the lowest estimate of N rate range recommended for the relevant crop(s) in the region in which they are grown. This can be demonstrated using one of the two approaches below (a or b below):

    a. Consistent with the total N rate recommended in official publications from these organizations, such as extension bulletins or soil test lab reports.

    b. Consistent with data output from approved N rate calculators. Examples of approved N rate calculators include the Iowa State University corn nitrogen rate calculator (http://extension.agron.iastate.edu/soilfertility/nrate.aspx) for multiple Midwest states, and the University of Wisconsin corn N rate calculator (http://ipcm.wisc.edu/iPhone/tabid/120/Default.aspx) for Wisconsin, both of which calculate the profitable N rate range for corn around the maximum return to nitrogen (MRTN) rate. Other N rate calculators can be used provided they have been made available to the public by a University Agriculture Extension Service, state department of agriculture, or a federal agency, such as the USDA NRCS or FSA. A worked example demonstrating the use of the Iowa State University corn nitrogen calculator is shown in Appendix H.

2. Written certification provided by a professional crop advisor (see below) stating that total amount of N to be applied to the project area during a cropping season is sufficient to generate expected annual yield similar to the average annual yield of the same crop(s) grown during the baseline period.

The professional crop advisor must be: (a) a Certified Crop Advisor (CCA) certified by the American Society of Agronomy (ASA); (b) a Certified Professional Crop Consultant (CPCC) certified by the Soil and

Water Conservation Society (SWCS); (c) a professional staff member of a University Agricultural Extension Service; (c) a professional staff member of the USDA NRCS or FSA; (d) a professional staff member of a state agriculture agency in the state in which the project is located; or (e) an equivalent professional crop advisor as demonstrated by similar professional qualifications.

9.3 Description of the Monitoring Plan

The data and parameters required for baseline validation and during the project period are detailed in sections 9.1 and 9.2, respectively.

Information on accepted methods for sampling and handling, and measuring mass and N content of fertilizer can be found in state university agricultural extension documents.

Data for monitored parameters are derived from farmer records that are used for compliance with a myriad of farm-related programs, including state and federal BMPs. These farmer records also are consistent with project documents required for verification during the project period.

10 APPENDICES

APPENDIX A - Equations for determining if leaching and runoff occur at project site

The approach presented here uses default (Tier 1) values for leaching and run-off from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, and the ratio of growing season values of precipitation to potential evapotranspiration.

A project site is considered to have a $Frac_{LEACH}$ default value of 0.30 kg N (kg N additions)$^{-1}$) when:

$$Precip_{GS} / PET_{GS} \geq 1.00 \quad \text{(A1)}$$

A project site is considered to have a $Frac_{LEACH}$ default value of 0.00 kg N (kg N additions)$^{-1}$) when:

$$Precip_{GS} / PET_{GS} < 1.00 \quad \text{(A2)}$$

Where:

$Precip_{GS}$	=	Precipitation during the growing season, mm;
PET_{GS}	=	Potential evapotranspiration during the growing season, mm.

The growing season is considered to occur from May – September inclusive, unless otherwise verifiable. Planting and harvesting or frost records can be used to verify that the growing season is other than May – September. While this period is appropriate for corn over most of the NCR, in southern parts of the US corn can be planted a number of weeks prior to the beginning of May. Also, for example, if winter annual crops such as winter wheat and fall canola are grown, the appropriate growing season may be October – July.

Where crop irrigation is employed, irrigation water is considered equivalent to rainfall, and as such, project proponents will add irrigation water input to precipitation data to calculate total precipitation during the growing season or annually as required. Water from drip irrigation is excluded.

Average values for precipitation and irrigation water and potential evapotranspiration for baseline determination are calculated from the same time period used to determine baseline fertilizer N rate, i.e., consistent with project proponents' records (Approach 1) or county level data (Approach 2).

Information sources for determining if leaching and runoff occur at project site

If site specific data for precipitation and potential evapotranspiration are not readily available, data from local meteorological stations can be used. A centralized information source to identify these stations in the US can be found at the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) station information webpage: http://www.weather.gov/tg/siteloc.shtml. Archived data for all US meteorological sites can be found at the National Climatic Data Center (NCDC): http://lwf.ncdc.noaa.gov/oa/climate/stationlocator.html.

Individual US states may also have meteorological data available through academic or other institutions. In Michigan for example, annual precipitation and potential evapotranspiration data can be obtained from the Michigan Automated Weather Network (MAWN): http://www.agweather.geo.msu.edu/mawn.

Potential Evapotranspiration (PET) at project sites may also be calculated using the FAO Penman–Monteith equation. More information can be found in Allen et al. (1998).

APPENDIX B - Evidence relating to exclusion of soil C in methodology accounting

Appendix B can be used for projects using this methodology as a criterion to exclude the soil C pool.

Soil carbon is the primary pool of concern for ALM methodologies. In accordance with VCS AFOLU requirements v3.0, methodologies targeting N_2O emission reductions need to account for any significant reductions in soil C stocks.

In this methodology reductions in N fertilizer rate resulting from project implementation will not result in significant (> 5% of the total CO_2e benefits from reduction in N_2O emissions) decreases in soil C stock. Peer reviewed literature details how the soil C pool is deemed de minimis.

N fertilizer can increase soil C stocks by increasing crop growth and associated rates of crop residue production. Because this methodology will not result in significant crop growth (yield) declines and therefore no declines in residue inputs, there can be no associated decline in soil C stocks. In fact available evidence suggests that excess N can speed decomposition (Parton et al. 2007) and thereby lower (Khan et al. 2007) or maintain (Russell et al. 2009) C stocks that might otherwise increase, suggesting that this methodology may, if anything, promote soil C sequestration. We nevertheless make no such claim.

Therefore, the soil C pool is deemed de minimis and is excluded from methodology accounting.

APPENDIX C – Calculating baseline N fertilizer rate

Approach 1

The baseline fertilizer N rate is determined from the project proponents management records for at least the previous five years (monoculture) or six years (e.g., three cycles of a two crop rotation, or two cycles of a three crop rotation) prior to the proposed project implementation year.

Management records from which baseline fertilizer N rate can be directly determined are required. Examples of these include synthetic fertilizer purchase and application rate records, as well as manure application rate and manure N content history.

Determination of the baseline N_2O emissions are based on an average of the previous N rate applications for the specific crop(s).

Worked example - Calculating baseline fertilizer N rate for corn in a corn–soybean rotation

For a proposed project beginning in 2011, a producer (project proponent) has applied the following fertilizer N rates to a corn–soybean rotation in the previous 6 years (3 rotations, Table C1).

Table C1. Fertilizer N rates applied to a corn–soybean rotation (2005 – 2010).

Year	Crop/Rotation	Synthetic Fertilizer N rate (kg N ha^{-1} yr^{-1})	Organic Fertilizer N rate (kg N ha^{-1} yr^{-1})	Total Fertilizer N rate (kg N ha^{-1} yr^{-1})
2005	Corn	180	20	200
2006	Soybean	0	10	10
2007	Corn	160	30	190
2008	Soybean	20	0	20
2009	Corn	190	20	210
2010	Soybean	0	0	0
2005–2010 Average	Soybean	= (0+20+0)/3 =6.7	= (10+0+0)/3 = 3.3	= (10+20+0)/3 = 10
2005–2010 Average	Corn	= (180+160+190)/3 ≈ 177	= (20+30+20)/3 ≈ 23	= (200+190+210)/3 = 200
2005–2010 Average	Corn–Soybean	= (180+0+160+20+190+0)/6 ≈ 92	= (20+10+30+0+20+0)/6 ≈ 13	= (200+10+190+20+210+0)/6 = 105

The baseline fertilizer N rate for a corn crop in the proposed project to be planted in 2011 is calculated from the average of the total fertilizer N rate applied to the previous 3 corn crops during the previous 6 years, i.e., = (200 + 190 + 210)/3 = 200 kg N ha^{-1} yr^{-1}. Reductions from this baseline 'common practice' rate are considered additional and are credited.

N.B. The baseline synthetic and organic fertilizer N rate (Table C1) in each year (t), are calculated from:

($M_{B\ SF,\ t}$ * $NC_{B\ SF}$) and ($M_{B\ OF,\ t}$ * $NC_{B\ OF}$), respectively,

Where:

$M_{B\ SF,\ t}$	Baseline N containing synthetic fertilizer applied, Mg ha^{-1} in year t;
$M_{B\ OF,\ t}$	Baseline N containing organic fertilizer applied, Mg ha^{-1} in year t;
$NC_{B\ SF}$	Nitrogen content of baseline synthetic fertilizer applied g N $(100g\ fertilizer)^{-1}$;
$NC_{B\ OF}$	Nitrogen content of baseline organic fertilizer applied g N $(100g\ fertilizer)^{-1}$;

Approach 2

If the baseline fertilizer N rate cannot be determined from project proponent records (Approach 1), then Approach 2 is used. With Approach 2, the baseline fertilizer N rate is calculated from crop yield data at the county level (available from the United States Department of Agriculture – National Agricultural Statistics Service (USDA – NASS)) and equations for determining fertilizer N rate recommendations based on yield goal estimates (found in e.g., state department of agriculture and university agricultural extension documents). The baseline fertilizer N rate value calculated using Approach 2 represents the product of the mass and the N content of the synthetic N containing fertilizer, i.e., $M_{B\ SF,\ t}$ * $NC_{B\ SF}$. Approach 2 is not applicable for the calculation of the baseline organic fertilizer N rate, therefore the value of $F_{B\ ON,\ t} = 0$.

Worked example - Calculating baseline fertilizer N rate for corn in a corn–soybean rotation in Tuscola County, Michigan

From the methodology "During the project crediting period, adherence to 'Best Management Practices' (BMPs) for the management of synthetic and organic N fertilizer at the project site is required.

For a project developer based in Michigan, the Michigan Department of Agriculture publication Generally Accepted Agricultural Management Practices (GAAMP) for Nutrient Utilization, (2013, or most recent version) is consulted (Michigan Department of Agriculture 2013). This publication recommends the Michigan State University (MSU) Extension Bulletin E–2904 – Nutrient Recommendations for Field Crops in Michigan (Warncke et al. 2004), for selecting the appropriate rate of N fertilizer for corn.

From Extension Bulletin E–2904 the equation for calculating the N rate (lb N $acre^{-1}$) recommendation for a corn (grain) crop planted in rotation with soybean in mineral soil is given by:

$$N\ rate = (1.36 * YG_t) - 27 - NC \quad (C1)$$

Where:

YG_t	Yield goal of crop in year t, to which recommended N rate will be applied, bushel $acre^{-1}$;
NC	Nitrogen credit from previous soybean crop, lb N $acre^{-1}$.

In Extension Bulletin E–2904 soybean is given an N credit of 30 lb N acre^{-1}.

To calculate the predicted future corn yield the following equation is used:

$$YG_t = 1.05 * [(Y_{t-2} + Y_{t-4} + Y_{t-6}) / 3] \quad (C2)$$

Where:

Y_t = Project start date (year)

Y_{t-n} = Average county yield of crop in years 2, 4, and 6 prior to project adoption.

The approach of taking previous year's yield data and multiplying by 105% (1.05) in order to calculate the yield goal for the forthcoming crop is a common and conservative practice for producers. The approach is consistent with typical recommendations from university extension and agronomic organizations. Documentation outlining this approach is found for example in Fertilizer Suggestions for Corn – G174, University of Nebraska, Lincoln (Shapiro et al. 2003), and The Illinois Council on Best Management Practices (2001).

For Approach 2, the previous years yield data is determined from interrogation of the USDA – NASS web pages (Figures C1 and C2, http://www.nass.usda.gov).

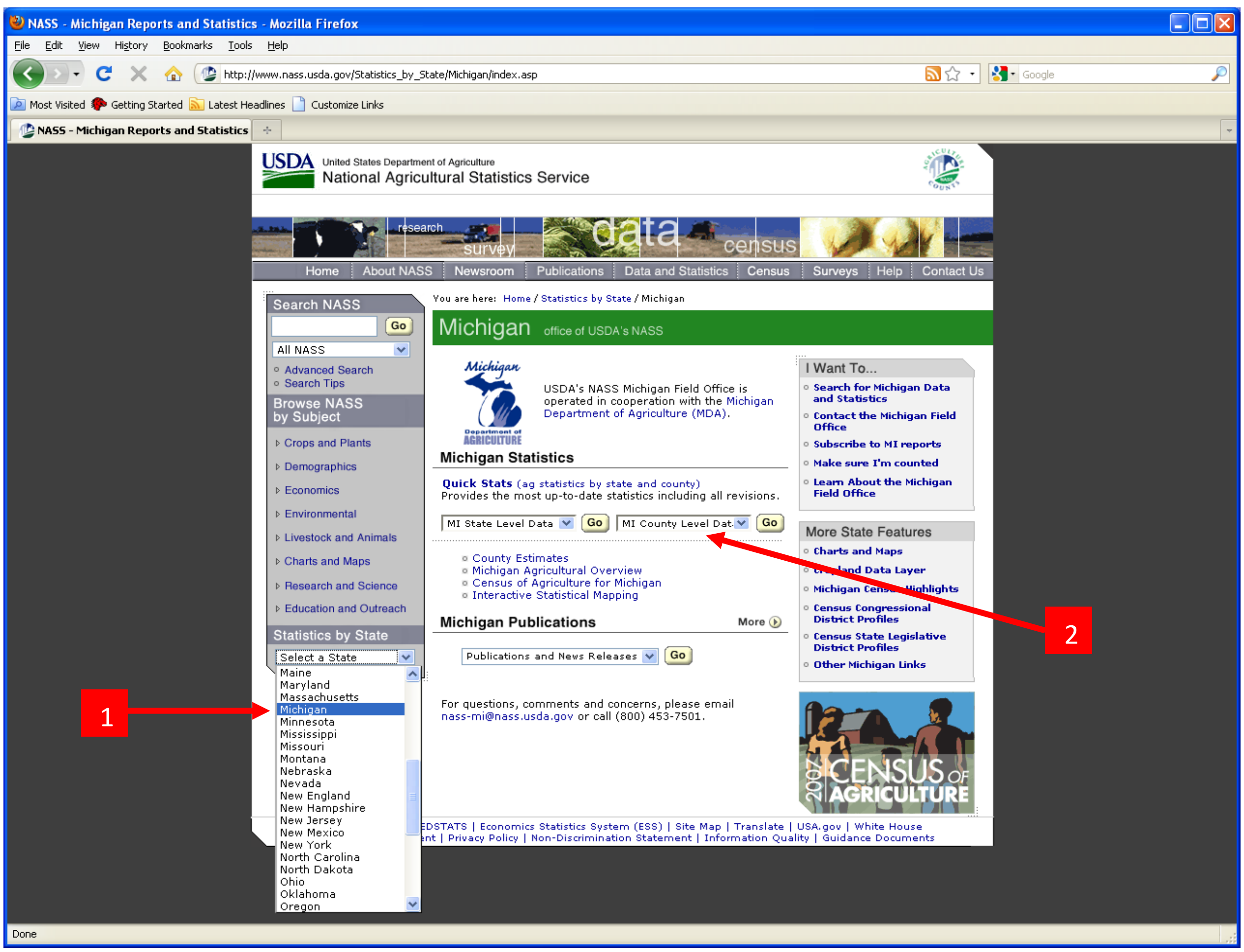

Figure C1. USDA – NASS screen shot showing selection menus for State (1), and County (2) level data inquiry.

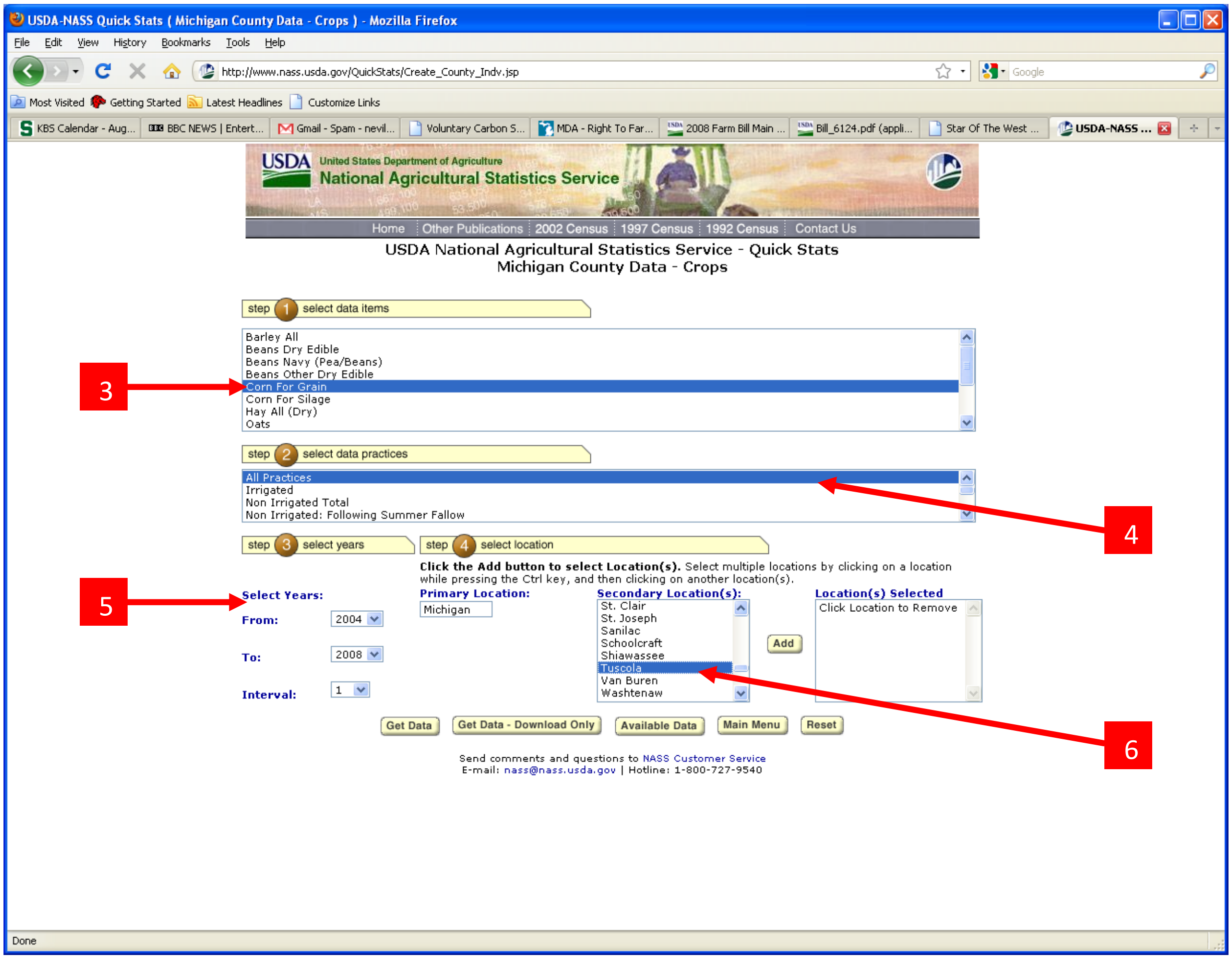

Figure C2. USDA – NASS screen shot showing selection menus for crop (3), practice (4), years (5) and County (6).

Data is downloaded as .csv files from which average yield data can be calculated (Table C2).

Table C2. Area planted, area harvested, yield data and total county production for corn (grain) in Tuscola county Michigan, for years 2005 through 2010.

	2005	2006	2007	2008	2009	2010
Yield (bushel acre^{-1})	148	154	134	174	164	148

The use of crop yield data from USDA – NASS must be consistent with the crop rotation history of the proposed project site(s). In this example a project field has had corn grown in rotation with soybean for at least the last six years (2005 – 2010, starting with corn). The calculation therefore must use USDA – NASS data for corn yield from 2005, 2007 and 2009 for a project start date of 2011. Using equation C2, we can calculate the yield goal for corn in 2011 (year t) as follows:

YG t = 1.05 * [(148 + 134 + 164) / (3)]

= 156.1 bushel $acre^{-1}$

From equation C1 the fertilizer N rate recommendation for corn (grain) in Michigan:

= (1.36 * 156.1) - 27 - 30

= 155.3 lb N $acre^{-1}$

For conversion from non SI (lb N acre-1) to SI (kg N ha-1) units, the value is multiplied by 1.12 (a conversion factor accepted by the American Society of Agronomy (ASA), the Crop Science Society of America (CSSA), and the Soil Science Society of America (SSSA).

http://www.soils.org/files/publications/journals-sitable-coversions.pdf.

The fertilizer N rate recommendation for corn (grain) is then:

= 174.0 kg N ha^{-1}

This value is considered the baseline fertilizer N rate for corn (grain) in a corn–soybean rotation for any proposed project site situated in the county of Tuscola, Michigan that had a project start date in 2011.

Depending on the proposed project details, similar equations for crops in other states can be utilized.

Note, as with Approach 1 the BAU baseline N fertilizer rate initially calculated remains fixed for the crediting period.

Information on the use of nitrogen credits from organic N fertilizer (manure) when Approach 2 is used is given in Appendix E.

APPENDIX D – Regulatory Surplus

To demonstrate additionality a project will need to pass a regulatory surplus test.

Project developers will pass this test if 'there is no mandatory law, statute or other regulatory framework in place at the local, state, or federal level, requiring producers to reduce fertilizer N input rate below that of a business–as–usual, i.e., common–practice scenario.'

The following paragraphs present some information and examples of regulations that deal with fertilizers and their application. The following is not meant to be an exhaustive list of regulations. Project developers must conduct a complete evaluation of federal, state and local regulations applicable to fertilizer use in the selected project location as part of the additionality assessment.

There is no Federal fertilizer statute and fertilizers are regulated under the individual States' authority. The Federal government does not regulate fertilizer directly however, there are regulations concerning the production, use and disposal of hazardous materials, drinking and surface water contamination and air pollution that are indirectly relevant to the use of hazardous materials in fertilizers and the application of fertilizers to land.

Below is a list of regulations at the Federal and State (Michigan) level that deal in some part with practices relating to synthetic and organic N fertilizer management in the agricultural sector.

Federal Regulations

The Food, Conservation, and Energy Act (2008)

The Military Munitions Rule (1997)

The Water Quality Amendment Act (1987)

The Superfund Amendments and Reauthorization Act (SARA) (1986)

Resource Conservation and Recovery Act of 1976 (RCRA) Statute - Solid Waste Disposal, Title 42, Chap. 82, Subchapter III - Hazardous Waste Management

The Federal Water Pollution Control Act (1972)

Hazardous Waste Regulation, 40 CFR, Part 503, Standards for the Use or Disposal of Sewage Sludge

The Occupational Safety and Health Administration (OSHA) Hazard Communication Standard (29 CFR 1910.1200)

State Regulations

Each state in the US has its own fertilizer regulatory program. State regulations for fertilizers are generally developed and administered by State agriculture departments. Such regulations primarily address efficacy claims and composition statements of the active ingredients displayed on fertilizer labels. Most States have fertilizer regulations similar to that of the Association of American Plant Food Control Officials (AAPFCO) model Uniform State Fertilizer Bill.

The Uniform State Fertilizer Bill is a model bill providing the legal authority to regulate the registration, packaging, labeling, sale, storage, distribution, use and application of fertilizer and fertilizer materials. There are specific requirements for the accurate and meaningful labeling of fertilizers, including terms and definitions, and regulations for the storage requirements for bulk fluid and dry fertilizers.

Other AAPFCO Uniform Bills which may relate to fertilizer N application include the Uniform Soil Amendment Bill, the Model Agricultural Liming Materials Bill, the Model Chemigation Bill and the Uniform State Ammonia Bill.

Example: Michigan State Regulations

Below are state level regulations indirectly relating to fertilizer N management as outlined in the Michigan Department of Agriculture Generally Accepted Agricultural and Management Practices (GAAMP) for Nutrient Utilization publication (Michigan Department of Agriculture, 2013).

These regulations apply to ‘a person applying, distributing, and storing fertilizer or organic materials in Michigan’ who ‘must comply with the relevant state and federal laws and regulations promulgated under these statutes, including but not limited to’:

Public Act 451: Natural Resources and Environmental Protection Act of 1994

Public Act 346: Commercial Drivers' License Law of 1988

Public Act 368: Michigan Public Health Code of 1978

Public Act 399: State of Michigan Safe Drinking Water Act of 1976

Public Act 154: Michigan Occupational Safety and Health Act (MIOSHA) of 1974

Public Act 162: Michigan Liming Materials Law of 1955

Further useful information regarding fertilizer regulations can be found at the Safe Fertilizer Information Institute (http://saffii.com/uslaw.aspx).

APPENDIX E – Business as Usual (BAU) practice for N fertilizer application and justification for Approach 2

In using this methodology, project proponents must exceed a performance benchmark. Project proponents exceed the performance benchmark by reducing their N fertilizer rate below the BAU rate, which is also the baseline value for N fertilizer rate for the proposed project. This baseline scenario equates the N fertilizer application with the widespread and general practice of producers to apply N fertilizer rates based upon recommendations derived from yield goal estimates. Reductions in N fertilizer rate below the baseline site specific value (Approach 1) or below the baseline value in the county where the project is to be conducted (Approach 2) will result in a project exceeding the performance benchmark. Both Approach 1 and 2, used to establish the project baseline, operate on the principle that a reduction in N fertilizer rate below the baseline results in a predictable, concomitant reduction in N_2O emissions. Project additionality is achieved through a reduction in N rate below the baseline scenario, such that 'new' N_2O emissions are prevented from entering the atmosphere. These avoided emissions occur immediately, are irreversible, and are permanent.

Evidence for the wide-scale historic, continued, and extensive use of the yield goal approach as the baseline (BAU) scenario, and therefore its legitimacy as a performance benchmark for testing additionality in crop-based agriculture, is given below.

Justification of the yield goal approach as a BAU baseline scenario

Since the 1970s it has been common practice throughout the NCR and the conterminous US in general for producers to apply rates of N fertilizer based on recommendations derived from yield goal estimates (e.g., Fixen, 2006; Shapiro et al. 2003; Warncke et al. 2004). The agricultural departments of land grant universities, state and federal agricultural organizations continue to endorse yield-goal N fertilizer rate recommendations (e.g., Michigan Department of Agriculture, 2013, USDA – NRCS, 2011; 2012). For example, the recently updated (July 2012) USDA – NRCS Conservation Effects Assessment Project (CEAP) states:

"Nutrient management systems have four basic criteria for application of commercial fertilizers and manure. 1. *Apply nutrients at the appropriate rate based on soil and plant tissue analyses and realistic yield goals.*"

All these organizations represent a common source of external information that provides advice directly or indirectly to producers. This network serves as the foundation for producer BAU practice in the NCR and beyond, constituting a sector-wide approach for calculating baseline N fertilizer rates and, by extension, emissions of N_2O.

Despite this, very few studies have quantitatively examined the numerous factors and their complex interactions and impact on a farmers' decision of how much N fertilizer to apply to a crop. Those that have done so indicate that the majority of farmers rely heavily on their own experience, as well as on advice from fertilizer dealers. For example, using USDA data Ribaudo et al. (2011) found that 72% of growers base their N fertilizer application decision on 'routine practice', and from a recent survey sent to 1000 farmers in SW Michigan, Stuart et al. (2012) found that almost all respondents receive information from fertilizer and seed dealers on how to determine their N fertilizer application rates; for 55% this represents the most important source of information; only 18% used university recommendations as their most important source.

Important though these data are, they do not report the dealers' rationale or calculations for the advice given. This data is scarce. However, university recommendations are based on yield goal calculations, and in the MI survey, Stuart et al. (2012) found that 72% of commercial corn farmers use a simple yield-goal calculation to derive their N rate. This value is identical to the percentage of growers who base their N fertilizer application decision on routine practice (Ribaudo et al. 2011). The remaining 28% appear to use some combination of other farmers, private consultants, magazine articles, and other informal sources unlikely to be as conservative (Stuart et al. 2012).

From the MI survey, of the farmers who fertilized using simple N-to-yield-goal ratios (lbs N per bushel of corn) the percentages who reported a particular ratio were 5 (>1.3), 21 (1.1 to 1.3), 55 (0.8 to 1), and 19 (<0.8).

If we use the five year average corn grain yield for MI between 2007 and 2011 of 143 bushels per acre, we can estimate N rate applications (kg N ha^{-1}) for these groups as >208, 176 to 208, 128 to 160, and <128, respectively. Extrapolating these trends nationally where average corn grain yield between 2007 and 2011 was 154 bushels per acre, we get >224, 190 to 224, 138 to 172, and <138, respectively.

It is not known whether respondents to the MI survey took into account N contributions (N credits) from other sources such as prior leguminous crops or manure. If not (as is likely), then on average there would be an increased percentage of respondents placed in the higher ratios (1.1 to 1.3, and > 1.3). In the survey, nearly half of the respondents used both commercial synthetic N fertilizers and manure on their crops (none used manure N only – consistent with national data, e.g., Ribaudo et al. 2011). However, nearly 60% never tested their manure for N content and 64% never kept any records if they did. This suggests that the N rates were under-reported, and therefore the respondent's N-to-yield-goal ratio underestimated. Under-reporting of N rate application has been reported elsewhere. For example, data from California across a wide range of crops indicate that on average producers apply approximately 38 lbs N per acre (~42 kg N per hectare) more than they report (Rosenstock et al. 2013). Data from Ribaudo et al. (2011) indicates that when farmers use both manure and commercial fertilizer, they apply on average 28% higher N rates to their crops, when compared to farmers who apply only synthetic N fertilizers. This is despite the recommendation to farmers who use both N sources to apply 10% less N than to those who use only synthetic N.

Despite decades-old concerns and quantitative evidence that yield goal-based recommendations are inaccurate (e.g., Lory and Scharf 2003) and too liberal for recommending N fertilizer rate, the practice is still widely recommended and followed. This inevitably leads to applications of N fertilizer in excess of crop requirements, principally as a result of unrealistic yield goal estimates (e.g., Vanotti and Bundy 1994). Furthermore, to maintain viable operations, farmers may manage temporal variability in weather and soil N by over-applying N to protect against downside risk (i.e., use an 'insurance' N application rate) (Sheriff, 2005; Babcock, 1992; Babcock and Blackmer, 1992). Additionally, farmers may take a 'safety net' approach to maximize economic returns by setting an optimistic yield goal for a given field based on an optimum weather year to ensure that the needed amount of N for maximum yields is available (Schepers et al., 1986; Bock and Hergert, 1991). Thus, during the years in which weather is not optimal for maximizing yields, N will be over-applied from an agronomic standpoint. By definition, optimal conditions are infrequent, so farmers over-fertilize crops in most years. It is therefore safe to conclude that reductions in N rate below those determined by yield-goal based calculations (i.e., the BAU baseline scenario) can be implemented to reduce the amount of excess N in cropland agriculture, thereby decreasing its N_2O burden without reducing crop productivity.

A regional approach to optimize crop yield has recently been developed that utilizes historical and current N fertilizer rate research data from field trials to determine economically profitable N inputs, expressed as a range of N rates around a maximum return to N (MRTN) at different N fertilizer and crop prices (Iowa State University Agronomy Extension 2004). The US Midwest states currently providing data for this approach are Iowa, Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. Producers with relevant cropping systems in these states (and other states that may subsequently become involved) may wish to adopt a N fertilizer rate for the project within the economically profitable N rate range calculated, using this approach (Millar et al. 2010). Use of MRTN to reduce N rate use is not required, however – other methods may be used to reduce rates to better match crop needs, including the use of improved fertilizer application timing, fertilizer formulations, cover-crop N capture, or any of a number of other practices known to better match N fertilizer input to crop N needs than BAU approaches (Robertson and Vitousek 2009).

Justification for Approach 2 for determining the baseline scenario

If the baseline fertilizer N rate for a specific crop cannot be established from project proponent records (Approach 1), then Approach 2 can be used. With Approach 2, baseline N fertilizer rate is calculated from crop yield data at the county level, available from United States Department of Agriculture – National Agricultural Statistics Service (USDA – NASS), and equations for determining N fertilizer rate recommendations based on yield goal estimates (e.g., found in state department of agriculture and land grant university agriculture department documents).

The use of crop yield data from USDA – NASS must be consistent with the crop rotation history of the proposed project site. For example, a project field in which corn has been grown in alternate years with soybean for the last six years (2006 – 2011; starting with corn) must use USDA – NASS data for corn yield for the relevant county from 2006, 2008 and 2010 for a project start date of 2012. This requirement reduces the uncertainty in baseline calculation, as county crop yield records for an individual year reflect the prevailing environmental and economic conditions at that time. This requirement also reduces the potential for 'gaming' as project proponents cannot select historical data that might have the effect of artificially increasing the baseline.

The rationale for why Approach 2 is conservative, and discussion on the trade-offs between false positives (the crediting of activities that are not additional) and false negatives (the exclusion of activities that are additional) in relation to Approach 2 calculations are presented below.

The use of Approach 2 will typically underestimate baseline N inputs due to two major factors: 1. the use of county level crop yield data sets that include non-commercial and small-scale farming operations that tend to have lower productivity than large scale operations; and, 2. the compulsory inclusion of N credits from organic fertilizer (manure) applications in yield goal equations as an artificial means to lower baseline N rate recommendations, and therefore baseline N_2O emissions. Overall, this underestimation will bias the award of offset credits towards a false negative outcome (the exclusion of activities that are additional).

The use of county level crop yield data

The county level crop yield data from USDA – NASS required to back-calculate baseline N fertilizer rates using Approach 2 includes data collected through the annual County Agricultural Production Survey (CAPS) and the Census of Agriculture (COA) conducted every five years.

The CAPS provides data needed to estimate production of crops at the county level for state and federal programs, and is conducted in 44 states with all counties in these states represented in the sampling. The target population is all farms and ranches in each state, with each state developing its own data collection strategy, typically a mail survey with second mailings or a telephone follow-up to ensure adequate coverage for each county. The average, annual county yield data therefore inherently covers crops to which only synthetic N fertilizer and both synthetic and organic N fertilizers have been applied.

As defined by the CAPS and COA, a farm is any place from which $1,000 or more of agricultural products are normally produced and sold during the surveyed year. Between 2002 and 2007 (latest available) the COA found that the number of farms with sales of less than $1,000 increased by 118,000, with most of the growth in US farm numbers coming from small operations. In 2007, 60% of total US agricultural sales came from farms where annual sales were less than $10,000. Small farms account for 91% of all farms in the US with a large percentage of these farms specializing in grain production.

Data linking farm size to crop yields is limited, but a specially conducted USDA ARMS survey on the cost of production of corn in 1996 found that part-time farmers and small farm operations tended to have lower production efficiency, higher corn production costs per bushel and lower than average yields (Foreman, 2001). Therefore the link between lower yields and small farm size and the continuing trend for increasing numbers of part-time farmers and small farm operations in the US provides evidence that the average county yield reported will tend to underestimate the yields obtainable from larger, more efficient operators who will most likely constitute the majority of project developers, at least in the short-term. This will result in lower county-level yields' biasing the fertilizer N estimate for the larger growers towards lower N application rates (a lower county-level yield will result in a lower predicted baseline N rate for those farmers with higher yields).

The compulsory inclusion of N credits from manure applications

The most common form of organic N applied to cropland in the US is animal manure. Most of the US cropland (~ 70%) receiving manure is used to grow corn (Ribaudo et al. 2011). Nationwide, about 14% of all N fertilized corn acres (~10% for all crops) are treated with both commercial synthetic N and manure N. Nationally, this amounts to approximately 13 million acres of corn based upon 2012 planting data (USDA – NASS). USDA ARMS data provides evidence that when used; manure is associated with over application of N. For example, with farmers who used a soil or tissue test as a means to estimate their N need, the average N application rate by those who used both synthetic and manure N was 175 lbs N per acre, compared to 136 lbs N per acre for growers who used synthetic N only. As noted earlier, this was despite a 10% lower recommendation for fields receiving both N sources compared to those receiving only a commercial synthetic N source (Ribaudo et al. 2011).

When using Approach 2, project proponents will include a nitrogen credit from organic N fertilizer (manure). The inclusion of an N credit for organic N fertilizer in some or all of the baseline years for which an estimate of the N fertilizer rate is required will, in effect, act to reduce the calculated average baseline N rate and therefore baseline N_2O emissions. Irrespective of the actual use of organic N fertilizers during the baseline period, and whether this is verifiable in part or not, this procedure will act to lower the baseline N_2O emissions of the project field when compared to a scenario when no N credit for organic N fertilizer is applied. This approach is conservative.

Seven hypothetical scenarios (some more likely than others) relating to document and data availability are presented below, along with the rationale for the required N credit associated with them:

1. No records are available to verify the timing (i.e., the year or growing season), amount, or N content of the organic N fertilizer;

2. Records are available that verify the timing, but not the amount or N content of the organic N fertilizer

3. Records are available that verify the timing, and amount, but not the N content of the organic N fertilizer

4. Records are available that verify the amount, but not the timing and N content of the organic N fertilizer

5. Records are available that verify the amount and timing, but not the N content of the organic N fertilizer.

6. Records are available that verify the N content, but not the amount or timing of the organic N fertilizer

7. Records are available that verify the amount and N content, but not the timing of the organic N fertilizer

In six of these seven cases, at least one of the three requirements is available to determine the organic N fertilizer applied during the entire baseline period. In three of these cases, two of the three requirements are available. If all three requirements regarding data were met then the project would use Approach 1 for calculation of the baseline N rate for organic fertilizer.

The rationale behind the approach matches an increased availability of records with a decreased N credit for organic N fertilizer, and therefore an increased baseline N rate, and baseline N_2O emissions. In effect the approach 'rewards' more comprehensive record keeping, as an increased baseline N rate will potentially allow for larger decreases in N rate during the project period and therefore greater financial payback through the award of offset credits. Note that all individual requirements are weighted equally.

There is therefore no incentive (financial or otherwise) to deliberately withhold documentary evidence establishing the application of organic (or indeed synthetic) N fertilizer during the baseline period. Doing so would act to artificially reduce the value of the baseline N rate (and therefore baseline N_2O emissions), thereby reducing: 1) the likelihood that an N rate reduction could take place at all; and 2) the magnitude of that reduction, without a producer's incurring a yield penalty or substantially increasing the risk of doing so.

Note that if records of the timing of organic fertilizer application (i.e., the year or growing season [but not necessarily the exact date]) are absent, but the amount and / or N content are available then it will be assumed that organic fertilizer has been applied in all relevant cropping cycles previous to the project crop in the project field during the baseline period.

Scenario crediting

The quantitative basis for applying the specific N credit for organic fertilizer (manure) is derived from the recent USDA ERS report "Nitrogen in Agricultural Systems: Implications for Conservation Policy" (Ribaudo et al. 2011). Using national Agricultural Resource Management Survey (ARMS) data, the report found that farmers who used both synthetic fertilizer and manure (all sources), applied on average 90 lbs N per acre from the manure.

So:

For scenario 1 where none of the three data requirements are available, the nitrogen credit from organic fertilizer will be:

$$90 * 1.5 = 145 \text{ lbs N per acre}$$

$$= 162 \text{ kg N ha}^{-1}$$

For scenarios where one of the three requirements is available (scenarios 2, 4, and 6), the nitrogen credit from organic fertilizer will be:

90 * 1.2	=	108 lbs N per acre
	=	121 kg N ha^{-1}

For scenarios where two of the three requirements are available (scenarios 3, 5, and 7, the nitrogen credit from organic fertilizer will be:

90 * 1.0	=	90 lbs N per acre
	=	101 kg N ha^{-1}

Using the worked example given for Approach 2 in Appendix C, where the N rate (lb N $acre^{-1}$) is calculated as:

$$N\ rate = (1.36 * YG_t) - 27 - NC \quad (E1)$$

Where:

YG_t = 156.1 bushel $acre^{-1}$

If we assume that two of the three data requirements are available from records, the N credit equals the sum of the N credit from the previous soybean crop (30 lbs N per acre) and the previous manure applications (90 lbs N per acre).

Therefore:

N rate	=	(1.36 * 156.1) - 27 - (30 + 90)
	=	65 lb N $acre^{-1}$
	=	73 kg N ha^{-1}

APPENDIX F - Default factors

The default (Tier 1) values used in the methodology for calculating direct and indirect emissions of N_2O from the baseline and project scenarios are taken from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Volume 4, Chapter 11).

The terminology of the factors used in this methodology differs from that used in the IPCC guidelines, but the factors are equivalent in value and usage.

The IPCC uncertainty ranges for each factor or fraction can be considered conservative with respect to their application to agricultural soils, as their use in IPCC Guidelines is applicable to a wider environmental coverage, i.e., managed soils, including forests and grasslands as well as agriculture.

Table F1. Default factors used to estimate direct and indirect emissions of N_2O in the methodology.

N_2O Emissions	Methodology factor	IPCC factor	Default value	Uncertainty range
Direct	EF_{BDM1}, EF_{PDM1}	EF_1	0.010	0.003 - 0.03
Indirect	EF_{BIV}, EF_{PIV}	EF_4	0.010	0.002 - 0.05
Indirect	EF_{BIL}, EF_{PIL}	EF_5	0.0075	0.0005 - .025
Direct/Indirect	$Frac_{GASF}$	$Frac_{GASF}$	0.10	0.03 - 0.3
Direct/Indirect	$Frac_{GASM}$	$Frac_{GASM}$	0.20	0.05 - 0.5
Direct/Indirect	$Frac_{LEACH}$	$Frac_{LEACH}$	0.30	0.1 - 0.8

Conversion of N_2O–N to N_2O

Conversion of N_2O–N (the mass of the nitrogen component of the nitrous oxide molecule emitted) to N_2O for reporting emission reductions in units of CO_2e is performed by multiplication of the ratio of the molecular weight of N_2O to the atomic weight of the two N atoms in the N_2O molecule:

$$N_2O = N_2O\text{–}N * 44/28$$

Global Warming Potential of N_2O

The GWP value of 310 for N_2O used in the methodology is the 100-year value proposed in the Intergovernmental Panel on Climate Change Second Assessment Report (SAR).

The value of 310 is the direct GWP for one molecule of N_2O on a mass basis for a 100 year time horizon, relative to one molecule of CO_2, which is ascribed a value of 1 by convention. This means that a molecule of contemporary N_2O released to the atmosphere will have 310 times the radiative impact of a molecule of CO_2 released at the same time. The conversion can be represented as:

$$N_2O_{GWP} = 310, \text{Mg } CO_2e \text{ (Mg } N_2O)^{-1}$$

APPENDIX G – Background research on Method 2 for estimating emissions

In the North Central Region (NCR), direct emissions of N_2O for baseline and project scenarios in corn-based, row-crop rotations can be calculated using Method 2. Method 2 uses an emissions factor determined from multi–year field studies conducted in Michigan. This emissions factor is consistent with IPCC Tier 2 methodological guidelines and in this methodology assigned the terms EF_{BDM2} and EF_{PDM2} for baseline and project emission calculations, respectively.

Full details of study sites, sampling, data analysis, results, and other information are in Hoben et al. (2011), and at http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2010.02349.x/suppinfo.

The uncertainty assessment for emissions reductions, including the derivation of the Tier 2 emissions factor are detailed below.

Overview

Previous research conducted by McSwiney and Robertson (2005), and more recently by Hoben et al. (2011) and Millar et al. (2013) show that N_2O emissions can increase exponentially with increasing N fertilizer rate, particularly at high rates that exceed the crop N uptake capacity.

These unique field studies in the North Central Region (NCR) specifically investigated long–term N_2O emission responses to a large number of N fertilizer rate treatments in row–crop agriculture. The large number of N rates and the small increments between them allow better resolution of the shape of the relationship between N rate and N_2O emissions.

The producer sites used in the development of the Tier 2 approach (Hoben et al. 2011) encompassed a wide range of soil type, texture, and grain yield that were comparable and broadly representative of commercial corn crop rotations and conditions throughout the NCR. During the study years, the sites experienced a wide range of environmental conditions throughout the growing season. In years with normal precipitation, crop yields at these sites are typical of the NCR as a whole (Smith et al. 2007). The N rates employed in Hoben et al. (2011) also are within the range commonly required for optimum corn-grain production and recommended for the US Midwest (Sawyer et al., 2006; Vitosh et al., 1995).

The non–linearity of N_2O emissions has significant consequences when comparing N_2O emissions reductions with the IPCC Tier 1 approach. An identical N fertilizer rate reduction will result in a significantly smaller reduction in N_2O emissions when the Tier 1 emission factor is used in calculations, when compared to the Tier 2 emission factor. The increasing divergence of N_2O emissions between Tier 1 and Tier 2 approaches, particularly at higher N rates, helps incentivize the reduction in N rate. Millar et al (2010) show an example of this.

Uncertainty assessment

Methodologies and procedures adopted to calculate emissions of N_2O have been refined over many years, and are conservative in nature. Here we outline assumptions, parameters and procedures that relate to uncertainty in N_2O emissions in the methodology. We focus on the derivation of the regional NCR emissions factor used in equation (6) and (15) in sections 8.1 and 8.2, respectively. More detailed information on field-sampling and laboratory analytical techniques is given in Hoben et al. (2011).

Appendix F (Table FI) provides information on uncertainty ranges for IPCC Tier 1 emissions factors for direct and indirect N_2O emissions and other factors used in the methodology. Use of these IPCC emissions factors is universally accepted as a mechanism for calculating N_2O emissions – they are science driven and used in many currently accepted AFOLU methodologies for calculating N_2O emissions. Further details on these factors, their derivation and their robustness for use in N_2O emissions calculations can also be found in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Revision Nov. 2008 - Chapter 11: N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application.

Application of N fertilizer

The methodology monitors five parameters during the project period. Four of these relate directly to the calculation of N rate applied at the project site. These are detailed along with their measurement and QA/QC procedures, in section 9.2 of the methodology.

All of these parameters are assumed to have negligible uncertainty.

Derivation of regional (NCR) emissions factor

Daily N_2O emissions

Values for daily N_2O emissions have negligible uncertainty; field and laboratory sampling and analytical techniques have been refined over many years to standardize methodologies and minimize analytical uncertainty. We used standard methods to measure daily emissions as described in Hoben et al. (2011).

Annual N_2O emissions

We determined total annual emissions by interpolating daily emissions between sampling days. This was carried out using linear interpolation – a broadly accepted mechanism in the scientific peer reviewed literature. In brief, the sum of the rate of N_2O emissions on two successive sampling days was divided by two (averaged), and this average rate was multiplied by the period (in days) between the two measurements, then added to the previous cumulative emissions total. This can be represented by:

$$C_B = C_A + [(D_A + D_B) / 2] * (B-A) \quad (G1)$$

Where:

C_B	=	Cumulative N_2O emission as of day B (g N_2O-N ha^{-1});
C_A	=	Cumulative N_2O emission as of day A (g N_2O-N ha^{-1});
D_A	=	Daily gas flux on day A (g N_2O-N ha^{-1} d^{-1});
D_B	=	Daily gas flux on day B (g N_2O-N ha^{-1} d^{-1});
B	=	Day of latest emissions measurement (day of year);
A	=	Day of previous emissions measurement (day of year).

Annual emissions (g N_2O-N ha^{-1} yr^{-1}) of N_2O for each field replicate were calculated from daily N_2O emissions (g N_2O-N ha^{-1} d^{-1}) measured in each block (4) at each N rate (6, including zero) at each site during the year for all site years (8), to give a total of 192 cumulative annual N_2O emissions data points (4 * 8 * 6). These individual cumulative annual emissions, calculated directly from daily N_2O emissions with negligible uncertainty, are also assumed to have negligible uncertainty.

The best-fit line that defines the mathematical relationship between N rate (kg N ha^{-1} yr^{-1}) and N_2O emissions (g N_2O-N ha^{-1} yr^{-1}) for all 192 data points is:

$$N_2O \text{ emissions} = 670 * \exp(0.0067 * N \text{ rate}) \quad (G2)$$

Where, N rate is the equivalent of $F_{B\,SN,t} + F_{B\,ON,t}$ for baseline N input (equation [2]) and $F_{P\,SN,t} + F_{P\,ON,t}$ for project N input (equation [11]).

The standard error (SE) associated with N_2O emissions, is:

N_2O emissions $_{(SE)}$ = 58 * exp (0.010 * N rate) (G3)

Figure G1 shows this relationship.

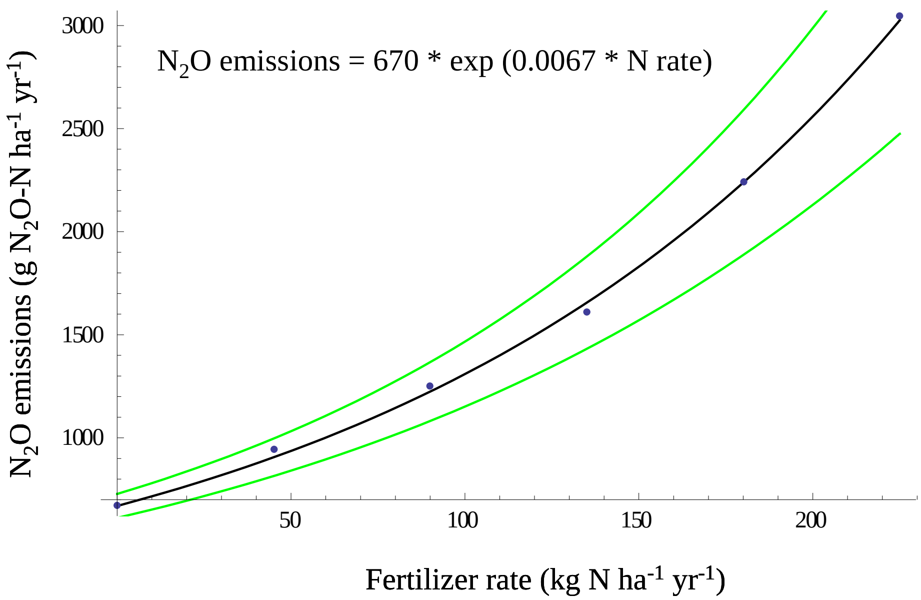

Figure G1. Relationship between N_2O emissions (g N_2O-N ha^{-1} yr^{-1}) and N fertilizer rate (kg N ha^{-1} yr^{-1}) for baseline and project N fertilizer rates (black line). Standard errors (± 58 * exp [0.010 * N rate]) are also shown (green lines). Calculated using Mathematica (v. 8, Wolfram Research Inc., 2011).

N_2O emissions reductions

Raw N_2O emissions reduction values were obtained by subtracting cumulative annual emissions of lower N application rates from cumulative annual emissions of higher N application rates (i.e., 0, 45, 90, 135, 180, and 225 kg N ha^{-1} yr^{-1}) within the same block, site, and year. This emissions difference was then divided by the difference in rate between the N rate pairs. Thus, we obtained 32 values (4 blocks * 8 site years) for the emission reductions for each of the 15 pairs (e.g., 45 → 0, 90→ 0, 90 → 45, etc.).

To best define the interpolation of the empirical data for emissions reductions - N_2O emissions $_{(RED)}$ - many types of function were tested, including linear and exponential functions with various parameter combinations. The function below (Equation [G4]) derived from equation [G2] above) was also tested.

N_2O emissions $_{(RED)}$ = 0.67 * {exp (6.7 * N_{Base}) - exp (6.7 * N_{Proj})} / (N_{Base} - N_{Proj}) (G4)

Where:

N_2O emissions $_{(RED)}$ = N_2O emissions reductions, g N_2O-N ha^{-1} yr^{-1};

N_{Base} = $F_{B\ SN,\ t}$ + $F_{B\ ON,\ t}$ baseline N input, Mg N ha^{-1} yr^{-1};

N_{Proj} = $F_{P\ SN,\ t}$ + $F_{P\ ON,\ t}$ project N input, Mg N ha^{-1} yr^{-1}.

Equation (G4) outperformed all linear functions and works as effectively as more complex exponential functions.

Emissions factors

The emissions factor for N_2O is defined as the fraction of N applied that is released as nitrogen in N_2O (N_2O-N) at a non-zero N rate minus the N_2O-N emitted at zero N rate.

The emissions factors for baseline and project calculations were obtained by dividing the reduction function (equation G4) by 1 * 10^6 (to convert g N_2O-N / Mg N rate to Mg N_2O-N / Mg N rate). We then formatted the equation to compare baseline and project N rates to zero N rate. Therefore we have:

$$EF_{Base} = 6.7 * 10^{-4} * (\exp[6.7 * N_{Base}] - 1) / N_{Base} \quad (G5)$$

$$EF_{Proj} = 6.7 * 10^{-4} * (\exp[6.7 * N_{Proj}] - 1) / N_{Proj} \quad (G6)$$

Where:

EF_{Base} and EF_{Proj} are equivalent to EF_{BDM2} (Equation [6]) and EF_{PDM2} (equation [15]), respectively.

Emissions reduction uncertainty

The standard error equation (G3) is useful for describing uncertainty in annual emissions but cannot be used to accurately describe uncertainty for emissions reductions in the range of smaller N rate reductions (10 – 20 kg N ha^{-1} yr^{-1}).

Instead the 32 values (4 blocks * 8 site years) for the emission reductions for each of the 15 pairs (e.g., 45 → 0, 90→ 0, 90 → 45, etc.) were used to obtain variability of the mean using the Bootstrap method (Monte Carlo algorithm with case re-sampling, Mathematica – v. 8, Wolfram Research Inc., 2011).

For each pair of N fertilizer rate reductions a random sample of 32 baseline values was taken and replaced with a random sample of 32 project values to compute a mean reduction. This process was repeated 100,000 times and the overall standard error of the means were calculated.

The standard error of the means was then multiplied by 1.645 (the critical value of normal one-sided test at 95% confidence) and divided by the average emissions reduction to give the fraction of the average that is within the 95% confidence interval. These values plotted against N rate are represented by Equation (G7), which calculates the uncertainty associated with a reduction in N rate during the project period:

$$N_2O\ Emissions_{(RED\ UNC)} \quad [1 - \{0.63 * \exp(-40 * [N_{Proj}]^2)\}] * 100 \quad (G7)$$

Where:

N_2O Emissions $_{(RED\ UNC)}$		Uncertainty in N_2O emissions reductions associated with a reduction in N rate, %;
N_{Proj}	=	$F_{P\ SN,\ t} + F_{P\ ON,\ t}$ project N input, Mg N ha^{-1} yr^{-1}.

Equation (G7) is identical to equation 19 in section 8.4 of this methodology.

Within the empirical N rate data range (0 – 225 kg N ha^{-1} yr^{-1}) the highest uncertainty was ~90%. There is no evidence to suggest that higher N rates would generate uncertainties above 100%, therefore the Gaussian function was used to constrain uncertainty below 100%.

Project proponents will use equation (G7) to calculate emissions reductions uncertainties (%) for a project. Confidence deductions as a result of uncertainty will be applied using the conservative factors specified in the CDM Meth Panel guidance on addressing uncertainty in its Thirty Second Meeting Report, Appendix 14 (Table G1).

Table G1: Conservativeness factors for emissions reductions based upon uncertainty at 95% confidence level.

Uncertainty range at 95% confidence level of project emissions reductions§	**Conservativeness factor**	**Uncertainty deduction***
< ± 15%	1.000	0.000
> ± 15% ≤ ± 30%	0.943	0.057
> ± 30% ≤ ± 50%	0.893	0.107
> ± 50% ≤ ± 100%	0.836	0.164

§ Uncertainty in emissions reductions does not exceed 100%. * Where uncertainty in emissions reductions is < ± 15%, no deductions will be applied. Uncertainty deduction (UNC) = (1 – Conservativeness factor).

APPENDIX H – Calculations to determine sufficiency of project N rate using N rate calculator

Below is a worked example demonstrating how the proposed N rate for a project area can be shown to be consistent with data output from an approved N rate calculator. In this example the Iowa State University corn nitrogen calculator is used (http://extension.agron.iastate.edu/soilfertility/nrate.aspx).

The Iowa State University corn nitrogen calculator calculates the profitable N rate range around the maximum return to nitrogen (MRTN) rate in continuous corn and corn-soybean rotations in seven states in the U.S. Midwest.

To show consistency, the total amount of N to be applied to the project area during a corn cropping season must be equal to or greater than 80% of the lowest estimate of the N rate range recommended for corn in the region in which it is grown.

Worked example for a proposed project in Michigan in a corn-soybean rotation

Calculating baseline fertilizer N rate for corn in a corn–soybean rotation
In the project area where corn will be grown, the farmer has previously applied N fertilizer to corn in rotation with soybean during 3 of the previous 6 years (Table H1). In this example the source of the N fertilizer is synthetic N but it could also have been organic N such as manure – the calculation would be the same.

Table H1. N fertilizer rates applied to corn in a corn–soybean rotation (2006 – 2011)

Year	Crop	Fertilizer N rate (kg N ha^{-1} yr^{-1})
2006	Corn	140
2007	Soybean	0
2008	Corn	160
2009	Soybean	0
2010	Corn	150
2011	Soybean	0
2006–2011 Average	Corn	= (140+160+150)/3 = 150

The baseline fertilizer N rate for the corn crop in the proposed project to be planted in 2012 is calculated from the average of the total N fertilizer applied to the previous 3 corn crops during the previous 6 years, i.e. 150 kg N ha^{-1} yr^{-1}. Reductions from this baseline rate are considered additional and are credited.

The proposed project N rate for the corn crop to be planted in 2012 is 125 kg N ha^{-1}.

Demonstrating consistency with Iowa State University corn nitrogen calculator

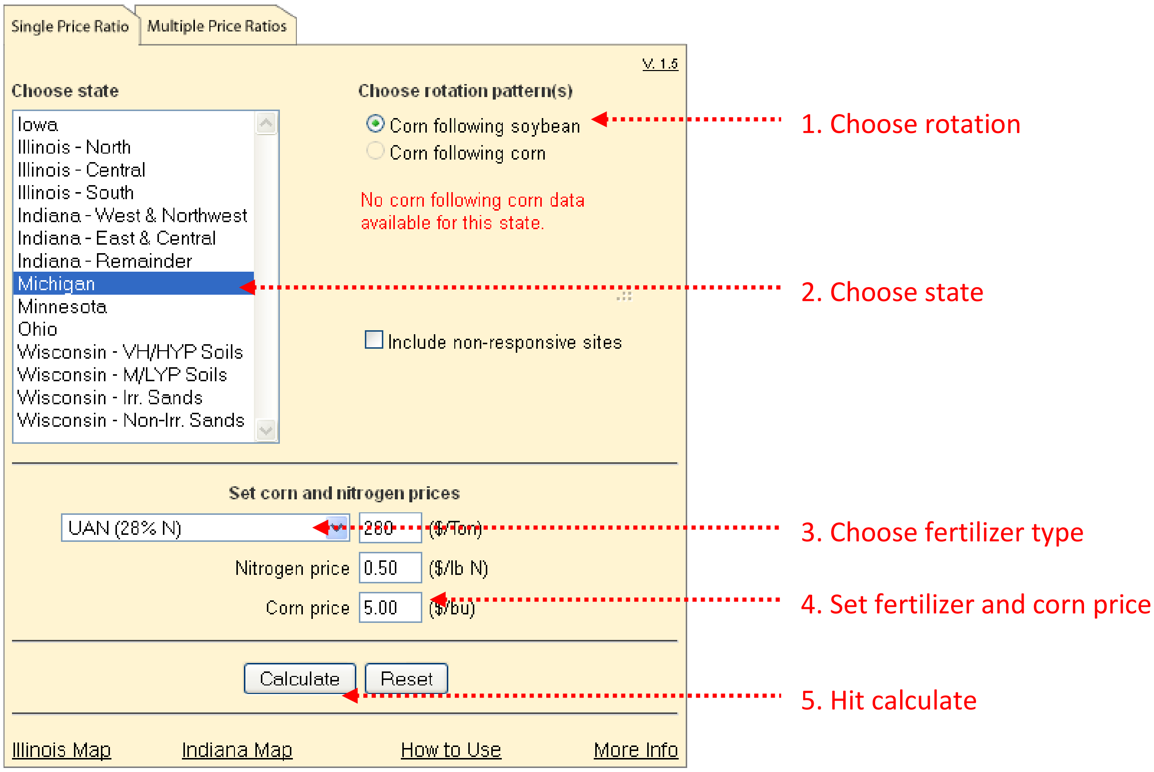

Figure H1. Screen shot of Iowa State University corn nitrogen calculator, showing selection menus for 1) rotation, 2) state, 3) N fertilizer type, and 4) N fertilizer and corn price.

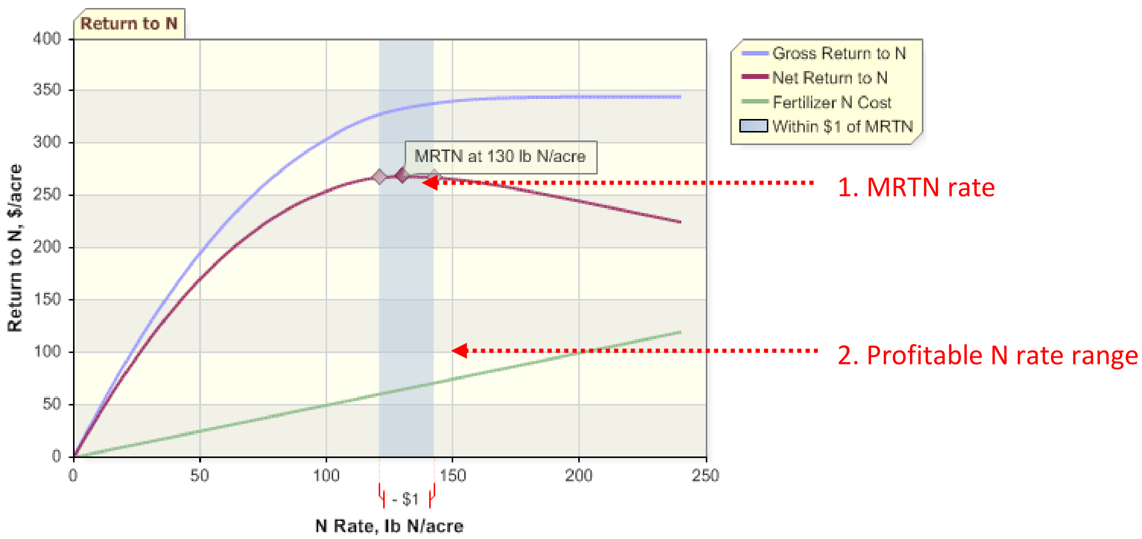

Figure H2. Screen shot of Iowa State University corn nitrogen calculator, showing 1) maximum return to nitrogen (MRTN) rate, and 2) profitable N rate range (blue shaded column; within $1.00 per acre of MRTN) for the project area specifications.

For the project conditions, the MRTN rate is 130 lb N acre^{-1}, with a profitable N rate range of 121 to 142 lb N acre^{-1}. For conversion from imperial units (lb N acre^{-1}) to metric (kg N ha^{-1}), the imperial value is multiplied by 1.12 (a conversion factor accepted by the American Society of Agronomy at http://www.soils.org/files/publications/journals-sitable-coversions.pdf). Therefore, in metric units the MRTN rate is 146 kg N ha^{-1}, with a profitable N rate range of 136 to 159 kg N ha^{-1}. 80% of the lowest recommended N rate is 109 kg N ha^{-1} (0.8 x 136 = 109); the proposed project N rate of 125 kg N ha^{-1} is higher than this so is consistent and eligible for use in the project area.

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DOCUMENT HISTORY

Version	Date	Comment
v1.0	5 Mar 2013	Initial version released
v1.1	30 September 2013	Errors in equations 6 and 15 and equations G5 and G6 in Appendix G equations have been corrected.

Approved VCS Methodology
VM0023

Version 1.0, 9 September 2013
Sectoral Scope 5

Reduction of GHG Emissions in Propylene Oxide Production

Methodology developed by:

South Pole Carbon Asset Management Ltd.

Table of Contents

1 SOURCES

CDM *Tool for the demonstration and assessment of additionality*

CDM *Tool to calculate baseline, project and/or leakage emissions from electricity consumption*

CDM *Tool to determine the baseline efficiency of thermal or electric energy generation systems*

CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology quantifies the GHG emission reductions resulting from the use of Hydrogen Peroxide-based Propylene Oxide (HPPO) technology, which requires less GHG-intensive reagents and requires less energy for the production of Propylene Oxide (PO) compared to other production processes.

This methodology is based on the project being developed by MTP HPPO Manufacturing Co., Ltd, a joint venture between The Siam Cement Public Co., Ltd and The Dow Chemical Company. The project involves the construction of a PO production facility that will use HPPO technology instead of the conventional Chlorohydrin (CHPO)-chlor-alkali process.

PO is an organic compound with the molecular formula CH_3CHCH_2O. This colorless volatile liquid is produced on a large scale industrially. PO is a very common chemical building block used to produce commercial and industrial products including polyether polyols, propylene glycols and propylene glycol ethers. It is among the most diffused chemical intermediates in the world and its production continues to grow.

There are many processes (or chemical routes) that are used in the industry to synthesize PO. Industrial production of PO generally starts from propylene. Two general approaches are then employed, one involving hydrochlorination and the other involving oxidation. The hydrochlorination route, which uses chlorohydrin technology, is the traditional route and proceeds via the conversion of propylene to PO. There are also other possible routes to produce PO based on co-oxidation of the organic chemicals isobutene or ethylbenzene. However, these alternative routes are characterized by substantial production of co-products, such as *t*-butyl alcohol or styrene, respectively.

This methodology is not designed to address all types of PO production processes. Its application is limited to projects wherein PO is the only output expected (ie, no co-products are produced in the process). The methodology is applicable only to greenfield projects where the project activity is the implementation of the HPPO process and where implementation of the CHPO-chlor-alkali process is identified as the baseline scenario.

In this methodology, the GHG emissions produced by different chemical manufacturing processes using different reagents are being compared. Comparing two processes that do not use the same input materials not only entails a comparison of emissions that occur in the PO production facility but requires a broader approach, similar to a life cycle assessment where emissions due to reagent production are also taken into account. The methodology therefore distinguishes (for both baseline and project processes) between two classes of emissions:

- **Upstream emissions**: includes emission sources linked to the reagents being used in the PO production process.

- **Process emissions**: includes emission sources located within the PO production facility and include emissions associated with the synthesis of the PO as well as emissions associated with by-product and waste treatment.

Since the product is the same in both the baseline and project scenarios, downstream emissions would be the same and have therefore not been considered. The emissions associated with the construction of the PO production facility are also ignored as they are not expected to be significantly different in the baseline and project scenarios. As such, this methodology considers only upstream and process emissions.

The methodology quantifies emission reductions from a more energy efficient PO production process, which has significant capital and recurring costs estimated to be over US$1,500 per tonne of PO. As a result, the methodology does not create any incentives for producing PO for the sole purpose of earning carbon credits.

The key elements of this methodology are as follows:

- **Applicability conditions:** The methodology is applicable to greenfield projects where PO is the only expected output (ie, no co-products are produced in the production process). Nevertheless, in practice, due to selectivity of the catalysts, by-products may be produced in the production process. Such by-products must not be more than 10% (in mass terms) relative to the PO output. As a consequence, the methodology is applicable only to projects where the project activity is the implementation of the HPPO process and where implementation of the CHPO-chlor-alkali process is identified as the baseline scenario.

- **Project boundary:** The project boundary includes upstream emissions from reagent production and process emissions from the synthesis of PO and from by-product and waste treatment.

- **Baseline scenario:** The baseline scenario is determined through an evaluation of the likely alternatives, accounting for local/national regulations and laws, investment analyses and/or barriers. A list of pre-defined alternatives is included in this methodology; this list is non-exhaustive and additional alternatives may be proposed by project proponents.

- **Additionality:** Additionality must be demonstrated through the application of the latest version of the CDM *Tool for the demonstration and assessment of additionality*.

- **Baseline emissions:** Baseline emissions include upstream emissions and process emissions.

  Upstream emissions include emissions associated with the baseline reagents. For simplification, and as a conservative approach, the following upstream emission sources are excluded:

  - Emissions associated with raw materials that are in an unprocessed or minimally processed state;
  - Raw material extraction;
  - Catalysts;
  - Transportation; and
  - Reagents common in quantity and quality to the project activity.

  Process emissions include emissions resulting from energy usage (eg, heat and electricity) for transforming the reagents into the final product and also for waste and by-product treatment. For simplification, and as a conservative approach, emissions linked to waste and by-products may be neglected if credible data to estimate same is not available. Process emissions due to energy usage are calculated based upon the specific energy required per tonne of PO production, and the associated emission factor for the thermal/electrical energy generation, respectively.

- **Project emissions:** Project emissions include upstream emissions and process emissions.

  Upstream emissions include emissions associated with the project reagents. For simplification, and as a conservative approach, the same upstream emission sources as under the baseline scenario are excluded for the project scenario.

  Process emissions include emissions resulting from energy usage (eg, heat and electricity) for transforming the reagents into the final product and also for waste and by-product treatment.

  Emissions linked to energy, electricity and steam are calculated using the latest versions of the CDM *Tool to calculate baseline, project and/or leakage emissions from electricity consumption* and the CDM *Tool to calculate project or leakage CO2 emissions from fossil fuel combustion,* respectively.

  Apart from waste contained in wastewater streams, most of the waste generated on-site is usually incinerated. Emissions from the incineration of such waste streams must be estimated by considering the carbon content of the waste stream (based on their chemical formula). By-products that can be recovered from the process and used for other processes within the project boundary are considered as carbon neutral since all emissions linked to their treatment are included in the project boundary and are already taken into account. Incineration of waste streams often involves co-firing of fossil fuels. Emissions from fossil fuel consumption are also considered.

- **Leakage:** Leakage is not considered an issue under this methodology.
- **Emission reductions:** The emission reductions are calculated as baseline emissions minus project emissions.
- **Monitoring:** As all parameters are related to the production process, monitoring must follow standard industrial practice.

Additionality	Project Method
Crediting Baseline	Project Method

3 DEFINITIONS

For the purposes of this methodology, the following definitions apply:

By-Products: Incidental (ie, undesired) products deriving from chemical processes. Water is not considered to be a by-product.

Chlorohydrin Process (CHPO Process): Process whereby propylene is combined with hypochlorous acid to form a chlorohydrin intermediate, which is subsequently dechlorohydronated to PO. This process leads to the formation of salts.

CHPO-Chlor-Alkali Process: A specific CHPO process where caustic soda facilitates a dechlorohydronation reaction, leading to large quantities of NaCl brine.

CHPO-Lime Process: A specific CHPO process where lime is used as a chlorine absorber. Quick-lime (CaO) is mixed with water to form calcium hydroxide which is mixed with a chlorohydrin solution. This process leads to large quantities of effluent with $CaCl_2$ loads.

Co-Oxidation: PO production process that co-produces styrene (POSM) and t-butyl (POTBA).

Co-Products: Products deriving from the chemical process which is not the primary product. Water is not considered to be a co-product.

Cumene Hydroperoxide Process (CHP Process): Process where CHP is used for the epoxidation of propylene[1]. This route produces DMBA as a co-product which may be further recycled to cumene.

Hydrogen Peroxide-Based PO Process (HPPO Process): Process consisting of the production of PO from propylene and hydrogen peroxide[2].

Oxidation: PO production process that does not lead to co-products.

Propylene Oxide Styrene Monomer Process (POSM Process): Hydroperoxidation production route to PO that co-produces styrene monomer. This process involves the co-oxidation of ethylbenzene and styrene, and produces PO and styrene.

Propylene Oxide Tertiary Butyl Alcohol Process (POTBA Process): Hydroperoxidation production route to PO that co-produces t-butyl. This process involves the co-oxidation of isobutene and styrene, and produces PO and t-butyl.

Propylene Oxide (PO): An organic compound with the molecular formula CH_3CHCH_2O. This colourless volatile liquid is produced on a large scale industrially, its major application being its use in the production of polyether polyols, which are used for making polyurethane plastics.

Waste: Material generated by the production process which is not sold or re-used in other processes on-site. Waste streams may be incinerated on-site, treated within the project boundary (eg, wastewater) or disposed of (eg, at solid disposal site).

4 APPLICABILITY CONDITIONS

This methodology is applicable under the following conditions:

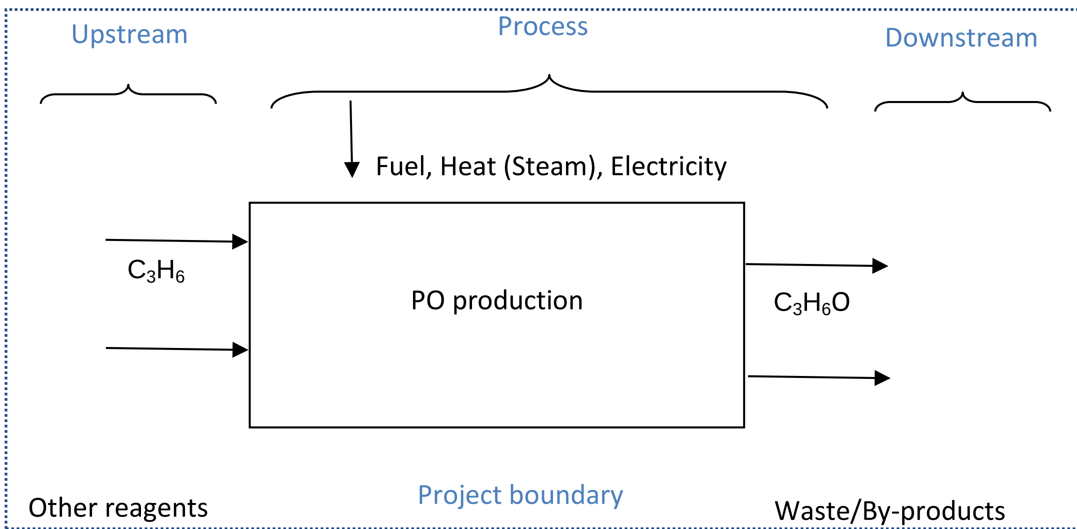
- The methodology is limited to greenfield projects (ie, new PO production facilities) wherein PO is the only output.
- The PO production process must not produce any co-products. There may be by-products produced in the PO production process, due to the selectivity of catalysts.
- The PO production process must not create more than 10% (in mass terms) by-product, relative to PO output.
- The methodology is applicable only to projects where the project activity is the implementation of the HPPO process and where implementation of the CHPO-chlor-alkali process is identified as the baseline scenario.

[1] Patented by Sumitomo (World patent 01/05778 A1).
[2] There are two patents linked to this process. One is owned by DOW (US patent 7,138,534), and the other by Degussa (6,878,836).

- The project may be located in any geographic region of the world.
- The applicability conditions of the tools referenced in this methodology also apply.

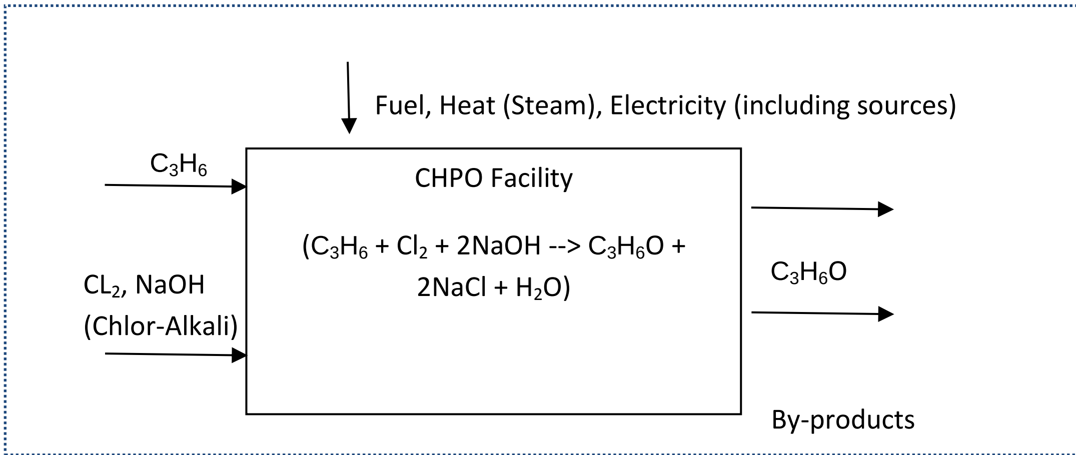
5 PROJECT BOUNDARY

The spatial extent of the project boundary encompasses (1) the upstream emissions from reagent production and (2) the emissions from the PO production facility (ie, the cumulative emissions beginning from reagents admission and synthesis of PO through to the treatment of by-products and waste from the production process).

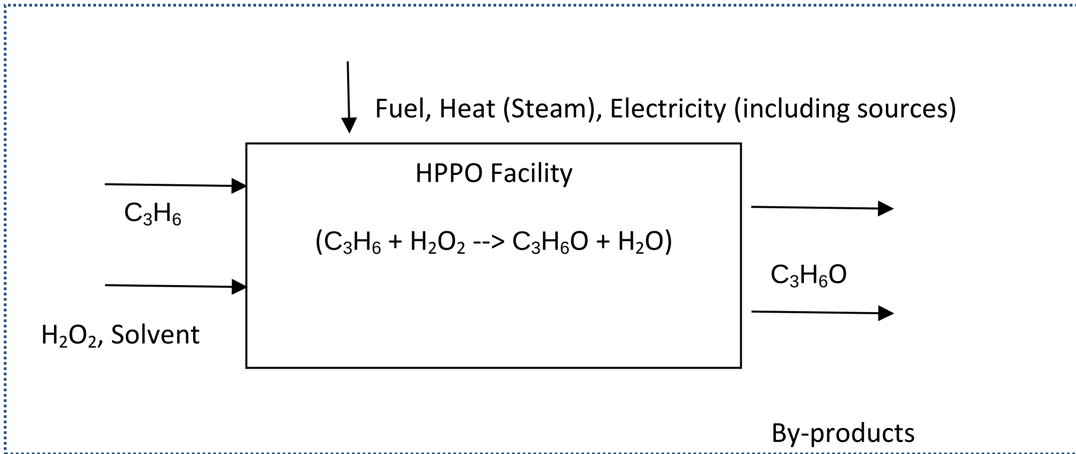


The project boundary also encompasses the project's electricity system(s) and the heat/steam generation system that the PO production facility is connected to. The spatial extent of the project electricity system consists of the power plants that are physically connected through transmission and distribution lines to the project activity and that can be dispatched without significant transmission constraints. The spatial extent for the heat (steam) system is similar, including the heat/steam generating systems that are physically connected to the project activity and that can be displaced without significant constraints.

For the CHPO-chlor-alkali process (baseline scenario), the spatial extent of the project boundary is defined as follows:



For the HPPO process (project activity), the spatial extent of the project boundary is defined as follows:



The greenhouse gases included in, or excluded from, the project boundary are shown in the table below:

Source		Gas	Included?	Justification/Explanation
Baseline	Emissions associated with the production of baseline reagents	CO_2	Yes	The emissions associated with Cl_2 and NaOH (chlor-alkali) production are accounted for as these are generally not found naturally and are produced in an industrial facility. The emissions associated with C_3H_6 have, however, not been accounted for as its usage would be essentially the same as in the project activity.
		CH_4	No	Excluded for simplification, this is conservative.
		N_2O	No	Excluded for simplification, this is conservative.
	Emissions associated with steam and electricity requirements of the production process	CO_2	Yes	Emissions could arise from the combustion of fossil fuels for providing steam and/or electricity to the PO production facility.
		CH_4	No	Excluded for simplification, this is conservative.
		N_2O	No	Excluded for simplification, this is conservative.
	Emissions associated with treatment of waste produced by the production process	CO_2	Yes	Emissions could arise from the incineration of waste.
		CH_4	No	Excluded for simplification, this is conservative.
		N_2O	No	Excluded for simplification, this is conservative.

Source		Gas	Included?	Justification/Explanation
Project	Emissions associated with the production of project reagents	CO_2	Yes	The emissions associated with H_2O_2 production and methanol as a solvent (make-up) have been accounted for as these reagents are generally not found naturally and are produced in an industrial facility. The emissions associated with C_3H_6 have, however, not been accounted for as its usage would be essentially the same as in the baseline activity.
		CH_4	No	Excluded for simplification, this is conservative.
		N_2O	No	Excluded for simplification, this is conservative.
	Emissions associated with steam and electricity requirements of the production process	CO_2	Yes	Emissions could arise from the combustion of fossil fuels for providing steam and/or electricity to the PO production facility
		CH_4	No	Excluded for simplification, this is conservative.
		N_2O	No	Excluded for simplification, this is conservative.
	Emissions associated with treatment of waste produced by the production process	CO_2	Yes	Emissions could arise from the incineration of waste (eg, low boils, waste gas, etc.).
		CH_4	No	Excluded for simplification, this is conservative.
		N_2O	No	Excluded for simplification, this is conservative.

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

Project proponents must apply the following steps to identify the baseline scenario:

Step 1: Identification of plausible alternative scenarios

This step serves to identify all alternative scenarios to the project activity which could qualify as the baseline scenario. Alternatives must be able to deliver outputs or services[3] that are equivalent to what has been implemented previously, or is currently being implemented in the relevant country/region. Given that the only output intended from production is PO (ie, no co-products), identified alternatives must therefore consist of all commercially available PO technologies. The list of alternatives must therefore consist of at least (but not limited to):

P1: The project activity without carbon revenues;

P2: A PO production facility with comparable capacity using a CHPO process (CHPO-lime or CHPO-chlor-alkali processes);

P3: A PO production facility with comparable capacity using any other commercially available technology.

Step 2: Consistency with mandatory applicable laws and regulations

This step serves to eliminate alternatives that are not in compliance with all applicable mandatory legal and regulatory requirements.

Step 3: Barrier analysis

This step serves to identify barriers and to assess which alternative scenarios are prevented by these barriers. Scenarios that face prohibitive barriers must be eliminated by applying Step 3 of the latest version of the CDM *Tool for demonstration and assessment of additionality*.

If only one alternative remains, this must be considered the baseline scenario. If more than one alternative remains, proceed to Step 4.

Step 4: Economic analysis

This step serves to compare the economic or financial attractiveness of all alternatives that are remaining and identify the scenario that is the most economically and/or financially attractive. The economic analysis must be completed by applying Step 2 of the latest approved version of the CDM *Tool for the demonstration and assessment of additionality*.

[3] The processes wherein co-products are produced (eg, CHP, POSM and POTBA processes) are not considered as likely alternatives.

This methodology is only applicable if implementation of the CHPO-chlor-alkali process is identified as the baseline scenario.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

The additionality of the project activity must be demonstrated and assessed using the latest version of the CDM *Tool for the demonstration and assessment of additionality*. While demonstrating the additionality of the project activity, the project proponent must consider the different baseline alternatives described in the section above.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

Baseline emissions are calculated as follows:

$$BE_y = BE_{Upstream,y} + BE_{Process,y} \tag{1}$$

Where:

BE_y	Baseline emission in year y (tCO_2)
$BE_{Upstream,y}$	Emissions associated with the baseline reagents required for the production of PO in year y (tCO_2)
$BE_{Process,y}$	Emissions due to energy usage (heat and electricity) for transforming the baseline reagents into the final product (PO) and also for waste and by-product treatment in year y (tCO_2)

Upstream emissions (**$BE_{Upstream,y}$**):

The upstream emissions are based on the various reagents used in the process. The reagents used in the baseline (CHPO-chlor-alkali process) are C_3H_6, Cl_2 and NaOH. The emissions associated with C_3H_6, however, are not accounted for as usage would be essentially the same as in the project activity. The emissions associated with Cl_2 and NaOH (chlor-alkali) production have been included as these are generally not found naturally and are be produced in an industrial facility.

The emissions associated with chlor-alkali production are calculated as follows:

$$BE_{Upstream,y} = be_{Chlor-Alkali,y} \times PO_y \tag{2}$$

Where:

$be_{Chlor\text{-}Alkali,\,y}$	Quantity of CO_2 emitted from chlor-alkali production per unit of PO in year y (tonnes)
PO_y	Quantity of PO produced in year y (tonnes)

The chlor-alkali production process involves the electrolysis of aqueous sodium chloride (brine) in a membrane cell. The CO_2 emissions associated with chlor-alkali production are calculated as follows[4]:

$$be_{Chlor-Alkali,y} = \left(\frac{71}{58}\right) \times ec_{Chlor-Alkali,y} \times EF_{EL,y} \qquad \textbf{(3)}$$

Where:

$ec_{Chlor\text{-}Alkali,\,y}$	Energy consumption per tonne of Cl_2 production in year y (MWh/tCl_2)
$EF_{EL,y}$	Emission factor for electricity generation in year y (tCO_2/MWh)
71/58	Ratio between the molecular weights of Cl_2 and C_3H_6O (mass units/mass units)

Process emissions (**$BE_{Process,y}$**):

The process emissions arise due to energy usage (eg, heat and electricity) for transforming the reagents into the final product and also from waste treatment.

The emissions associated with energy usage are calculated as follows:

$$BE_{Process,y} = BE_{Heat,y} + BE_{Elec,y} + BE_{Waste,y} \qquad \textbf{(4)}$$

Where:

$BE_{Heat,y}$	Emissions due to thermal energy (heat/steam) for transforming the baseline reagents into the final product (PO) and also for waste treatment in year y (tCO_2)
$BE_{Elec,y}$	Emissions due to electrical energy for transforming the baseline reagents into the final product (PO) and also for waste treatment in year y (tCO_2)
$BE_{Waste,y}$	Emissions due to treatment of waste in year y (tCO_2)

[4] The equation has been presented in terms of chlorine and PO, and so the energy consumption is also linked to chlorine.

The CO_2 emissions from thermal energy (heat/steam) are calculated as follows:

$$BE_{Heat,y} = SSC_{CHPO} \times PO_y \times EF_{Steam,y} \quad (5)$$

Where:

SSC_{CHPO}	Specific thermal energy consumption ratio in PO production through the CHPO-chlor-alkali process (TJ/tonne of PO)
$EF_{Steam,y}$	Emission factor for thermal energy generation in year y (tCO_2/TJ)

The emission factor for thermal energy generation is calculated as follows:

$$EF_{Steam,y} = EF_{CO2,i,y} / \eta_{Boiler,y} \quad (6)$$

Where:

$EF_{CO2,\,I,\,y}$	Weighted average CO_2 emission factor of fuel type i in year y (tCO_2/TJ)
$\eta_{Boiler,y}$	Efficiency of the steam generating system in year y

The CO_2 emissions from electrical energy are calculated as follows:

$$BE_{Elec,y} = SEC_{CHPO} \times PO_y \times EF_{El,y} \quad (7)$$

Where:

SEC_{CHPO}	Specific electrical energy consumption ratio in PO production through the CHPO-chlor-alkali process (MWh/tonne of PO)
$EF_{El,y}$	Emission factor for electricity generation in year y (tCO_2/MWh)

For the specific thermal energy consumption ratio in PO production through the CHPO-chlor-alkali process, data must be derived from an independent third party report from a recognized, credible source which must be reviewed by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency.

The CO_2 emissions from waste treatment are calculated as follows:

$$BE_{Waste,y} = \left(\frac{44}{12}\right) \times \left(CA_{Waste,Baseline}\right) + FC_{i,Baseline} \times COEF_i \quad \textbf{(8)}$$

Where:

$CA_{Waste, Baseline}$	Carbon amount in the waste stream derived from the carbon amount in the propylene feed, PO and by-products in the baseline (tonnes)
44/12	Ratio between the molecular weights of CO_2 and carbon (mass units/mass units)
$FC_{i,Baseline}$	Quantity of fuel type i combusted in the incinerator in the baseline (mass or volume unit/year)
$COEF_i$	CO_2 emission coefficient of fuel type i (tCO_2/mass or volume unit)

The carbon amount in the waste stream derived from the carbon amount in the propylene feed, PO and by-products in the baseline must be determined by applying equations 17 and 18.

The CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion* must be used to calculate the CO_2 emission coefficient.

The carbon amount in the waste stream and fuel combusted in the incinerator must be presented in terms of PO output.

For simplification, and as a conservative approach, the emissions linked to waste and by-products may be neglected if data from an independent third party report from a recognized, credible source (reviewed by an appropriately qualified, independent organization or appropriate peer review group) or published by a government agency, to estimate same is not available.

8.2 Project Emissions

Project emissions are calculated as follows:

$$PE_y = PE_{Upstream,y} + PE_{Process,y} \quad \textbf{(9)}$$

Where:

PE_y	Project emissions in year y (tCO_2)
$PE_{Upstream,y}$	Emissions associated with the project reagents for the production of PO in year y (tCO_2)
$PE_{Process,y}$	Emissions due to energy usage (heat and electricity) for transforming the

project reagents into the final product (PO) and also for waste treatment in year y (tCO_2)

Upstream emissions ($PE_{Upstream,y}$ ***):***

The upstream emissions are based on the various reagents used in the PO production process. The reagents used in the project scenario (HPPO process) are C_3H_6 and H_2O_2. However, the emissions associated with C_3H_6 are not accounted for as its usage would be essentially the same as in the baseline activity. The emissions associated with H_2O_2 production have been included as this compound is generally not found naturally and is produced in an industrial facility. Further, since the reaction is carried out in solvents[5], the emissions associated with the make-up solvent (in this case methanol) are considered as well.

The upstream emissions are calculated as follows:

$$PE_{Upstream,y} = PE_{Upstream,H2O2,y} + PE_{Upstream,Solvent,y} \quad \textbf{(10)}$$

The emissions associated with H_2O_2 production are calculated as follows:

$$PE_{Upstream,H2O2,y} = \left(\frac{34}{58}\right) \times pe_{HP} \times PO_y \quad \textbf{(11)}$$

Where:

pe_{HP}	Quantity of CO_2 that would be emitted per tonne of H_2O_2 (tCO_2/tH_2O_2)[6]
PO_y	Quantity of PO produced in year y (tonnes)
34/58	Ratio between the molecular weights of H_2O_2 and C_3H_6O (mass units/mass units)

The emissions associated with make-up methanol are calculated as follows:

$$PE_{Upstream,Solvent,y} = pe_{Sol} \times sol_y \times PO_y \quad \textbf{(12)}$$

Where:

pe_{Sol}	Quantity of CO_2 that is emitted per tonne of solvent (tCO_2/tonne of solvent)

[5] Typically solvents of polar nature are used, such as alcohols, ketones, ethers, etc.

sol_y	Quantity of solvent required per tonne of PO in year y (tonnes)
PO_y	Quantity of PO produced in year y (tonnes)

Note that sol_y, as found in equation 12 above, is used only for ex-ante estimations, and its value must be estimated based upon the design details of the project. For ex-post calculations, "sol_y x PO_y" is represented by Sol_y in equation 12 above, the value of which is monitored in accordance with the procedures described in Section 9.2.

Process emissions (**$PE_{Process,y}$**):

The process emissions arise from the energy usage (eg, heat and electricity) required for transforming the reagents into the final product, and for by-product and waste treatment.

The process emissions are calculated as follows:

$$PE_{Process,y} = PE_{Heat,y} + PE_{Elec,y} + PE_{Waste,y} \quad \textbf{(13)}$$

Where:

$PE_{Heat,y}$	Emissions due to thermal energy (heat/steam) for transforming the project reagents into the final product in year y (tCO_2)
$PE_{Elec,y}$	Emissions due to electrical energy for transforming the project reagents into the final product in year y (tCO_2)
$PE_{Waste,y}$	Emissions due to treatment of waste products in year y (tCO_2)

The CO_2 emissions from thermal energy (heat/steam) are calculated as follows:

$$PE_{Heat,y} = SSC_{HPPO,y} \times PO_y \times EF_{Steam,y} \quad \textbf{(14)}$$

Where:

$SSC_{HPPO,\, y}$	Specific thermal energy consumption ratio in PO production through the HPPO process in year y (TJ/tonne of PO)
$EF_{Steam,y}$	Emission factor for thermal energy generation in year y (tCO_2/TJ)

Note that SSC_{HPPO}, as found in equation 14 above, is used only for ex-ante estimations, and its value must be estimated based upon the design details of the project. For ex-post calculations, "$SSC_{HPPO,y}$ x PO_y" is represented by SC_{HPPO} in equation 14 above, the value of which is monitored in accordance with the procedures described in Section 9.2.

The emission factor for thermal energy generation is the same as calculated for the baseline emissions.

The CO_2 emissions from electrical energy are calculated as follows:

$$PE_{El,y} = SEC_{HPPO,y} \times PO_y \times EF_{El,y} \quad \textbf{(15)}$$

Where:

$SEC_{HPPO,y}$	Specific electrical energy consumption ratio in PO production through the HPPO process in year y (MWh/tonne of PO)
$EF_{El,y}$	Emission factor for electricity generation in year y (tCO_2/MWh)

Note that SEC_{HPPO}, as found in equation 15 above, is used only for ex-ante estimations, and its value must be estimated based upon the design details of the project. For ex-post calculations, "SEC_{HPPO} x PO_y" is represented by EC_{HPPO} in equation 15 above, the value of which is monitored in accordance with the procedures described in Section 9.2.

The emission factor for electricity generation is the same as calculated for the baseline emissions.

The CO_2 emissions from waste treatment are calculated as follows:

$$PE_{Waste,y} = \left(\frac{44}{12}\right) \times \left(CA_{Waste,y}\right) + FC_{i,y} \times COEF_{i,y} \quad \textbf{(16)}$$

Where:

$CA_{Waste,y}$	Carbon amount in the waste stream derived from the carbon amount in the propylene feed, solvent, PO and by-products in year y (tonnes)
44/12	Ratio between the molecular weights of CO_2 and carbon (mass units/mass units)
$FC_{i,y}$	Quantity of fuel type i combusted in the incinerator in year y (mass or volume unit/year)
$COEF_{i,y}$	CO_2 emission coefficient of fuel type i in year y (tCO_2/mass or volume unit)

The CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion* must be used to calculate the CO_2 emission coefficient.

The carbon amount in the waste stream must be calculated as follows:

$$CA_{Waste,y} = CA_{Propylene,y} + CA_{Solvent,y} - \left(CA_{PO,y} + CA_{Byproducts,y}\right) \quad \textbf{(17)}$$

Where:

$CA_{Propylene,\ y}$	Carbon amount in the propylene feed in year y (tonnes)
$CA_{Solvent,\ y}$	Carbon amount in the solvent used in year y (tonnes)
$CA_{PO,\ y}$	Carbon amount in PO produced in year y (tonnes)
$CA_{Byproducts,\ y}$	Carbon amount in the by-products in year y (tonnes)

The total amount of carbon in a particular product is a function of the respective carbon fraction and the quantity of the product, expressed as follows:

$$CA_{x,y} = ca_{x,y} \times Q_{x,y} \quad \textbf{(18)}$$

Where:

$CA_{x,\ y}$	Carbon amount in the product x in year y (tonnes)
$ca_{x,\ y}$	Carbon fraction in the product x in year y (mass units/mass units)
$Q_{x,\ y}$	Quantity of the product x in year y (tonnes)
x	propylene, solvent, PO, by-product, waste

For example, where methanol is being used as a solvent, which gives the by-product monopropyleneglycol ($C_3H_8O_2$), equation 17 is represented as follows:

$$CA_{Waste,y} = \left(\frac{36}{42}\right) \times Q_{Propylene,y} + \left(\frac{12}{32}\right) \times Sol_y - \left(\frac{36}{58}\right) \times PO_y - \left(\frac{36}{76}\right) \times Q_{Byproduct,y} \quad \textbf{(19)}$$

Where:

36/42	Carbon fraction in propylene (mass units/mass units)
12/32	Carbon fraction in methanol (mass units/mass units)
36/58	Carbon fraction in PO (mass units/mass units)
36/76	Carbon fraction in monopropyleneglycol (mass units/mass units)
$Q_{Propylene,\ y}$	Quantity of propylene used in year y (tonnes)

Sol_y	Quantity of make-up methanol used in year y (tonnes)
PO_y	Quantity of PO produced in year y (tonnes)
$Q_{Byproduct, y}$	Quantity of monopropyleneglycol produced in year y (tonnes)

8.3 Leakage

Leakage is not considered an issue under this methodology. The main emissions potentially giving rise to leakage in the context of the project are emissions arising due to construction of the PO production facility and transportation of reagents. These emissions sources are excluded as these would be higher in the baseline scenario as compared to project scenario.

8.4 Summary of GHG Emission Reduction and/or Removals

Emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y - LE_y \quad (20)$$

Where:

ER_y	Emission reductions in year *y* (tCO_2e/yr)
BE_y	Baseline emissions in year *y* (tCO_2/yr)
PE_y	Project emissions in year *y* (tCO_2e/yr)
LE_y	Leakage emissions in year y (tCO_2e/yr)

9 MONITORING

9.1 Data and Parameters Available at Validation

Data Unit / Parameter:	$ec_{Chlor\text{-}Alkali, y}$
Data unit:	MWh/tCl_2
Description:	Energy consumption per tonne of Cl_2 production in year y.
Source of data:	Independent third party report from a recognized, credible source which must be reviewed by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency.
Justification of choice of data or description	The membrane cell process is the preferred

of measurement methods and procedures applied:	process for new PO production facilities. Thus, it is assumed that production of chlor-alkali in the baseline PO production facility is through the membrane cell process[7].
Any comment:	-

Data Unit / Parameter:	SSC_{CHPO}
Data unit:	TJ/tonne of PO
Description:	Specific thermal energy consumption ratio in PO production through the CHPO-chlor-alkali process.
Source of data:	Independent third party report from a recognized, credible source which must be reviewed by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency.
Justification of choice of data or description of measurement methods and procedures applied:	Steam consumption is converted conservatively into energy terms using enthalpy values and accounting for any condensate return.
Any comment:	-

Data Unit / Parameter:	SEC_{CHPO}
Data unit:	MWh/tonne of PO
Description:	Specific electrical energy consumption ratio in PO production through the CHPO-chlor-alkali process.
Source of data:	Independent third party report from a recognized, credible source which must be reviewed by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency.
Justification of choice of data or description of measurement methods and procedures applied:	-
Any comment:	-

[7] http://www.miga.org/documents/ChlorAlkali.pdf

Data Unit / Parameter:	pe_{HP}
Data unit:	tCO_2/tH_2O_2
Description:	Quantity of CO_2 emitted per tonne of H_2O_2.
Source of data:	Independent third party report from a recognized, credible source which must be reviewed by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency.
Justification of choice of data or description of measurement methods and procedures applied:	-
Any comment:	-

Data Unit / Parameter:	pe_{Sol}
Data unit:	tCO_2/tonne of methanol solvent
Description:	Quantity of CO_2 emitted per tonne of methanol.
Source of data:	Independent third party report from a recognized, credible source which must be reviewed by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency.
Justification of choice of data or description of measurement methods and procedures applied:	-
Any comment:	-

Data Unit / Parameter:	$ca_{Waste, Baseline}$
Data unit:	tC/tonne of PO
Description:	Carbon amount in the waste stream combusted in the incinerator in the baseline per tonne of PO.
Source of data:	Independent third party report from a recognized, credible source which must be reviewed by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency.
Justification of choice of data or description of measurement methods and procedures applied:	-
Any comment:	-

Data Unit / Parameter:	$fc_{i,Baseline}$
Data unit:	Mass or volume unit in baseline per tonne of PO
Description:	Quantity of fuel type i combusted in the incinerator in the baseline per tonne of PO.
Source of data:	Independent third party report from a recognized, credible source which must be reviewed by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency.
Justification of choice of data or description of measurement methods and procedures applied:	-
Any comment:	-

9.2 Data and Parameters Monitored

Data Unit / Parameter:	PO_y
Data unit:	Tonnes
Description:	Final quantity of PO produced in year y.
Source of data:	PO production facility records.
Description of measurement methods and procedures to be applied:	Flow-rate meters, mass meters, cross-check with stock verification records.
Frequency of monitoring/recording:	Data monitoring is continuous and aggregate recording must be performed at least monthly.
QA/QC procedures to be applied:	Meters must be calibrated regularly according to manufacturer's guidelines or national standards, and cross-checked with production stock inventory.
Any comment:	-

Data Unit / Parameter:	Sol_y
Data unit:	Tonnes
Description:	Quantity of make-up methanol solvent used in year y.
Source of data:	PO production facility records.
Description of measurement methods and procedures to be applied:	Flow-rate meters, mass meters, cross-check with stock verification records.

Frequency of monitoring/recording:	Data monitoring is continuous and aggregate recording must be performed at least monthly.
QA/QC procedures to be applied:	Meters must be calibrated regularly according to manufacturer's guidelines or national standards, and cross-checked with stock inventory.
Any comment:	Note that sol_y, as found in equation 12, is used only for ex-ante estimations, and its value must be estimated based upon the design details of the project. For ex-post calculations, "sol_y x PO_y" is represented by Sol_y in equation 12, the value of which is monitored in accordance with the procedures described above.

Data Unit / Parameter:	$EF_{EL,y}$
Data unit:	tCO_2/MWh
Description:	Emission factor for electricity generation in year y.
Source of data:	Calculate the emission factor using the procedures in the latest approved version of the CDM *Tool to calculate the emission factor for an electricity system*.
Description of measurement methods and procedures to be applied:	As per the CDM *Tool to calculate the emission factor for an electricity system.*
Frequency of monitoring/recording:	As per the CDM *Tool to calculate the emission factor for an electricity system.*
QA/QC procedures to be applied:	As per the CDM *Tool to calculate the emission factor for an electricity system.*
Any comment:	-

Data Unit / Parameter:	$EF_{CO2, I, y}$
Data unit:	tCO_2/TJ
Description:	Weighted average CO_2 emission factor of fuel type i in year y.
Source of data:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
Description of measurement methods and procedures to be applied:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
Frequency of monitoring/recording:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel*

	combustion.
QA/QC procedures to be applied:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
Any comment:	-

Data Unit / Parameter:	$\eta_{Boiler,y}$
Data unit:	-
Description:	Efficiency of the steam generating system in year y.
Source of data:	As per the CDM *Tool to determine the baseline efficiency of thermal or electric energy generation systems.*
Description of measurement methods and procedures to be applied:	As per the CDM *Tool to determine the baseline efficiency of thermal or electric energy generation systems.*
Frequency of monitoring/recording:	As per the CDM *Tool to determine the baseline efficiency of thermal or electric energy generation systems.*
QA/QC procedures to be applied:	As per the CDM T*ool to determine the baseline efficiency of thermal or electric energy generation systems.*
Any comment:	-

Data Unit / Parameter:	$SC_{HPPO,\ y}$
Data unit:	TJ
Description:	Thermal energy consumption in PO production through the HPPO process in year y.
Source of data:	PO production facility records.
Description of measurement methods and procedures to be applied:	This parameter must be determined as the difference of the enthalpy of the process heat (steam) supplied to PO production process in the project method, minus the enthalpy of the feed-water, the boiler blow-down and any condensate return. The respective enthalpies are determined based on the mass (or volume) flows, the temperatures and, in case of superheated steam, the pressure. Steam tables or appropriate thermodynamic equations may be used to calculate the enthalpy as a function of

	temperature and pressure.
Frequency of monitoring/recording:	Data monitoring is continuous and aggregate recording must be performed at least monthly.
QA/QC procedures to be applied:	Meters must be calibrated regularly according to manufacturer's guidelines, and cross-checked with other PO production facility records.
Any comment:	Note that SSC_{HPPO}, as found in equation 14, is used only for ex-ante estimations, and its value must be estimated based upon the design details of the project. For ex-post calculations, "$SSC_{HPPO,y}$ x PO_y" is represented by SC_{HPPO} in equation 14, the value of which is monitored in accordance with the procedures described above.

Data Unit / Parameter:	$EC_{HPPO, y}$
Data unit:	MWh
Description:	Electrical energy consumption in PO production through the HPPO process in year y.
Source of data:	PO production facility records.
Description of measurement methods and procedures to be applied:	Electrical consumption is monitored continuously and the average specific electrical energy consumption is calculated based on PO production.
Frequency of monitoring/recording:	Data monitoring is continuous and aggregate recording must be performed at least monthly.
QA/QC procedures to be applied:	Meters must be calibrated regularly according to manufacturer's guidelines or national standards.
Any comment:	Note that SEC_{HPPO}, as found in equation 15, is used only for ex-ante estimations, and its value must be estimated based upon the design details of the project. For ex-post calculations, "SEC_{HPPO} x PO_y" is represented by EC_{HPPO} in equation 15, the value of which is monitored in accordance with the procedures described above.

Data Unit / Parameter:	$Q_{Propylene,y}$
Data unit:	Tonnes
Description:	Quantity of propylene used in year y.

Source of data:	PO production facility records
Description of measurement methods and procedures to be applied:	Flow-rate meters, mass meters, cross-check with stock verification records.
Frequency of monitoring/recording:	Data monitoring is continuous and aggregate recording must be performed at least monthly
QA/QC procedures to be applied:	Meters must be calibrated regularly according to manufacturer's guidelines or national standards, and cross-checked with stock inventory.
Any comment:	-

Data Unit / Parameter:	$Q_{By\text{-}product,y}$
Data unit:	Tonnes
Description:	Quantity of by-product produced in year y.
Source of data:	PO production facility records
Description of measurement methods and procedures to be applied:	Flow-rate meters, mass meters, cross-check with stock verification records.
Frequency of monitoring/recording:	Data monitoring is continuous and aggregate recording must be performed at least monthly
QA/QC procedures to be applied:	Meters must be calibrated regularly according to manufacturer's guidelines or national standards, and cross-checked with stock inventory.
Any comment:	-

Data Unit / Parameter:	$FC_{i,y}$
Data unit:	Mass or volume unit/year
Description:	Quantity of fuel type i combusted in the incinerator in year y.
Source of data:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
Description of measurement methods and procedures to be applied:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
Frequency of monitoring/recording:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
QA/QC procedures to be applied:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*

Any comment:	-

Data Unit / Parameter:	$COEF_{i,y}$
Data unit:	tCO_2/mass or volume unit
Description:	CO_2 emission coefficient of fuel type i in year y.
Source of data:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
Description of measurement methods and procedures to be applied:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
Frequency of monitoring/recording:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
QA/QC procedures to be applied:	As per the CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*
Any comment:	-

9.3 Description of the Monitoring Plan

The project proponent must establish, maintain and apply a monitoring plan and GHG information system that includes criteria and procedures for obtaining, recording, compiling and analyzing data, parameters and other information important for quantifying and reporting GHG emissions relevant for the project and baseline scenario. Monitoring procedures must address the following:

a) Types of data and information to be reported;

b) Units of measurement;

c) Origin of the data;

d) Monitoring methodologies (eg, estimation, measurement, calculation);

e) Type of equipment used, if any;

f) Monitoring times and frequencies;

g) QA/QC procedures;

h) Monitoring roles and responsibilities; and

i) GHG information management systems, including the location, back up, and retention of stored data.

Where measurement and monitoring equipment is used, the project proponent must ensure the equipment is calibrated according to current good practice (eg, relevant industry standards). All data collected as part of monitoring must be archived electronically and kept at least for two years after the end of the last project crediting period.

QA/QC procedures include, but are not limited to:

Data Gathering, Input and Handling Measures

- Input data checked for typical errors, including inconsistent physical units, unit conversion errors, typographical errors caused by data transcription from one document to another and missing data for specific time periods or physical units.
- Input time series data checked for large unexpected variations (eg, orders of magnitude) that could indicate input errors.
- All electronic files use version control to ensure consistency.
- Physical protection of monitoring equipment (eg, sealed meters and data loggers).
- Physical protection of records of monitored data (eg, hard copy and electronic records).

Data Documentation

- Input data units checked and documented.
- All sources of data, assumptions and emission factors documented.
- Changes to data, assumptions and emission factors documented.
- Documented assumptions and algorithms validated based on best practices.

Calculations

- Units for input data and conversion factors documented.
- Units for all intermediate calculations and final results documented.
- Input data and calculated data clearly differentiated.
- Comparison to previous results to identify potential inconsistencies.
- Results aggregated in various ways to identify potential inconsistencies.

10 REFERENCES AND OTHER INFORMATION

The latest approved versions of CDM tools referenced by this methodology are available at:

http://cdm.unfccc.int/Reference/tools/index.html

DOCUMENT HISTORY

Version	Date	Comment
v1.0	9 Sep 2013	Initial version released

VCS | VERIFIED CARBON STANDARD
A Global Benchmark for Carbon

Approved VCS Methodology VM0024

Version 1.0, 30 January 2014
Sectoral Scope 14

Methodology for Coastal Wetland Creation

Methodology developed by:

Louisiana Coastal Protection and Restoration Authority

Methodology prepared by:

CH2M Hill

EcoPartners

Table of Contents

1 SOURCES

This methodology was developed based on the requirements in the following documents:

- *VCS Standard, v3.3*
- *AFOLU Requirements, v3.3*
- *Program Definitions, v3.4*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	Activity Method
Crediting Baseline	Project Method

This methodology quantifies the greenhouse gas benefits of wetland creation activities. The scope of this methodology includes two primary project activities – substrate establishment and vegetation establishment – typically implemented in combination in order to create new wetlands (ie, to restore wetlands that have degraded to open water.) The methodology also allows for implementation of either project activity individually.

The methodology also addresses the potential for the establishment of woody vegetation. As such, this methodology is categorized as a Restoring Wetland Ecosystems (RWE) + Afforestation, Reforestation and Revegetation (ARR) methodology.

This methodology is only applicable to projects located in the United States of America, as set out further in the applicability conditions.

2.1 Project Activities

Wetland creation projects must be designed such that the wetland, over time, will support the ecological processes and functions of a mature wetland habitat. If retention dikes are part of the design, natural degradation and manual breaches must be planned in order to allow for regular tidal exchange or hydrologic connectivity to the surrounding area. The created wetland must support wetland vegetation species capable of contributing to soil carbon accumulation.

The project proponent must include a plan for the establishment and maintenance of a permanent wetland plant community after project construction. The plan must provide evidence that the project area will meet the definition of a wetland upon completion of project activities (but a formal wetland delineation survey is not required). This plan may include natural colonization or manual planting or seeding of the project area. The plan also must demonstrate how the project will be maintained over the project crediting period. Maintenance requirements and activities will vary geographically due to different ecological and physical processes which may influence the project area (eg, elevation deficit vs. shoreline erosion).

Active maintenance may not be required if the created wetland is designed and constructed to offset local processes – including impaired hydrological connectivity – which may have led to the initial deterioration of the historic wetland. For instance, projects created in more protected areas may not be as susceptible to shoreline erosion forces. In addition, other non-related restoration projects near the project area may help alleviate historic issues such as nutrient and sediment source deficits. In Louisiana, for example, future planned diversions of Mississippi River water are designed to supply fresh water, nutrients, and sediment to surrounding wetlands and may influence and sustain the project area depending on proximity to and configuration with the diversion.

The project proponent must demonstrate that the project engineering and design takes into account local water level elevation, tidal range, geotechnical characteristics, sea level rise projections, and the range of plant growth within those constraints.

Monitoring Requirements: Project Activities
The monitoring report must include the following whenever substrate is established: **MRR.1** Plan for establishment of a permanent wetland plant community after project construction. Plan must include long-term monitoring of emergent vegetation and plans for continued maintenance should it become necessary. This documentation must demonstrate that the project activity results in the accumulation or maintenance of soil carbon stock and that, upon completion of the project activities, the project area must meet the definition of a wetland. **MRR.2** Evidence that the project engineering and design takes into account local water level elevation, tidal range, geotechnical characteristics, sea level rise projections, and the range of plant growth within those constraints.

2.1.1 Substrate Establishment

Wetland creation projects are formed with materials including, but not limited to, excavated or dredged sediments from waterways such as rivers, channels, canals, and embayments. Excavated sediments must be placed in open water areas to create tidal wetlands that support emergent plant establishment and growth.

The project activity of creating a wetland from open water first requires the project proponent to select a proper site location that is adjacent to a sediment source which contains a sufficient volume and is within the technical capabilities of delivering the required sediment to the project site to meet design criteria. It is common, but not required, to construct a temporary retention dike around the project area to contain the sediment material and allow for dewatering and compaction in the initial years after project construction. The temporary dike is typically constructed by machinery such as an excavator. Once complete, the project area is filled with sediment via hydraulic or mechanical dredge, pipelines, or other mechanical methods to the proper elevation as determined in the engineering and design documents based on water levels (current and projected), sediment characteristics and geotechnical analyses. The retention dikes may be designed to naturally subside to elevations which will allow for tidal exchange and hydrologic connectivity but may require manual breaches or removal after the project area sediment has consolidated to target levels.

The project proponent must provide documentation of the substrate establishment activities to demonstrate the expected post-construction conditions in the project area.

Monitoring Requirements: Substrate Establishment
The monitoring report must include the following whenever substrate is established: **MRR.3** Post-construction report, including an as-built drawing showing plan view and cross section of the project area along with an estimate of post-construction sediment elevation relative to a geodetic or tidal datum. **MRR.4** Aerial image of the project area within three years prior to construction and an aerial image within one year post-construction.

2.1.2 Vegetation Establishment

The project proponent may use natural colonization, seeding or transplantation to accomplish vegetation coverage. Depending on the time of year when the project construction is complete or the time required for substrate settlement, planting or seeding may need to occur at a future time. When seeding or transplantation occurs, the project proponent may provide a description or design drawing of post-planting or seeding, indicating the species, quantity, and photographs of the operation.

The project proponent must provide documentation of the vegetation establishment activities to demonstrate that the activities result in the accumulation or maintenance of soil carbon stock.

When the activity includes the establishment of woody vegetation, ARR+RWE requirements and methods apply to the project. Such ARR+RWE establishment activities must not include nitrogen fertilization, active peatland drainage, or lowering of the water table depth (eg, draining or construction of channels in order to harvest). Projects with an ARR+RWE component must not include commercial harvest of woody biomass; the extent of ARR requirements is limited to vegetation establishment with no management as reflected by applicability condition 6 in Section 4.

Monitoring Requirements: Vegetation Establishment
The monitoring report must include the following whenever vegetation is established: **MRR.5** A description of the quantity, species, date and location of vegetation establishment, and photographs of the operation. **MRR.6** Aerial image of the project area indicating where species were established.

2.2 Application Overview

If the project meets the applicability conditions of this methodology (see Section 4), the project proponent must follow five steps to ensure that the design of the project activities and monitoring methods meet the requirements of this methodology. Upon completion of the final step, emissions reductions and/or removals are quantified.

2.2.1 Step One: Define the Project

The first step is to identify the boundary of the project area in accordance with Section 5, following the current VCS requirements for RWE project activities. Selecting GHG sources may require an *ex-ante* analysis of expected emissions reductions and/or removals from project activities to determine *de minimis* sources (see Section 8.4.3). The project area is the location where project activities will be implemented, defined in Section 5.3.

2.2.2 Step Two: Characterize Baseline

In this step, the project proponent uses Section 6 to demonstrate that the project area would have remained as open water (see applicability condition 3) and whether dredging would have occurred in the baseline scenario. It is possible that dredging would not have occurred in the baseline scenario, which is allowed by this methodology. In the case where dredging would have occurred in the baseline scenario, emissions from energy consumption must be quantified (see Section 8.1.1).

2.2.3 Step Three: Plan Project and Monitoring Activities

Project activities must adhere to the requirements established in Section 2.1. Monitoring activities must be designed in accordance with Section 9 and are documented in a monitoring plan. Methods for monitoring are described in Appendices A, B, C, D and E. The use of any different methods must be justified by the project proponent as a methodology deviation, in accordance with the VCS rules.

The project proponent determines which sources are *de minimis*, if any, prior to validation (see Sections 8.4.3.1 and 8.4.3.2).

2.2.4 Step Four: Implement Project Activities

The project must be implemented in accordance with the validated project description. If the project is a grouped project, project activities may be implemented as separate project activity instances rather than as a single project activity instance (see Section 9.5).

2.2.5 Step Five: Monitor and Report

During and after the implementation of project activities, the project proponent must use the monitoring plan as the basis for determining emissions reductions and/or removals (see Section 9). For carbon stocks, all plots must be measured prior to the first verification event. The data from monitoring are used in Section 8.

For grouped projects, there are additional monitoring requirements (see Section 9.5). New project activity instances may require modifications to the monitoring plan.

2.3 Notation

The notation used in this methodology is meant to communicate the variables and mathematical processes used to quantify carbon stock, gas fluxes, and greenhouse gas emission reductions over time.

2.3.1 Equations

Equations in this methodology are bracketed (eg, [G.1] in-text) and the full equations are located in Appendix G. Equations in Appendix G contain additional information including citations, literature sources and comments.

At times, similar operations are performed in multiple places on different variables. Rather than repeating nearly identical equations, a single, generic equation with the placeholder x or y is given. To estimate each pool or GHG source, the relevant variable or equation may be substituted for x as indicated within the methodology.

2.3.2 Variables

Variables in this methodology and their units are enumerated in the list of variables in Appendix J. For most of these variables, their units are in tonnes of carbon dioxide equivalents. The variables x and y (with and without subscripts) are sometimes used as placeholder variables — they may stand in for another variable or the results of an equation as indicated by the methodology text.

2.3.2.1 Variable, Subscript and Superscript Designations

Some variables are noted with special designations that allow the reader to immediately identify important information about the variable. The absence of designations also implies information about the variable.

The types of designations are given in Table 1, with examples of the use of these designations given in Section 2.2.3.2. Designations are only provided for variables in Sections 8 and 9.

Table 1: Variable designations and designation descriptions

Designation	Description
Quantity	The type of quantity that the variable represents (see Sections 2.3.6, 2.3.9, 2.3.10, 2.3.11, 2.3.12 and 2.3.15).
Accounting Level	The type of accounting level implies that the variable is part of monitoring.
Change	If the Δ symbol is designated, then the quantity represents a change over a monitoring period rather than cumulative since the project start date. The absence of a change designation implies that the quantity is cumulative since the project start date or that the quantity is part of monitoring which may not be cumulative or over the monitoring period.
Source	The type of source is specified as an acronym in Section 3.1. The absence of source implies that the variable is part of monitoring or that the variable is from multiple sources.
Period	The reference to a monitoring period (see Section 2.3.7).
Index	The reference to a unit.

2.3.2.2 Designation Examples

Tables 2, 3, 4, 5 and 6 provide example variables with designations and designation descriptions.

Table 2: Example variables with designations and designation descriptions

$E_{B\,\Delta\,EC}^{[m]}$		
Component	Designation	Description
E	Quantity	This indicates an emission or an emission reduction and/or removal (see Section 2.3.14). Uppercase means the unit is a total for the project area.
B	Accounting Level	Indicates the emission or an emission reduction and/or removal occurred in the baseline scenario (see definition for P).
Δ	Change	The emission or emission reduction and/or removal is for a period of time.
EC	Source	The emission or emission reduction and/or removal is from energy consumption.
$[m]$	Period	This emission or emission reduction and/or removal is from the monitoring period.

Table 3: Example variables with designations and designation descriptions

$F_{P\,\Delta\,CH4}^{[m-1]}$		
Component	Designation	Description
F	Quantity	This indicates a flux (see Section 2.3.11). Uppercase means the unit is a total for the project area.
P	Accounting Level	Indicates the flux is as a result of the project.
Δ	Change	The flux is for a period of time.
$CH4$	Source	The flux is for methane.
$[m-1]$	Period	This flux is for the prior monitoring period.

Table 4: Example variables with designations and designation descriptions*

$E_{GER\,\Delta}^{[m=1]}$		
Component	Designation	Description
E	Quantity	This indicates an emission or an emission reduction and/or removal (see Section 2.3.14). Uppercase means the unit is a total for the project area.
GER	Accounting Level	The emission or an emission reduction and/or removal constitutes the Gross Emission Reductions (see definition for GERs).
Δ	Change	The emission or emission reduction and/or removal is for a period of time.
$[m=1]$	Period	The emission or emission reduction and/or removal is for the first monitoring period.

*Note that the absence of a P, B or L in the example given in Table 4 above indicates the emission or emission reduction and/or removal is not specific to the project, baseline or leakage.

Table 5: Example variables with designations and designation descriptions*

$E_{NER}^{[m]}$		
Component	Designation	Description
E	Quantity	This indicates an emission or emission reduction and/or removal (see Section 2.3.14). Uppercase means the unit is a total for the project area.
NER	Accounting Level	The emission or emission reduction and/or removal is constitutes the Net Emission Reductions (see definition for NERs).
$[m]$	Period	This emission or emission reduction and/or removal is for the monitoring period.

*Note that the absence of a P, B or L indicates the emission or emission reduction and/or removal is not specific to the project, baseline or leakage. The absence of a Δ indicates the emission or emission reduction and/or removal is not over a period of time, but rather cumulative since the project start date.

Table 6: Example variables with designations and designation descriptions*

$g_{B\,(ty)}^{[m]}$		
Component	Designation	Description
g	Quantity	This indicates a unit of energy (see Section 2.3.12). Lower-case means the unit is per metric tonne of sediment.
B	Accounting Level	Indicates the unit of energy would have resulted in the baseline (see definition for P)
(ty)	Index	The unit of energy is for type ty. The parentheses indicate that ty is an index rather than a designation (such as *P* for project scenario).
$[m]$	Period	This unit of energy is for the monitoring period.

*Note that the absence of a Δ indicates the unit of energy is not over a period of time, but rather cumulative since the project start date.

2.3.3 Summations

Summations use set notation. Sets of variables are indicated using script notation, which reduces the number of variables used as well as the complexity of summations.

2.3.4 Standard Deviations and Variances

Standard deviation is indicated by the σ symbol, with subscripts used to indicate the quantity for which it is estimated. Variance is indicated by the σ^2 symbol and is the square of standard deviation. Standard deviations may not necessarily be in units of tCO_2e.

2.3.5 Standard Errors

Estimated standard error is indicated by the U symbol, with additional subscripts used to indicate the quantity for which the uncertainty is estimated. Standard errors are always in units of tCO_2e.

2.3.6 Theoretical Parameters and Parameterized Models

Parameters to model are denoted by variables, such as the surface friction velocity parameter u_*. When such parameters have a "hat" on them – such as the parameter $\hat{p}_{B\ (ty)}$– they refer to an estimated value rather than a known quantity.

2.3.7 Monitoring Periods

Monitoring periods are notated using bracketed superscripts $[m]$. The first monitoring period is denoted by $[m = 1]$, the second monitoring period $[m = 2]$, and so forth. These superscripts should not be confused with references to equations numbers, as equation numbers are never in superscript. Also see the definition for monitoring period. A verification event is the reporting and verification of NERs claimed for a monitoring period. A monitoring period that is $[m = 0]$ denotes "prior to the project start date."

2.3.8 Baseline, Project and Leakage Estimates

Estimates related to baseline, project and leakage emissions reductions and/or removals and carbon stocks are specifically denoted with B, P and L in the subscripts of variables, respectively.

2.3.9 Averages for Stocks

Average carbon (measured in tCO_2e/ha) to which accounting is applied is denoted by a lower-case c, with subscripts to differentiate between carbon pools as indicated in the list of variables. For example, $c_{P\ SOC}^{[m]}$ indicates the average carbon stock in soil organic carbon in the project area in monitoring period $[m]$. Subscripts from carbon pools are acronyms listed in Section 3.1.

2.3.10 Totals for Stocks

Total carbon (measured by tCO_2e) to which accounting is applied is denoted by a capital C, with subscripts to differentiate between carbon pools as indicated in the list of variables. Subscripts from carbon pools are acronyms listed in Section 3.1.

2.3.11 Fluxes for Methane and Nitrous Oxide

Fluxes are expressed in units of tCO_2e per day by the variable F with subscripts to differentiate between GHG sources as indicated in the list of variables. Fluxes always contain a Δ in the subscript when the flux emissions are over the monitoring period. For example, $F^{[m]}_{P\,\Delta\,CH4}$ indicates the methane flux in the project area in monitoring period $[m]$. Subscripts from GHG sources are acronyms listed in Section 3.1. Some equations in Appendices B and C use a lower-case f, signifying that the units are tCO_2e per acre per day. It is important to note that although the units for fluxes are in tCO_2e per day, this does not imply that monitored fluxes have a daily resolution. Monitoring may be periodic or seasonal, as per Section 9.2.2.4.1.

2.3.12 Units of Energy or Fuel

Energy or fuel consumption is expressed as a total or per different units as specified in Table 10, denoted by a capital G for a total and a lower-case g per unit (which may be metric tonne of sediment). For example, $G^{[m]}_{P\,\Delta\,FC\,(ty)}$ indicates the total project energy consumption for energy type (ty) during monitoring period $[m]$.

2.3.13 Masses of Sediment

Sediment transport is used to estimate energy consumption in Section 8.1.1, denoted over a monitoring period as a total with an uppercase M. For example, $M^{[m]}_{P\,\Delta}$ indicates the total sediment transport as a result of project activities during monitoring period $[m]$. Masses of sediment are always quantified as metric tonnes.

2.3.14 Emissions Reductions and/or Removals

Total emissions reductions and/or removals (measured as tCO_2e) from accounting are denoted by a capital E, with subscripts to differentiate between carbon pools as indicated in the list of variables. For example, $E^{[m]}_{P\,\Delta}$ indicates the project emissions reductions and/or removals during monitoring period $[m]$. Subscripts from carbon pools and GHG sources are acronyms listed in Section 3.1.

Emissions are represented by negative E values, while emissions removals are represented by positive E values.

2.3.15 Quantified Uncertainties

Uncertainties in major carbon pools or fluxes are expressed as standard error of a total (measured by tCO_2e or tCO_2e/day, respectively) and are denoted using a capital letter U. For example, $U^{[m]}_{P\,\Delta\,CS}$ is used to indicate the uncertainty in estimated carbon stocks at monitoring period $[m]$. Because this methodology's gas flux measurement methods (described in Appendix B and Appendix C) are inherently conservative, no uncertainty is calculated for methane and nitrous oxide gas fluxes. Thus, uncertainties are calculated for carbon stock estimates only.

2.4 Documentation Requirements

2.4.1 Project Description Requirements

To ensure the project meets the requirements set out in the methodology, this methodology includes Project Description Requirements (PDRs). The project proponent must provide evidence and documentation for each PDR. PDRs are listed in each section of this methodology and in Appendix K.

Project proponents must note that in addition to the PDRs set out in this methodology, the project must adhere to all VCS rules when applying this methodology (ie, the PDRs cover all the requirements of the methodology, but they do not necessarily cover each and every VCS requirement relevant to the project).

2.4.2 Monitoring Report Requirements

To ensure the project's compliance with the methodology, this methodology includes Monitoring Report Requirements (MRRs). The project proponent must provide evidence and documentation for each MRR. MRRs are listed in each section of this methodology and in Appendix L.

2.5 Units versus Resolution of Emissions Reductions and/or Removals Accounting

The methodology accounts for emission reductions and/or removals using daily units in Section 8. Accounting is specified by day to facilitate intra-annual monitoring events and the verification of monitoring periods that may span more or less than exactly a single year.

Although emissions reductions and/or removals are calculated on a daily basis, they may not be measured or monitored on a daily basis. The requirements in Section 9 and in Appendices B, C, D and E specify that measurements are taken periodically throughout the monitoring period, and the duration or interval of those measurements does not need to be daily.

3 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions apply to this methodology:

Accretion Depth
Vertical measurement of accumulated soil material from $t^{[m-1]}$ to $t^{[m]}$

Baseline Emissions
For any monitoring period, baseline emissions $E_{B\,\Delta}^{[m]}$ are a sum of estimated emissions over selected carbon pools during the time between two verification events

Baseline Reevaluation
Revision of the baseline scenario which occurs every 10 years

Buffer Release
A periodic release of buffer credits from the AFOLU pooled buffer account

Chamber Sampling Type
A type of temporal sample using static chambers that is either peak, seasonal, or monthly (see Section 9.2.2.4.1)

Coarse Root
A root greater than or equal to 2 mm in diameter

Covariate
A variable possibly predictive of the outcome under study. Synonymous with the term *proxy*, as defined in VCS document *Program Definitions*

de minimis
Considered a negligible source of emissions (<5% of total GHG benefit generated by the project) and therefore not accounted for (see Section 8.4.3)

Degraded Wetland
Area that previously met the definition of a wetland, but now no longer meets that definition due to disruptions in normal hydrological and ecological processes and linkages (ie, the wetland converted to open water, or similar degraded state, in response to impaired sediment supply, sea level rise, impaired water quality, or similar reason). A degraded wetland may include areas of open water.

Direct Measurement
A method used to quantify energy consumption by measuring the volume of fuel consumed (see Section 9.2.4.1)

Dredging
The removal or excavation of bottom sediments from an aquatic environment for the creation or maintenance of waterways

Ebullition
The sudden release to the atmosphere of bubbles of gas (usually methane) from submerged sediment

Eddy Covariance Sampling Type
A type of temporal sample using eddy covariance that is either peak periodic, peak cumulative, seasonal, or monthly (see Section 9.2.2.4.2)

Eddy Covariance
A micrometeorological technique to estimate flux of heat, water, atmospheric trace gases and pollutants that relies on turbulence to calculate fluxes

Energy Type
A type of energy listed in Table 10

Estuarine
A tidal water body or wetland with mixing of fresh and (ocean-derived) salt water, where salinity is greater than or equal to 0.5 ppt (parts per thousand) during the period of average annual low flow

Fixed Soil Sample Depth
At the time of project validation, a fixed depth for soil sampling of the original project soil is defined by the project proponent, which cannot exceed 100 cm. The only time when the fixed sample depth may be exceeded is when accretion depth is measured from $t^{[m-1]}$ to $t^{[m]}$. For any monitoring event, a total sample depth (for carbon stock) cannot exceed the pre-defined fixed soil sample depth and the accretion depth from the current and previous monitoring event.

Flux
A flow of gas into the atmosphere expressed as a rate of mass per unit time and area (accounted for in terms of tCO_2e/ac/day)

Gross GHG Emission Reductions and Removals (GERs)
Tonnes of carbon dioxide equivalent (tCO_2e) emissions that are reduced or removed from the atmosphere due to project activities, given as the difference between baseline and project emissions or emissions reductions and/or removals, minus emissions from leakage (see Sections 8.1, 8.2 and 8.3)

Herbaceous Marsh
Wetland that is periodically flooded and generally characterized by a growth of grasses, sedges, cattails and rushes

Hydrologically Connected Areas
Two or more areas which may share matter, energy, and organisms as a result of water movement

Monitoring Period
An interval of time following the project start date and designated for systematically verifying project claims of GHG emissions reductions and/or removals. Specifically, an interval of time from $t^{[m-1]}$ to $t^{[m]}$ where $t^{[m-1]} \geq 0$ (the project crediting period start date) and $t^{[m-1]} < t^{[m]}$. The length of the monitoring period is $t^{[m]} - t^{[m-1]}$ where m denotes the number of any single monitoring period and t the number of days after the project crediting period start date that is the end of the monitoring period. A monitoring period that is $[m = 0]$ denotes "prior to the project start date."

Net GHG Emission Reductions and/or Removals (NERs)
Tonnes of carbon dioxide equivalent (tCO_2e) emissions that are reduced or removed from the atmosphere due to project activities, given as GERs adjusted for certain deductions and additions (see Sections 8.4.1, 8.4.2.1 and 8.4.2.3)

Non-Tree
Vegetation such as shrubs, grasses, sedges and other herbaceous plants which does not meet the definition of a tree

Open Water
Water with 90% of its area having a depth that does not support emergent vegetation, and no more than 10% sparse vegetation. Water with dense vegetation is not considered open water.

Original Project Soil
Soil resulting from the emplacement of sediments at the project start date

Permanent Plot
A plot with fixed area and location used to repeatedly measure change in carbon stocks over time

Programmatic Dredging Project
Routine, ongoing dredging often associated with maintaining navigability

Project Area
The geographic area controlled by the project proponent where project activities are implemented

Project Emissions or Emissions Reductions and/or Removals
Project emissions or emissions reductions and/or removals for any monitoring period $[m]$ as estimated by the events of accretion, flux and energy consumption

Project Performance
A comparison of ex-post credit generation to ex-ante estimates over time

Reference Area
An area delineated by the project proponent used to estimate emissions from methane ebullition in the baseline

Sampling Period
The period of months for static chamber or eddy covariance measurement of methane flux corresponding to a sample type (see Section 9.2.2.4.2)

Single Event Dredging Project
A dredging event associated with a discrete planned project

Soil
Unconsolidated mineral or organic material on the immediate surface of the Earth that serves as a natural medium for the growth of land plants

Soil Organic Matter
The organic matter that may be found in soil, not including coarse roots

Substrate Establishment
Adding sediment to an area devoid of sediment, or to add sediment in an open water system to raise the land elevation such that emergent plants can colonize

Tree
A perennial plant containing secondary wood and that is at least three meters tall at maturity

Tidal
A water body or wetland exposed to vertical water level fluctuations corresponding to lunar-solar gravitational cycles. The area may have freshwater or saltwater characteristics (eg, freshwater riverine and lacustrine systems may experience tidal influence without ocean-derived salts).

Vegetation Establishment
The process of seeding or transplanting vegetation to the soil, or providing adequate conditions for natural plant colonization

Verification Event
The reporting and verification of NERs claimed for a monitoring period

Water Impoundment
A body of water created or stored by impoundment structures, such as dams, dikes and levees

Water Table
The surface where water pressure in the soil is equal to the atmospheric pressure

3.1 Acronyms

AG	Above ground
AGNT	Above ground non-tree
AGT	Above ground tree
ARR	Afforestation, reforestation, and revegetation
AS	Activity-shifting
B	Baseline scenario
BA	AFOLU pooled buffer account

BG	Below ground
BGNT	Below ground non-tree
BGT	Below ground tree
BR	Buffer release
CF	Carbon fraction
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CS	Carbon stock
CWA	Clean Water Act
EC	Energy consumption
GERs	Gross GHG Emissions Reductions and/or Removals
GHG	Greenhouse gas
GIS	Geographic Information System
GPS	Global Positioning System
L	Leakage
LQD	Liquid
ME	Market-effects
MRR	Monitoring Report Requirement
NERs	Net GHG Emission Reductions and/or Removals
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
N_2O	Nitrous oxide
P	Project scenario
PAI	Project Activity Instance
PAIA	Project Activity Instance Area
PD	Project Description
PDR	Project Description requirement
PM	Proxy method for energy consumption
SE	Standard error

SLD	Solid
SPC	Species
U	Uncertainty
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
VCS	Verified Carbon Standard
VCUs	Verified Carbon Units
VVB	Validation/Verification Body
WR	Wetland restoration

4 APPLICABILITY CONDITIONS

This methodology applies to project activities that create tidal or estuarine wetlands through substrate establishment and/or vegetation establishment.

This methodology is applicable under the following conditions:

1. Project activities must include activities intended to create new wetlands in coastal ecosystems through substrate establishment, vegetation establishment, or both.
2. Project activities must not actively lower the water table depth.
3. The project area must meet the definitions of tidal or estuarine, open water, and degraded wetland before project activities are implemented and would have remained open water in the absence of the project activities (see Section 6.1).
4. The project area must be entirely within tidal or estuarine areas within the coastal zone boundary,[1] and must meet the definition of Waters of the United States,[2] excluding the Great Lakes.[3]

[1] Areas within the coastal zone boundary, as defined by each state of the US. Refer to NOAA's Ocean and Coastal Resource websites or individual coastal zone management maps: http://coastalmanagement.noaa.gov/mystate/welcome.html and http://coastalmanagement.noaa.gov/mystate/docs/StateCZBoundaries.pdf.

[2] For definition of Waters of the United States, refer to: http://www.epa.gov/region6/6en/w/watersus.htm.

[3] Great Lakes: The geographic scope does not include portions of Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio, Pennsylvania and New York which are hydrologically connected to the Great Lakes.

6 When ARR+RWE project activities are implemented and include the establishment of woody vegetation, there must not be commercial harvest activities, nitrogen fertilization or active peatland drainage (see Section 2.1.2).

7 The project proponent must have obtained the necessary permits to demonstrate that the project will not have a significant negative impact on hydrologically connected areas (see Section 8.3.3). This applicability condition must be satisfied at validation or at the first verification event.

PD Requirements: Applicability Conditions
The project description must include the following: **PDR.1** For each applicability condition, credible evidence in the form of analysis, documentation or third-party reports to satisfy the condition.

5 PROJECT BOUNDARY

5.1 Selecting GHG Sources

The greenhouse gases included in, and excluded from, the project boundary are set out in Table 7 below.

Table 7: GHG sources

	Source	Gas	Included?	Justification/Explanation	Affected by Project?
Baseline	Dredging, transport and re-handling for navigability or maintenance	CO_2	Yes	Emitted by fuel combustion regardless of fuel type.	No
		CH_4	Yes		
		N_2O	Yes		
		Other	None		
	Methane ebullition	CO_2	No	Methane bubbling may occur in open water; the quantity thereof may be included and monitored if desired.	No
		CH_4	Optional		
		N_2O	No		
		Other	None		
Project	Dredging, transport and placement for project activities	CO_2	Yes	Emitted by fuel combustion regardless of fuel type.	Yes
		CH_4	Yes		
		N_2O	Yes		
		Other	None		
	Habitat regeneration	CO_2	Yes	Major pool considered.	Yes
		CH_4	Yes	Wetland creation may result in an increase in CH_4 emissions in comparison to the open water baseline scenario.	
		N_2O	Yes, if significant	Wetland creation may result in an increase in N_2O emissions in comparison to the open water baseline scenario.	
		Other	None		

PD Requirements: GHG Sources
The project description must include the following: **PDR.2** A list of the included and excluded GHG sources.

5.2 Selecting Carbon Pools

The carbon pools included in or excluded from the project boundary are shown in Table 8 below.

Table 8: Carbon pools

Pool	Included?	Relevant to:	Justification/Comments
Above ground tree biomass	Included	Project	Major carbon pool required by VCS *AFOLU Requirements*.
Above ground non tree biomass	Optional	Project	May be conservatively excluded.
Below ground biomass	Optional	Project	May be conservatively excluded, but recommended when applicable root-shoot ratios are available. Only applicable in forested or woody habitats, not herbaceous ones.
Litter	Excluded	-	Conservatively excluded.
Dead wood	Excluded	-	Conservatively excluded.
Soil organic carbon	Included	Project	Major carbon pool expected to increase due to project activities.
Wood products	Excluded	-	Conservatively excluded. Not expected to be a significant pool.

Optional pools may always be conservatively excluded. The baseline scenario allows for up to 10% vegetation cover (see definition of open water in Section 3), but it is conservative to exclude the CO_2 emissions that occur from the likely loss of wetlands, CH_4 emissions from ongoing biogeochemical activity in the remaining vegetation or methane ebullition that would be expected to occur in the baseline scenario. The set of selected carbon pools is denoted by $\mathcal{C}$.

PD Requirements: Carbon Pools
The project description must include the following: **PDR.3** A list of the selected and excluded carbon pools.

5.2.1 Allochthonous Carbon in Soil Organic Carbon Pool

Autochthonous carbon sequestration, resulting from the growth of vegetation in the project area, must be estimated separately from allochthonous carbon, where there is reasonable evidence that the mass of carbon that is imported to the site exceeds that which is exported. The fate of transported organic matter must be conservatively assessed, where relevant. The opposite condition also may exist, where the mass of exported carbon from the growth of vegetation as a result of project activities is greater than the mass of carbon that would be washed out to sea under baseline conditions.

5.2.1.1 Criteria for Projects Located Within Louisiana

For projects located within Louisiana, and not within the direct influence of a river diversion or river mouth, project proponents are not required to account for allochthonous carbon import because such import has been demonstrated to be negligible (see Appendix I).

Where river diversions are implemented to enhance growth and maintenance of created wetlands, and where such river diversions are designed to import substantial quantities of mineral-associated carbon, the project proponent must justify the exclusion of allochthonous carbon using the criteria listed in Section 5.2.1.2, or must quantify the carbon import per the procedures described in Section 9.2.6.

Where there exists an artificial water impoundment which affects the hydrological regime of the project area, the project proponent must justify the exclusion of allochthonous carbon using the criteria listed in Section 5.2.1.2, or must quantify the carbon import per the procedures described in Section 9.2.6.

5.2.1.2 Criteria for Projects Located Outside Louisiana

For projects located outside Louisiana, the project proponent may conservatively exclude allochthonous carbon by using publicly available regional case studies, peer-reviewed literature or regional models to justify that the import of organic matter will not cause carbon accretion estimates to be significantly overestimated. The justification and evidence must be commensurate with the justification provided in Appendix I for projects located within Louisiana. The justification must include the following evidence which must be applicable to the geomorphology of the project area:

- Description of the dominant sources of sediments with respect to external (ie, fluvial) inputs or internal (within estuary or tidal freshwater wetland) recycling.
- Proximity of the project area with respect to direct fluvial inputs or near-shore sediment sources.
- An annual mass estimate of the total carbon imported or exported from the estuary or tidal freshwater wetland where the project area is located.
- Description of the project area/region with respect to tidal energy (such as flood- or ebb-dominated) or tidal dispersive flux. Under ebb-dominated conditions, ‘outwelling’ or transfer of carbon from the tidal wetland to the ocean would be reasonably expected.

If the project proponent cannot demonstrate that allochthonous carbon sedimentation in the project area can be conservatively excluded, monitoring of allochthonous carbon must follow the methods in Section 9.2.6, where marker horizons are used to differentiate between carbon accreted in the project area as a result of project activities and allochthonous carbon imported into the project area.

PD Requirements: Allochthonous Carbon in Soil Organic Carbon Pool
For projects located outside Louisiana, the project description must include the following in order to demonstrate that allochthonous carbon import can be conservatively ignored: **PDR.4** Narrative justification that the import of organic matter will not cause carbon accretion estimates to be significantly overestimated including citations to case studies, literature or models. **PDR.5** Description of the dominant sources of sediments with respect to external (ie, fluvial) inputs or internal (within estuary or tidal freshwater wetland) recycling. **PDR.6** Proximity of the project area with respect to direct fluvial inputs or near-shore sediment sources. **PDR.7** An annual mass estimate of the total carbon imported or exported from the estuary or tidal freshwater wetland where the project is located. **PDR.8** Description of the project area with respect to tidal energy (such as flood- or ebb-dominated) or tidal dispersive flux.

5.3 Delineating Spatial Boundaries of Project Area

The spatial boundaries of the project must be delineated using GIS techniques. The project area may consist of multiple project activity instances. That is, the project area need not be spatially contiguous and may comprise one parcel or multiple adjacent or non-adjacent parcels. The project proponent must demonstrate control of the project area as described in the most recent version of the VCS *AFOLU Requirements*.

At the project start date, the entire project area must meet the definition of open water (see Section 3 for definition). The project proponent also must demonstrate that the project area meets the definition of tidal or estuarine open water wetlands which once supported emergent wetland vegetation – such as freshwater or saltwater herbaceous marsh, scrub-shrub or forest (eg, mangrove, cypress-tupelo swamp) – but which are degraded (prior to the implementation of project activities) to a flooded or subtidal condition. In order to demonstrate that the project area is located in a tidal or estuarine system, the project proponent must provide one of the following:

- Federal or state agency supporting documentation describing the project's tidal or salinity designation. For example, the National Wetland Inventory *Wetlands Mapper* provides both tidal and salinity descriptors or modifiers for the coastal areas of the United States, or

- Peer-reviewed literature showing the proximity of the project area to study areas and the evidence of tidal influence or presence of salinity greater than 0.5 ppt (parts per thousand), or
- The location of the tide gage adjacent to the project area and data which show either a discernible diurnal, semi-diurnal or mixed-tide signal; salinity greater than 0.5 ppt (parts per thousand) during the year; or evidence of a tidal datum designation (MLLW, MSL, MHHW, etc.).

Further, the project proponent must demonstrate compliance with the most current version of the VCS *AFOLU Requirements* regarding the clearing of native ecosystems.

Additionally, the project proponent must assess the hydrological connectivity of the project area to surrounding areas using the procedures described in Section 8.3.1 and demonstrate that there are no negative impacts to hydrologically connected areas and that any adjacent hydrologically connected areas are not likely to affect the GHG emissions of the project area.

Sea level rise may affect the project area by converting wetlands into shallow open water if the rate of sea level rise exceeds the rate of soil elevation gain. Because the project boundaries are fixed throughout the lifetime of the project, any lateral movement of wetlands in the project area caused by sea level rise is inherently captured by monitoring activities (see Section 9). However, given the significant potential impact of sea level rise on constructed wetlands in the coastal zone, the proponent must demonstrate that the project's spatial boundaries and wetland establishment activities have taken into account projections of future sea level rise. In particular, the project proponent must review current technical scientific literature relevant to the area (considering sources such as the most recent IPCC assessment report and peer-reviewed literature), document expected sea level rise in the vicinity of the project area, and demonstrate that wetland construction activities have been designed to withstand expected sea level rise.

In addition, the project description must include the following:

- A description of the existing natural or constructed measures for ensuring resilience to sea level rise (eg, how existing landforms or constructed features offer physical protection of the project area).
- A description of the post-construction soil surface elevation relative to mean sea level, taking into account estimated accretion, subsidence and sea level rise parameters within the project area.

After project activities commence, it is possible that one or more tidal channels will develop within the project area. Such areas must remain part of the project area and must not be excluded.

PD Requirements: Delineating Spatial Boundaries
The project description must include the following: **PDR.9** GIS-based maps of the project area with, at a minimum, the features listed in Section 5.3 above. **PDR.10** Documentation that the entire project area is/was open water at the project start date. **PDR.11** Evidence that the project area meets the definition of tidal or estuarine open water wetlands which once supported emergent wetland vegetation. **PDR.12** Evidence that the project area is compliant with the most current version of the VCS *AFOLU Requirements* regarding the clearing of native ecosystems. **PDR.13** If methane emissions are included in the baseline scenario, an estimate of the average water depth in the project area prior to the implementation of project activities (see Section 6.3). **PDR.14** Documentation that the project proponent has control over the project area, in accordance with the most recent version of the VCS *AFOLU Requirements*. **PDR.15** Documentation of the assessment of effects to hydrologically connected areas as further described in Section 8.3.1. **PDR.16** Documentation of projected sea level rise in the vicinity of the project area, evidence that existing landforms or constructed features are expected to withstand project sea level rise, and a description of the post-construction soil surface elevation relative to mean sea level.

5.4 Defining Temporal Project Boundaries

Temporal project boundaries define the period of time when the project area was under the control of the project proponent and are used to determine the dates at which project activities, monitoring activities, and baseline reevaluation must occur. The following temporal project boundaries must be defined:

- The project start date.
- The length of the project crediting period.
- The dates and periodicity of baseline reevaluation and monitoring periods. A baseline reevaluation after the project start date and monitoring must conform to the VCS rules.

Within six months of the project crediting period start date and prior to the first verification event, the monitoring equipment must be installed per Sections 9.2.1.1 and 9.2.2.4. Upon the project start date, records of energy consumption must be maintained per the requirements of Section 9.2.4.

For the project duration, the project proponent must reevaluate the baseline in accordance with the VCS rules (see Section 6.4).

The project proponent must document the planned duration of monitoring periods and corresponding frequency of verification events.

PD Requirements: Temporal Project Boundaries
The project description must include the following: **PDR.17** The project start date. **PDR.18** The project crediting period start date and length. **PDR.19** The date by which mandatory baseline reassessment must occur after the project start date. **PDR.20** A timeline including the first anticipated monitoring period showing when project activities will be implemented. **PDR.21** A timeline for anticipated subsequent monitoring periods.

Monitoring Requirements: Temporal Project Boundaries
The monitoring report must include the following: **MRR.7** The project start date. **MRR.8** The project crediting period start date and length. **MRR.9** Evidence of the start of monitoring per the frequency requirements described in Sections 5.4, 9.2.1.1, 9.2.2.4, and 9.2.3.4.

5.5 Grouped Projects

In addition to the requirements for grouped projects set out in the *VCS Standard*, the project proponent must establish criteria at the time of project validation that include the following:

- Landscape configuration: All project activity instances must be similar with respect to biogeochemical processes, which are affected principally by such factors as vegetation type, salinity, and presence or absence of external nitrate loading.
- Monitoring methods: In order to facilitate the consistent accounting of all project activity instances within a single project, all project activity instances must employ the same methods to monitor emissions reductions and removals (eg, direct measurement, models from literature, or proxy model) for each included GHG source. Similarly, all project activity instances must employ the same modeling assumptions and sampling protocols for the selected monitoring methods.

Additional monitoring requirements must also be followed for grouped projects, per Section 9.5.

The set of all project activity instances is denoted by $\mathcal{G}$.

PD Requirements: Grouped Projects
If grouped projects are developed, the project description must include the following, as per the requirements set out in the *VCS Standard*: **PDR.22** A list and descriptions of all enrolled project activity instances in the group at the time of validation. **PDR.23** A map of the designated geographic area within which all project activity instances in the group may be located, indicating that all instances are in the same region. **PDR.24** A list of eligibility criteria for project activity instances.

Monitoring Requirements: Grouped Projects
If grouped projects are developed, the monitoring report must include the following, as per the requirements set out in the *VCS Standard*: **MRR.10** A list and description of all project activity instances in the project. **MRR.11** A map of the boundaries of all project activity instances in the project demonstrating that all instances are in the designated geographic region.

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

6.1 Demonstrating the Most Plausible Baseline Scenario

The project proponent must consider a range of alternative land uses when determining the baseline scenario for both RWE and ARR+RWE projects. Possible baseline scenarios may include a continuation of open water, additional wetland loss in accordance with long-term trends, natural reestablishment of the wetland or alternative wetland reestablishment activities not associated with carbon finance. The project description must include a comparative assessment of the implementation barriers and net benefits faced by the project and its alternatives.

As per the applicability conditions, this methodology is only applicable where the following baseline scenario is identified:

> The project area must meet the definitions of tidal or estuarine, open water, and degraded wetland before project activities are implemented and would have remained open water in the absence of the project activities.

The project proponent must use one of the analysis methods described in Section 6.1.1 or 6.1.2 to demonstrate the baseline scenario.

To demonstrate that this applicability condition has been met, it is recommended that the project proponent acquire data from USGS data sets (ie, Couvillion 2012) or the U.S. Fish & Wildlife Service's National Wetlands Inventory to show that the project area historically met the definition of a wetland and thus the definition of degraded wetland. If the applicability condition is met as required under the methodology, the only possible baseline scenario is open water. To support the chosen analysis method, the project proponent also must provide evidence of long-term water level changes in the project area with minimum record length of 20 years of hydrological data (eg, water table, water level, sea level). The evidence must demonstrate the long-term nature of the documented pattern of wetland loss.

The project proponent must also demonstrate that wetland creation is unlikely to occur in the project area based upon historical evidence of land accretion and loss.

PD Requirements: Baseline Scenario
The project description must include the following: **PDR.25** Results of a comparative assessment of the implementation barriers and net benefits faced by the project and its alternatives, and justification for the most plausible baseline scenario. **PDR.26** Documentation to demonstrate that the project area previously met the definition of a wetland before converting to open water. Documentation must include hydrological data to show evidence of long-term patterns of wetland loss. **PDR.27** The selected method for demonstrating the baseline scenario in the project area (regional land use change or spatial analysis).

6.1.1 Using a Published Regional Land Use Change Analysis

The baseline scenario may be demonstrated through documentation regarding land loss rates in the hydrologic basin in which the project area is located. Documentation must be based on Landsat or other satellite or aerial imagery that shows a trend of continued land loss or static condition in the basin for a period of at least 10 years prior to the project start date or the date of baseline reevaluation (see Section 6.4). Examples include the US Geologic Survey publication 'Land Area Change in Coastal Louisiana from 1932 to 2010', or the US Fish & Wildlife Service, National Wetlands Inventory, 'Wetlands Status and Trends' report series. The documentation must be from peer-reviewed literature, government publication or third party publication and must be publicly available.

The project proponent must also identify the boundary of the project area and its proximity to any existing and/or future water management activities (eg, river diversions) which could influence the project area. If water management activities are identified (either existing or planned over the next 10 years), the project proponent must address the potential for land-building based on significant deposition of sediment in the project area in the absence of project activities. An updated figure of water management activities must also be identified in the baseline reassessment.

PD Requirements: Regional Land Use Change for Baseline Scenario
The project description must include the following: **PDR.28** A reference to the document providing evidence of continued land loss or static condition in the basin for a period of 10 years prior to the project start date. **PDR.29** A summary of the referenced document indicating where in the document the evidence is provided. **PDR.30** Documentation of water management activities (eg, river diversions) that could influence the baseline scenario.

6.1.2 Conducting a Spatial Analysis

The baseline scenario may be demonstrated using high-resolution satellite or aerial imagery that demonstrates that the area of open water (ie, non-wetland) has not decreased over time in the region surrounding the project area. Sections 6.1.2.1 and 6.1.2.2 provide guidance on conducting the analysis. For such analysis, the following requirements must be met:

- The analysis must be conducted using data from two points in time (image dates) at least ten years apart, one of which is within two years prior to the project start date or date of baseline reevaluation (see Section 6.4).
- The two image dates must be within the same three-month period of their respective years to prevent seasonal variability.
- The study region must be at least three times the size of the project area.
- The study region must be located in an area near the project area, with similar climatic and edaphic conditions.
- Cloud cover must not exceed 20% of the study region for either image date.
- Accuracy determined by error checking or ground-truthing must be at least 90%.
- The analysis must infer that the area of open water in the study region has not decreased over time via natural processes.

The region of analysis may or may not include the project area.

PD Requirements: Spatial Analysis for Baseline Scenario	
The project description must include the following:	
PDR.31	A report describing how the analysis was conducted, including data sources and dates, demonstration of conformance with the requirements listed in Section 6.1.2, and justification for the selection of the region in which the analysis was conducted.
PDR.32	A map of the region in which the analysis was conducted.
PDR.33	The quantified change in water area.

6.1.2.1 Selecting Image Type

Aerial or satellite imagery must be high-resolution or multispectral in order to accurately delineate wetland vs. open water. Multiple images from each image date may be used to increase cloud-free coverage of the study region. The analysis must consider varying water levels on land areas at the time of the imagery, and the potential impact on interpretation of imagery. Proper pre-processing techniques must be observed, such as geometric and radiometric corrections, cloud and shadow removal and reduction of haze, as needed.

6.1.2.2 Classifying and Post-Processing

Change detection analysis may be used to determine the change in water area over time. Post-processing must include error checking and ground-truthing as needed to ensure accurate land cover assessment. For further information, see the detailed maps included with the US Geologic Survey publication 'Land Area Change in Coastal Louisiana from 1932 to 2010,' as well as Klemas (2011) for a detailed description regarding remote sensing techniques to monitor changes in wetlands.

6.2 Determining Dredging in Baseline Scenario

In the baseline scenario, dredging may or may not occur for navigation or maintenance purposes. Dredging may include hydraulic and mechanical machinery and the methods of sediment removal and disposal may be classified as permanent or temporary (see dredging activities described in Table 9). If dredging is included in the baseline scenario, this must be clearly identified in the project description.

In large rivers or near-shore coastal environments, navigation dredging may include a combination of temporary displacement (thalweg or current disposal) and temporary open water disposal that occurs within the banks of the river or within an embayment. In the case of temporary displacement/disposal, sediments may be re-handled multiple times before permanent removal occurs. The project proponent may account for sediment re-handling. Permanent sediment removal also may occur with dredging, transportation, and disposal at open water sites or confined disposal areas (facilities).

For the baseline scenario, the process of dredging must be described based on a single event (planned project) or routine programmatic dredging. The baseline dredging must contain a description of equipment types, method of dredging/transport/disposal/re-handling, sediment volume, and energy type and energy quantity used. The documentation of dredging activities also must include a description of the likely fate of dredged sediments in the baseline, thus indicating that the sediments would not be used for wetland creation activities in the baseline scenario.

Acceptable documents for describing single event dredging projects or programmatic dredging projects may include but are not limited to a Section 10 permit (River and Harbors Act 1899), Dredge Material Management Plan (USACE) and interagency project documents that provide descriptions or authorization for project-specific or routine operations (eg, Beneficial Use of Dredge Material, BUDMAT).

Table 9: Types of dredging activities and alternative sediment fates (permanent or temporary)

	Sediment Fate	Typical Equipment	Description
Baseline	Temporary displacement	Dustpan dredge; cutterhead suction dredge; mechanical excavator	Sediments are dredged and displaced in the river/nearshore current, subject to subsequent downstream removal from the waterway. The process of temporary sediment displacement is also described as *agitation* or *thalweg disposal*.
	Temporary removal and disposal	Hopper dredge; barge; mechanical excavator	Sediments are dredged, then transported in a confined vessel and disposed of in a temporary area, subject to subsequent downstream removal from the waterway.
	Permanent disposal	Cutterhead suction dredge; hopper dredge; mechanical excavator	Permanent sediment disposal may include confined upland disposal, non-wetland beneficial use, ocean dredge material dump site.

PD Requirements: Determination of Dredging
The project description must include the following: **PDR.34** Statement regarding whether dredging is included in the baseline scenario. **PDR.35** If dredging is included in the baseline scenario, a description of the single event or programmatic dredging projects, including the likely fate of dredged sediments in the baseline scenario.

6.2.1 Determining Navigability of Dredge Site Waterway

The project proponent must demonstrate whether navigation or maintenance dredging would have occurred in the baseline. Acceptable documents for demonstrating dredging would have occurred may include but are not limited to a Section 10 permit (River and Harbors Act 1899) or Dredge Material Management Plan (USACE) or interagency project documents that provide descriptions or authorization for project-specific or routine operations (eg, Beneficial Use of Dredge Material, BUDMAT).

If navigation or maintenance dredging in the baseline cannot be demonstrated, then baseline emissions from energy consumption must be zero per Section 8.1.1.

PD Requirements: Demonstration of Navigability
The project description must include the following if navigation or maintenance dredging can be demonstrated in the baseline scenario: **PDR.36** Map of dredging activities, including justification for planned dredging locations. **PDR.37** Documents that demonstrate dredging would have occurred.

6.2.2 Determining Energy Consumption for Dredging

When dredging occurs in the baseline scenario for navigation or maintenance, the project proponent must estimate the energy types and quantities used for dredging. For each energy type in Table 10, the project proponent must estimate the unit of energy consumed per metric tonne of sediment removed from the sediment source in the baseline scenario. These estimates must be based on private industry or federal cost-engineering procedures or data. These estimates may include energy consumption from dredging, transport, disposal and re-handling of sediment. The assumptions of equipment type(s), sediment production rates, duration of operations, and conveyance distances must be used to justify these estimates.

The project proponent must use conservative assumptions when determining these estimates. In the baseline scenario, low estimates of energy consumption for dredging are more conservative than high estimates.

The set of all energy types in the baseline scenario is denoted $\mathcal{T}_{B\ EC}$ and the unit of energy consumed per metric tonne of sediment removed from the sediment source for energy type (ty) is denoted by $g_{B\ EC\ (ty)}$ (see Section 8.1.1).

PD Requirements: Determination of Baseline Energy Consumption
The project description must include the following: **PDR.38** For each energy type in Table 10, the estimate of the unit of energy consumed per metric tonne of sediment dredged. **PDR.39** Description of equipment types and method or process of sediment dredging, transport, disposal, re-handling, sediment production rates, duration of operations and conveyance distances. **PDR.40** Estimates of cumulative sediment quantity excavated and re-handled, including temporary disposal and displacement activities, if applicable. **PDR.41** Source of procedures or data on which these estimates are based.

6.3 Determining Methane Emissions in Baseline Scenario

Methane ebullition, or bubbling from sediments, sometimes occurs in open water and may increase the GHG emissions associated with the baseline scenario in which the project area remains open water. It is optional to include emissions from methane ebullition in the baseline scenario. If baseline emissions from methane ebullition are included, the project proponent must monitor such emissions in an area of open water – referred to as a reference area – located near the project area and with environmental conditions similar to those found in the project area prior to the start of wetland creation activities (see Section 6.3.1). Methane emissions must then be monitored in the reference area (see Section 9.2.7).

6.3.1 Delineating Reference Area Boundaries

If emissions from methane ebullition are included in the baseline scenario, the project proponent must define a reference area in which emissions flux from ebullition is measured and demonstrate that the reference area is similar to the project area with respect to the following criteria:

a. Hydrologically and biogeochemically similar to the project area:

   i. Must meet the definition of open water, with no soil exposed during normal tidal cycle,

ii. Must be devoid or mostly devoid of vegetation,

iii. Must exhibit similar salinity and presence or absence of tidal influence, and

iv. Must be similar with respect to presence or absence of external nitrate loading (see Section 9.2.3.1).

b. Similar landscape configuration with respect to proximity to river delta(s), specifically if the project area is not within a delta, the reference area must not be located within a delta.

c. Soil type of similar substrate to the project area as of the project start date, specifically the soils must be classified as the same *Soil Series* as reported by the USDA NRCS Soil Survey; or if the *Soil Series* is different, then the percent organic matter of the upper 30cm of soil must occur within a common range.

d. Constrained to a minimum water depth no less than the minimum depth in the project area.

Furthermore, water depth must be recorded at each sample point. The average depth of these measurements must be at least as deep as the average depth measured in the project area as of the project start date.

Measurements in the reference area are described in Section 9.2.7.

PD Requirements: Determination of Baseline Methane Emissions
The project description must include the following: **PDR.42** Description and justification for the selected reference area.

6.4 Reevaluating the Baseline Scenario

The baseline scenario must be reevaluated every ten years in accordance with the VCS rules. The baseline reevaluation must meet the requirements in Section 6.1. If new project activity instances have been added in the case of a grouped project, the reevaluation must meet the requirements in Section 6.2.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

This methodology uses an activity method for the demonstration of additionality. Project activities that meet the applicability conditions of this methodology (see Section 4) and demonstrate regulatory surplus are deemed as additional.

7.1 Regulatory Surplus

Project proponents must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the *VCS Standard*.

PD Requirements: Demonstration of Project Additionality
The project description must include the following: **PDR.43** Demonstration that pertinent laws and regulations have been reviewed and that none mandate the project activities.

7.2 Positive List

The applicability conditions of this methodology represent the positive list. The project must demonstrate that it meets all of the applicability conditions, and in so doing, it is deemed as complying with the positive list.

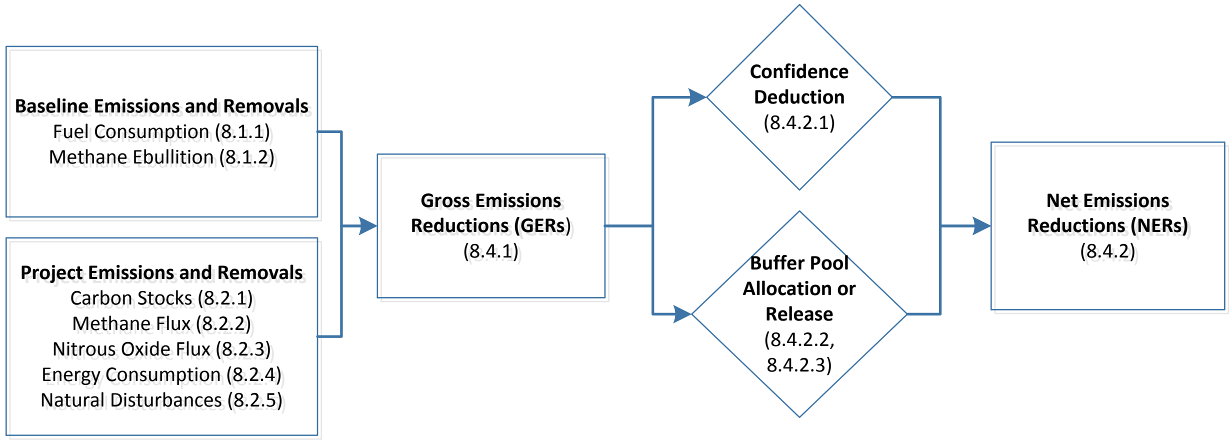
The positive list was established using the activity penetration option (Option A in the *VCS Standard*). Demonstration of additionality following this approach is set out in Appendix H – Supporting Information on Development of Positive List.

PD Requirements: Demonstration of Project Additionality
The project description must include the following: **PDR.44** Evidence that project activities comply with all applicability conditions set out under Section 4 above.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

The project proponent must calculate gross emissions reductions and/or removals (GERs) in each monitoring period. GERs are calculated by subtracting project emissions or emissions reductions and/or removals from baseline emissions. The project proponent must then calculate net emissions reductions and/or removals (NERs) by taking into account a confidence deduction (if any) and buffer pool allocation.

Cumulative GERs and NERs are quantified as those since the project crediting period start date up to the end of the monitoring period. Current GERs and NERs are quantified as those since the end of the previous monitoring period to the end of the monitoring period.



When quantifying GHG emissions reductions and removals, the project proponent must note the difference between units and resolution of monitoring data described in Section 2.5.

8.1 Baseline Emissions

Baseline emissions $E_{B\,\Delta}^{[m]}$ for the monitoring period are given by equation [G.6], equal to the sum of baseline emissions from energy consumption and emissions from methane ebullition for the monitoring period. Note that $E_{B\,\Delta}^{[m]}$ is always less than or equal to zero.

Monitoring Requirements: Baseline Emissions
The monitoring report must include the following: **MRR.12** Calculations of current baseline emissions $E_{\mathrm{B}\,\Delta}^{[m]}$ for the (current) monitoring period. **MRR.13** Calculations of baseline emissions $E_{\mathrm{B}\,\Delta}^{[m-1]}$ for prior monitoring periods.

8.1.1 Calculating Emissions from Energy Consumption

Baseline emissions from energy consumption are given by equation [G.3] where $g_{B\,(ty)}^{[m]}$ is the energy consumed per metric tonne of sediment dredged in the baseline using energy type (ty), and $M_{P\,\Delta}^{[m]}$ is the mass of sediment dredged from the sediment source as a result of project activities during the monitoring period. Note that, since $E_{B\,\Delta\,EC}^{[m]}$ is an emission, its value is always less than or equal to zero.

The energy consumed per metric tonne of sediment dredged in the baseline is determined in Section 6.2.2. The mass of sediment dredged from the sediment source is determined each monitoring period using Section 9.2.5.

The emissions coefficients $e_{(ty)}$ for each energy type are given in Table 10. Energy emissions coefficients for fuels are defined by the EPA Final Mandatory Reporting of Greenhouse Gases Rule, while electricity emissions are determined using the most recent U.S. EPA eGRID database. For both, it is important to note that these factors are updated periodically and that the factor which is applicable for the year in which the emissions occurred must be used. Refer to Appendix M for documentation and sources of the emission coefficients listed in Table 10.

Table 10: Emissions coefficients (including CO_2, CH_4, N_2O) for energy types

Energy Type (ty)	Project Proponent Reports As:	Emission Coefficient $\boldsymbol{e_{(ty)}}$
Diesel	Gal	0.010241 tCO_2e / gal
Motor gasoline	Gal	0.008809 tCO_2e / gal
Biodiesel	Gal	0.009459 tCO_2e / gal
Compressed natural gas	Scf	0.000055 tCO_2e / scf
Electric grid	kWh	eGRID regional emission factor (tCO_2e/kWh)

Monitoring Requirements: Emissions Coefficients
The monitoring report must include the following if an emission coefficient is used for the electric grid: **MRR.14** Source and date of the emission coefficient. **MRR.15** Reference to the exact page number or worksheet cell in the source.

8.1.2 Calculating Emissions from Methane Ebullition

If baseline emissions from open water methane ebullition are included in the project accounting, these emissions $\boldsymbol{E_{B\,\Delta\,CH4}^{[m]}}$ are calculated using equation [G.5] and are expressed in units of tCO_2e. These emissions are the product of the daily flux and the number of days in the monitoring period. Note that, since $E_{B\,\Delta\,CH4}^{[m]}$ is an emission, its value is always less than or equal to zero.

8.2 Project Emissions or Emission Reductions and/or Removals

Project emissions or emission reductions and/or removals $E_{P\,\Delta}^{[m]}$ for the monitoring period are given by equation [G.15], equal to emissions or emission reductions and/or removals from change in carbon stocks, nitrous oxide, methane and energy consumption resulting from the implementation of project activities.

Project emissions will occur if the flux emissions and emissions from energy consumption are greater than carbon accretion for the monitoring period, in which case $E_{P\,\Delta}^{[m]}$ will be negative. Likewise, project emission removals will occur if carbon accretion is greater than flux emissions and emissions from energy consumption, in which case $E_{P\,\Delta}^{[m]}$ will be positive.

Monitoring Requirements: Project Emissions or Emission Reductions and/or Removals
The monitoring report must include the following: **MRR.16** Calculations of current project emissions or emissions reductions and/or removals $E_{P\,\Delta}^{[m]}$ as of the monitoring period. **MRR.17** Calculations of project emissions or emissions reductions and/or removals $E_{P\,\Delta}^{[m-1]}$ from prior monitoring periods.

8.2.1 Calculating Emission Removals in Carbon Stocks

Carbon stocks must be monitored during the project crediting period to calculate the GHG emissions or removals that occur as a result of project activities. Current emissions or emissions reductions and/or removals from carbon stocks $E_{P\,\Delta\,CS}^{[m]}$ are defined as the difference between carbon stocks from the prior monitoring period and carbon stocks from the monitoring period as given in equation [G.8] for a project that is not grouped and equation [G.9] for a grouped project; carbon stock estimates are derived from methods described in Section 9.2.1. Note that $E_{P\,\Delta\,CS}^{[m]}$ is positive if vegetation growth has occurred and carbon stocks have not been reduced by disturbances.

8.2.2 Calculating Emissions from Methane

Project emissions from methane $E_{P\,\Delta\,CH4}^{[m]}$ are calculated using equation [G.11] and are expressed in units tCO_2e. These emissions are the product of the daily flux and the number of days in the monitoring period. Note that, since $E_{P\,\Delta\,CH4}^{[m]}$ is an emission, its value is less than or equal to zero.

8.2.3 Calculating Emissions from Nitrous Oxide

Project emissions from nitrous oxide $E_{P\,\Delta\,N2O}^{[m]}$ are calculated using equation [G.13] and are expressed in units tCO_2e. These emissions are the product of the daily flux and the number of days in the monitoring period, as described in Section 9.2.2. Note that, since $E_{P\,\Delta\,N2O}^{[m]}$ is an emission, its value is less than or equal to zero.

8.2.4 Calculating Emissions from Energy Consumption

Project emissions from energy consumption are given by equation [G.14], the total energy consumed as a result of project activities. Energy use and type must be monitored per Section 9.2.4. The emissions coefficients $e_{(ty)}$ for each energy type are given in Table 10 found in Section 8.1.1. Note that, since $E_{P\,\Delta\,EC}^{[m]}$ is an emission, its value is less than or equal to zero.

8.2.5 Calculating Emissions from Disturbances

Emissions from natural disturbances and other events within the project area are inherently captured by the monitoring of carbon stocks (see Section 9.2.1). The project area must be monitored regularly for evidence of significant disturbance. The following disturbance events may be significant:

- Hurricanes
- Fires
- Marsh dieback

For guidance on how to define a significant disturbance, project proponents should refer to the definition of *loss event* in the current version of the *VCS Program Definitions.*

In the event that a significant disturbance is apparent, the project proponent must document the nature and extent of the disturbance and, if necessary, re-measure existing plots or install new plots in the disturbed area. In order to estimate these carbon stocks, the project area may need to be re-stratified per Appendix A as part of monitoring (see Section 9). If the disturbance is likely to qualify as a loss event, the loss event must be reported in accordance with VCS rules.

If re-stratification is necessary, the new strata must be effective as of the date of the disturbance, thus ensuring that the stratification accurately represents conditions in the project area.

PD Requirements: Emissions or Emissions Reductions and/or Removals Events in Project Area
The project description must include the following: **PDR.45** The selected definition of a significant disturbance.

Monitoring Requirements: Emissions or Emissions Reductions and/or Removals Events in Project Area
The monitoring report must include the following: **MRR.18** The selected definition of a significant disturbance. **MRR.19** A map of the boundaries of any significant disturbance in the project area during the monitoring period. **MRR.20** Evidence that plots were installed into these disturbed areas and were measured per Section 9.2.1.

8.3 Leakage

8.3.1 Determining Activity-Shifting Leakage

Activity-shifting leakage is zero because the project area continues to be open water in the baseline scenario, and wetland creation does not materially change the land use activities outside of the project area. Thus, leakage from shifting livestock, agricultural activities or communities cannot occur. Further, dredging emissions occur in both the baseline and project scenarios and as such are not considered as leakage emissions from machinery.

8.3.2 Determining Market-Effects Leakage

Market-effects leakage is zero as there is no commercial value to the baseline scenario of open water. As a result, no change in supply and demand can exist, nor can shift in production exist elsewhere outside of the project area.

8.3.3 Demonstrating No Ecological Leakage

As a result of adding sediment to the project area during wetland creation, the watershed-scale hydrology could be affected. These effects could cause displacement of water (either standing or flowing) to areas not inundated prior to the project start date. The project proponent must demonstrate that the project will not have a significant negative impact on hydrologically connected areas, and therefore, that there will be no ecological leakage.

In order to demonstrate that the project will not have a significant negative impact on hydrologically connected areas, the project proponent must demonstrate compliance with Section 404 of the Clean Water Act by providing an individual or general permit issued by the USACE, prior to the completion of the first verification event. Where applicable, compliance with Section 10 of the Clean Water Act (River and Harbors Act) must also be demonstrated. Likewise, any NEPA analyses and decision documents must be provided (ie, a Finding of No Significant Impact [FONSI] for an Environmental Assessment or a Record of Decision [ROD] for an Environmental Impact Statement), where applicable.

Where the project proponent demonstrates that the project will not have a significant negative impact on hydrologically connected areas in accordance with the requirements above, ecological leakage is considered to be zero.

PD Requirements: Hydrologic Effects
The project description must include the following: **PDR.46** Where possible at validation, demonstration that the project will not have a significant negative impact on hydrologically connected areas, in accordance with the requirements of Section 8.3.3.

Monitoring Requirements: Hydrologic Effects
The monitoring report must include the following: **MRR.21** Demonstration that the project will not have a significant negative impact on hydrologically connected areas, in accordance with the requirements of Section 8.3.3, where same has not already been demonstrated at validation.

8.4 Summary of GHG Emission Reduction and/or Removals

The GHG emissions reductions resulting from the project activities are quantified in two steps: Gross Emissions Reductions (GERs) and Net Emissions Reductions (NERs), Sections 8.4.1 and 8.4.2, respectively. The quantity of NERs are those that are available for retirement or sale, and are GERs minus a confidence deduction (Section 8.4.2.1) and allocation to the AFOLU pooled buffer account (Section 8.4.2.2), plus a buffer release (Section 8.4.2.3). The quantity of GERs is the difference between baseline and project emissions or emissions reductions and/or removals.

8.4.1 Quantifying Gross Emission Reductions and/or Removals

Gross Emissions Reductions (GERs) for a monitoring period $[m]$ are quantified using equation [G.16] and are equal to the total baseline emissions over the monitoring period minus the total project emissions or emissions reductions and/or removals over the monitoring period.

Monitoring Requirements: Quantification of GERs	
The monitoring report must include the following:	
MRR.22	Quantified GERs for the monitoring period including references to calculations.
MRR.23	Quantified GERs for the prior monitoring period.
MRR.24	A graph of GERs by monitoring period for all monitoring periods to date.

8.4.1.1 Handling Reversals Resulting from Energy Consumption

In the event that quantified GERs are negative – indicating that project emissions or emissions reductions and/or removals are greater than baseline emissions – and that the cause of this event is the consumption of energy by project activities, the project must not generate NERs until cumulative GERs $E_{GER}^{[m]}$ are greater than zero per equation [G.17]. Note that although cumulative GERs may be greater than zero, a reversal may still occur.

8.4.2 Quantifying Net Emissions Reduction and/or Removals

Net Emissions Reductions (NERs) are equivalent to quantified GERs less a confidence deduction (if any) and AFOLU pooled buffer account allocation. NERs generated during a monitoring period $[m]$ are determined using equation [G.21]. Quantified NERs should be rounded down to the nearest whole number.

Monitoring Requirements: Quantification of NERs	
The monitoring report must include the following:	
MRR.25	Quantified NERs for the monitoring period including references to calculations.
MRR.26	Quantified NERs for the prior monitoring period.
MRR.27	A graph of NERs by monitoring period for all monitoring periods to date.

8.4.2.1 Calculating the Confidence Deduction

The confidence deduction $E_{U\,\Delta}^{[m]}$ is given by equation [G.19] where uncertainty in the estimate of the total carbon stock is given by equation [G.18], the sum of squared-uncertainty in all selected carbon pools $\mathcal{C}$. If the monitoring plan specifies a different sampling design, equations for uncertainty will differ for biomass and soil (see Section 9).

Uncertainty is calculated solely on the basis of the carbon stock estimate and does not include uncertainty in the measurements of methane and nitrous oxide. Although estimates of methane and nitrous oxide flux are uncertain, the flux measurement methods set out in in this methodology (Sections 9.2.2 and 9.2.3) are designed to provide conservative (ie, high) estimates of project emissions or emissions reductions and/or removals from these GHG sources. Thus, the uncertainty associated with an unbiased estimate of these fluxes is expected to be negligible when compared to the intentional difference between these estimates and the true (but unknown) fluxes. Therefore, the confidence deduction does not include uncertainty from methane or nitrous oxide estimates.

The confidence deduction must be greater than or equal to zero. If the result from equation [G.19] is less than zero, the confidence deduction must be set to zero.

Monitoring Requirements: Confidence Deduction	
The monitoring report must include the following:	
MRR.28	The calculated confidence deduction and supporting calculations.
MRR.29	Any methodology deviations. Such deviations must include the text that is being modified and the proposed new language.

8.4.2.2 Determining Allocation to AFOLU pooled buffer account

The project proponent must undertake an assessment of non-permanence risks that apply to the project. This assessment must conform to current VCS requirements and must be used to determine the allocation of GERs to the AFOLU pooled buffer account. GERs allocated to the AFOLU pooled buffer account are denoted by $E_{BA\,\Delta}^{[m]}$ as given in equation [G.20] and must be based on the change in carbon stocks for the monitoring period as described in Section 8.2.1. GERs allocated to the AFOLU pooled buffer account must be rounded up to the nearest whole number.

Monitoring Requirements: AFOLU pooled buffer account	
The monitoring report must include the following:	
MRR.30	Reference to the VCS requirements used to determine the AFOLU pooled buffer account allocation.
MRR.31	Reference to calculations used to determine the AFOLU pooled buffer account allocation.

8.4.2.3 Determining Release from AFOLU pooled buffer account

Periodically, the project may be eligible for a release of credits from the AFOLU pooled buffer account. The buffer release $E_{BR\,\Delta}^{[m]}$ must be determined in accordance with VCS requirements.

Monitoring Requirements: Buffer Release	
The monitoring report must include the following:	
MRR.32	Reference to the VCS requirements used to determine the release from the AFOLU pooled buffer account.
MRR.33	Reference to calculations used to determine the buffer release.

8.4.2.4 Quantifying Vintages over a Monitoring Period

When the monitoring period spans more than one calendar year, NERs must be allocated by year, proportional to the number of calendar days in each year relative to the total number of days in the monitoring period. Quantified NERs should be rounded to the nearest whole number for each vintage year such that the sum of vintages in each monitoring period is equal to the NERs for that monitoring period.

Monitoring Requirements: Vintages
The monitoring report must include the following: **MRR.34** Quantified NERs by vintage year for the monitoring period including references to calculations.

8.4.3 Estimating Ex-Ante GHG Emission Reductions and/or Removals

To calculate ex-ante estimates of greenhouse gas reductions and removals, use the steps outlined in Section 8, substituting estimates of parameters that require monitoring with conservative estimates of those parameters derived from scientific literature or preliminary sampling as applicable. The following table lists the parameters required and provides guidance for estimating ex-ante project benefits in a conservative fashion. Note that derived quantities are not shown in this table.

Data / Parameter	Unit	Description	Ex-Ante Source of Data	Guidance for Conservative Estimation
$b^{[m]}$	Unit-less	Buffer withholding percentage calculated as required by the VCS AFOLU Non-Permanence Risk Tool	VCS AFOLU Non-Permanence Risk Tool	The non-permanence risk tool is to be applied at validation, therefore the value of $b^{[m]}$ should be known.
$C_{P\ CS}^{[m]}$	tCO_2e	Cumulative carbon stocks in project area for monitoring period	Scientific literature or preliminary sampling in areas of past wetland creation	It is conservative to underestimate carbon stocks.
$E_{P\ \Delta\ N2O}^{[m]}$	tCO_2e	Total emissions for nitrous oxide in project area over monitoring period	Select appropriate estimates from the tables given in Section 8.4.3.2	NA
$E_{P\ \Delta\ CH4}^{[m]}$, $E_{B\ \Delta\ CH4}^{[m]}$	tCO_2e	Total methane emissions in project area over monitoring period	Scientific literature or preliminary sampling	It is conservative to overestimate methane emissions in the project scenario.
$E_{BR\ \Delta}^{[m]}$	tCO_2e	Buffer release	See current VCS requirements	
$e_{(ty)}$	tCO_2e/gal	Emissions coefficient from Table 10 in Section 8.1.1 for energy type ty	Apply coefficients as given in Table 10	NA
$p_{B\ (ty)}$	unitless	Proportion of energy for energy type ty consumed in the baseline scenario	Records of past energy use for similar activities	It is conservative to assume that energy types with lower emission factors would have been used predominantly in the baseline scenario.
$p_{P\ (ty)}$	unitless	Proportion of energy for energy type ty consumed in the project scenario	Records of past energy use for similar activities	It is conservative to assume that energy types with higher emission factors would have been used predominantly in the project scenario.

Data / Parameter	Unit	Description	Ex-Ante Source of Data	Guidance for Conservative Estimation
U_s	tCO_2e	Standard error for a set of strata	Guidance from Appendix A may be used to plan sampling that is likely to meet a targeted precision level	See Appendix A

8.4.3.1 Determining Whether Emissions from Methane are *de minimis*

In systems with high salinity (>18 ppt), methane emissions may be *de minimis*. Such emissions are considered *de minimis* if, together with any other sources which may be *de minimis*, they account for less than 5% of the total GHG benefit generated by the project. The project proponent may choose one of the following methods to demonstrate that methane emissions are *de minimis*:

1. Models from literature (see Section 9.2.2.1)
2. Proxy models (see Section 9.2.2.2)
3. Direct measurements (see Section 9.2.2.3)

8.4.3.2 Determining Whether Emissions from Nitrous Oxide are *de minimis*

In systems without nitrate loading, nitrous oxide emissions may be *de minimis*. Such emissions are considered *de minimis* if, together with any other sources which may be *de minimis*, they account for less than 5% of the total GHG benefit generated by the project. The project proponent may choose one of the following methods to demonstrate that nitrous oxide emissions are *de minimis*:

1. Default factors (see Section 9.2.3.1)
2. Proxy models (see Section 9.2.3.2)
3. Direct measurements (see Section 9.2.3.3)

8.4.4 Evaluating Project Performance

Project performance must be evaluated each verification event and deviations from *ex-ante* NERs must be described. Differences in credit generation from *ex-ante* estimates may result from changes in the quality of data (literature estimates versus carbon stock estimates), changes in measurement approaches, occurrences of disturbance events or baseline re-evaluation.

Monitoring Requirements: Project Performance
The monitoring report must include the following: **MRR.35** Comparison of NERs presented for verification relative to those from *ex-ante* estimates. **MRR.36** Description of the cause and effect of differences from *ex-ante* estimates.

9 MONITORING

Project proponents must monitor the applicable GHG sources and selected carbon pools identified for the project (see Section 5.1 and Section

5.2). Table 11 provides a step-by-step summary of the monitoring program. Given that multiple GHG sources must be monitored across multiple carbon pools, it is likely that stratification of the project area will improve sampling efficiency and overall monitoring costs (see Section 9.1). Thus, stratification is performed prior to any field measurements.

The project proponent must then develop a monitoring plan to guide monitoring activities. The methods for measuring and estimating carbon stocks and gas fluxes described in the monitoring plan must adhere to the requirements provided in Section 9.2. The monitoring plan must be implemented in the first monitoring period and must guide ongoing monitoring for the duration of the project crediting period.

Using the monitoring plan as a guide, the values of data and parameters identified in Sections 9.3 and 9.4 must be reported in the project description (PD) or monitoring report (MR). When monitoring carbon stocks and fluxes, the project proponent must note the difference between accounting units (typically tCO_2e/day) and the frequency and interval monitoring activities (see Section 2.5).

Finally, grouped projects must report additional information in the Monitoring Report per Section 9.5.

Table 11: Stages of the monitoring program

Development Task	Selection of GHG sources and carbon pools →	Stratification →	Monitoring plan →	Monitoring activities
Key Activities	Identify applicable GHG sources. Select carbon pools for measurement and accounting. Determine which sources are *de minimis*, if any	Stratify project area to focus monitoring effort and reduce costs.	Develop sampling methods and procedures. Schedule dates and locations of monitoring events. Develop methods for storing, auditing and reporting monitoring data.	Perform monitoring activities. Synthesize and report monitoring data. In the event of a significant disturbance, re-stratify per Section 8.2.5 as described in Sections 9.1 and 9.2.1.2.
Section of Methodology	5.1 and 5.2	9.1 and 9.2.1.2	9.2	9.2, 9.3 and 9.4

In the case of a methodology deviation, alternative criteria and procedures relating to monitoring and measurement must still meet the requirements of Section 9.2.

9.1 Stratification

Stratification is recommended for the direct measurement of carbon stocks, and is required for the direct measurement of methane and nitrous oxide fluxes. Appendix A provides general guidelines for stratifying the project area, including guidance on allocating sampling and measurement units within strata. Different stratification systems may be used for estimating different emissions or emissions reductions and/or removals from different GHG sources.

In the case of direct measurement of carbon stocks, stratification may be used to improve sampling efficiency and thereby reduce the effort and costs associated with monitoring. In particular, stratification is likely to reduce the uncertainty of population estimates within each stratum, which often will reduce the number of plot measurements needed to meet VCS precision requirements.

For methane and nitrous oxide fluxes, stratification is used to identify the stratum that is likely to yield the greatest flux of each gas on an annual basis. The project proponent must measure the identified stratum for each gas. If desired, other strata may be measured as well.

In order to further streamline monitoring activities, in cases where the project proponent encounters a very small stratum (eg, a tidal channel that becomes established naturally within the project area), it is permissible to combine the stratum with another stratum with higher estimated emissions flux per unit of area. In the event that the very small stratum is combined with another stratum with lower estimated emissions flux per unit area, the project proponent must show that the difference in emissions is expected to be *de minimis*.

9.1.1 Multiple Flux Monitoring Methods in Strata

The project proponent may select one method for monitoring methane or nitrous oxide emissions fluxes across all strata (as described in Sections 9.2.2 and 9.2.3). Alternatively, the project proponent may choose to apply different methods to different strata.

For example, the project proponent may choose to use a well-accepted model to predict methane flux in a stratum that is well-vegetated (provided the project proponent can demonstrate the requirements of Section 9.2.2.1) and chamber measurements to directly measure methane flux elsewhere. Per Sections 9.2.1.2 and 9.2.1.3, the project proponent then allocates the chambers to the stratum and locations within the stratum that will likely yield the greatest methane flux over the course of the year.

The project proponent must clearly indicate in the monitoring plan the methods that are to be used and to which stratum each is to be applied (see Section 9.2).

The project proponent must use a stratum-area weighted average to calculate emissions fluxes for the purpose of accounting in Section 8.

9.2 Description of the Monitoring Plan

The project proponent must develop a monitoring plan to guide monitoring activities. The monitoring plan must include a description of measurement methods and procedures and an approximate schedule indicating when the project proponent will perform each monitoring activity throughout the entire project crediting period. The monitoring plan must include the following:

1. The purpose of monitoring;
2. Sampling procedures for carbon stocks and fluxes;
3. Anticipated dates and locations for sampling over a five-year period;
4. Organizational structure, responsibilities and competencies of individuals and organizations responsible for monitoring;
5. Methods for generating, recording, storing, aggregating, collating and reporting data per Sections 9.2.1, 9.2.2 and 9.2.3; and
6. Methods for internal auditing and handling of any identified non-conformities to the monitoring plan.

The schedule for monitoring activities must be based upon the guidance provided in this methodology for the frequency of measurement for the applicable GHG sources.

Table 12: Approximate schedule of monitoring activities by GHG source

<table>
<tr><th colspan="2"></th><th>First verification</th><th>Years 1-10 after first verification</th><th>Years 11 + after first verification</th></tr>
<tr><td colspan="2">Carbon stocks (9.2.1.4)</td><td>All plots measured.</td><td>All plots measured at least once. May ‘cycle’ through a portion of plots each year.</td><td>All plots measured at least once every 5 years. May ‘cycle’ through a portion of plots each year.</td></tr>
<tr><td rowspan="2">Methane</td><td>Project (9.2.2.4)</td><td>Flux measured regardless of monitoring method.</td><td colspan="2">Model from literature: No direct measurements. Assess applicability of methods at each verification event.
Proxy model: Direct measurement of covariates every monitoring period.
Direct measurement: Flux measured every year. (Chamber method: at least 2 measurement events per year; eddy covariance method: at least 21 days of measurements per year)</td></tr>
<tr><td>Baseline (9.2.7)</td><td>Flux measured regardless of monitoring method.</td><td colspan="2">(same as above)</td></tr>
<tr><td colspan="2">Nitrous oxide (9.2.3.4)</td><td>Flux measured regardless of monitoring method.</td><td colspan="2">Model from literature: No direct measurements. Assess applicability of methods at each verification event.
Proxy model: Direct measurement of covariates every monitoring period.
Direct measurement: Flux measured every year. (at least 12 measurement events; see Section 9.2.3.4)</td></tr>
</table>

PD Requirements: Monitoring Plan
The project description must include the following: **PDR.47** A summary of carbon stock sampling procedures for the project area, with a copy of a sampling protocol used by field personnel to carry out measurements. **PDR.48** A summary of flux measurement procedures for the project area, with a copy of a flux measurement protocol used by field personnel to carry out measurements. **PDR.49** A reference to the monitoring plan. **PDR.50** Any methodology deviations. Such deviations must include the text that is being modified and the proposed new language.

Monitoring Requirements: Monitoring Plan	
The monitoring report must include the following:	
MRR.37	Documentation of training for field measurement crews.
MRR.38	Documentation of data quality assessment.
MRR.39	References to plot allocation for carbon stock measurement.
MRR.40	List of plot geodetic coordinates for plots and flux measurement devices.
MRR.41	Description and diagram of flux measurements devices for methane and/or nitrous oxide.
MRR.42	The estimated carbon stock, standard error of the total for each stock, and the sample size for each stratum in the project area.
MRR.43	Any methodology deviations. Such deviations must include the text that is being modified and the proposed new language.
MRR.44	Frequency of monitoring for each plot and flux measurement location – all carbon stock plots must be measured for the first verification.

9.2.1 Monitoring Project Carbon Stocks

Carbon stocks must be monitored prior to the first verification, at least once within 10 years after the first verification, and at least once every 5 years thereafter, and not necessarily at every verification event. Total carbon stock for the selected carbon pools is calculated using equation [G.7].

9.2.1.1 Requirements for First Verification

At the first verification, carbon stocks prior to the project start date must be estimated, denoted as $C_P^{[m=0]}$, using equation [G.7]. If plots were not installed prior to the project start date, stratification from aerial imagery may be required to estimate $C_P^{[m=0]}$ (see Section 9.2.1.2).

All plots must be measured at the first verification.

9.2.1.2 Requirements for Stratification

Stratification may be used to improve sampling efficiency, and may be required to estimate carbon stocks prior to the first monitoring period (see Section 9.2.1.1). Appendix A provides general guidelines for stratifying the project area, including guidance on allocating measurement units within strata. For measurements of carbon stocks, some strata may not be measured if these areas can conservatively be assumed not to accumulate soil or biomass carbon stock. For example, an aerial photo may be used to delineate unproductive areas in which minimal above ground biomass has accumulated in a given monitoring period. Rather than allocating sample units to these strata, the project proponent may conservatively assume that these areas have a stock of zero, focusing sampling efforts on areas that have more substantial biomass accumulation.

Strata boundaries may change over time to improve carbon stock estimates.

PD Requirements: Stratification
The project description must include the following if stratification is not elected for either biomass or SOC: **PDR.51** Justification for not stratifying carbon stocks.

9.2.1.2.1 Stratification for SOC

When estimating soil carbon stocks, the project proponent may stratify the project area according to factors such as water depth, elevation or relative terrain position, soil type maps, or vegetation cover. A map of all identified strata and their areas must be reported as well as the allocation of plots within each stratum.

PD Requirements: Stratification for SOC
The project description must include the following if the project area is stratified: **PDR.52** Description for how the strata were delineated. **PDR.53** Map(s) of the initial strata boundaries.

Monitoring Requirements: Stratification for SOC
The monitoring report must include the following if the project area is stratified: **MRR.45** Map(s) of the current strata boundaries. **MRR.46** A description of changes to the strata boundaries (if applicable).

9.2.1.2.2 Stratification for Biomass

When estimating biomass carbon stocks, the project proponent may stratify the project area according to factors such as vegetation type; age, stocking, or vegetation density; site quality; elevation or relative terrain position. A map of all identified strata and their areas must be reported as well as the allocation of plots within each stratum.

PD Requirements: Stratification for Biomass
The project description must include the following if the project area is stratified: **PDR.54** Description for how the strata were delineated. **PDR.55** Map(s) of the initial strata boundaries.

Monitoring Requirements: Stratification for Biomass
The monitoring report must include the following if the project area is stratified: **MRR.47** Map(s) of the current strata boundaries. **MRR.48** A description of changes to the strata boundaries (if applicable)

9.2.1.3 Direct Measurement for Stock Change

The project proponent must take direct measurements of biomass and SOC. The project proponent must use the protocols prescribed in Appendix D and Appendix E as the basis for carbon stock measurement in the monitoring plan.

The project proponent must describe the methods for allocating plots to strata and within strata.

PD Requirements: Measuring Carbon Stocks
The project description must include the following: **PDR.56** Method for allocating plots to stratum. **PDR.57** Description of plot sizes and layout (such as the use of nests and their sizes) for each carbon pool.

Monitoring Requirements: Measuring Carbon Stocks
The monitoring report must include the following: **MRR.49** Method for allocating plots to stratum. **MRR.50** Map of the location of plots within strata. **MRR.51** Description of plot sizes and layout (such as the use of nests and their sizes) for each carbon pool.

9.2.1.3.1 Soil Plot Design

Permanent plots must be randomly allocated in the project area. Artificial marker horizons (feldspar or other technique) may be used to define the original project soil surface after the implementation of project activities. The project proponent must specify the maximum soil sample depth, which will be fixed for the life of the project.

PD Requirements: Soil Plot Design
The project description must include the following: **PDR.58** Diagram of a soil plot showing the locations of artificial marker horizons and core samples within the plot over time. **PDR.59** Description of the fixed soil sample depth.

Monitoring Requirements: Soil Plot Design
The monitoring report must include the following: **MRR.52** For each measured soil plot, a diagram showing the location of installed artificial marker horizons and sampled cores. **MRR.53** Field report describing soil sample depths (accretion depth and fixed soil sample depth) and coring devices used to collect samples. The report must also include number of soil samples and their identification in a chain of custody form submitted to the laboratory.

9.2.1.4 Frequency of Measurement

All plots must be measured at the first verification. For the remainder of the project crediting period, carbon stocks must be monitored at least once within the next 10 years and at least once every five years thereafter, and not necessarily at every verification event. The project proponent may choose to 'cycle' through a portion of measurement plots over the five-year period.

PD Requirements: Frequency of Carbon Stock Measurements	
The project description must include the following:	
PDR.60	The anticipated frequency of monitoring for each plot and flux measurement location – all carbon stock plots should be measured for the first verification.

Monitoring Requirements: Frequency of Carbon Stock Measurements	
The monitoring report must include the following:	
MRR.54	List of plots measured during the monitoring period – all carbon stock plots should be measured for the first verification.

9.2.2 Monitoring Project Methane Flux

In the project case, methane flux $F^{[m]}_{P\,\Delta\,CH4}$ must be monitored using one of three approaches: models taken from peer reviewed scientific literature (Section 9.2.2.1), proxy methods developed by the project proponent (Section 9.2.2.2) or direct measurement of flux from the project area (Section 9.2.2.3). All three approaches result in an estimate of flux in units of tCO_2e/day, which is then used in equation [G.11] to predict emissions as a result of project activities (see Section 8.2.2). Specific field methods for measuring methane flux are described in Appendices B and C.

In deciding which monitoring approach to use, keep in mind that direct measurement is usually the most demanding in terms of time and cost. If the project proponent is able to identify a model that meets the requirements herein, it will likely be the most efficient method.

Once an approach is selected, it cannot be changed after the first verification event unless it is being changed to direct measurement.

PD Requirements: Monitoring Methane
The project description must include the following: **PDR.61** The selected approach for monitoring methane.

9.2.2.1 Models from Literature

Methane flux may be predicted using a process model or proxy model selected from peer-reviewed scientific literature but only after the model has been demonstrated to be applicable to the project area. In selecting a model and demonstrating that it is applicable to the project area, the project proponent must do the following:

1. Provide a description of the model that includes references to key technical papers and justifies why the selected model is appropriate for predicting methane flux in the project area.

2. Enumerate the assumptions (or applicability conditions) of the model, explain how each of those assumptions is satisfied in the application of the model to the project area.

3. List all parameters of the model, providing the values applied, the source of those parameters, and providing a justification for why the selected value is appropriate to the project area. If parameters are selected by the user to calibrate the model, the project proponent must justify the values selected for these parameters conservatively predicts emissions. Modeling conducted in support of credit generation activities must use parameter values that are specific to the project area where it is possible to do so (ie, the model must be calibrated based on measurements made at the project site, not applied with default settings).

4. List any forcing variables or covariates (for example, meteorological or hydrological measureable variables available at each time step for which the model is run) that drive the model and provide a plan to obtain project area-specific values for those parameters.

At the initial project verification and at baseline reevaluation, the model's applicability must be assessed by comparison to direct field measurements of methane flux. The project proponent must do all of the following to determine if the model is applicable to the project area:

1. Directly measure methane flux for one season as described in Appendix B. The measurements must meet all assumptions outlined in Appendix B. Appendix B is designed to provide conservative (high) estimates of methane flux.

2. Use the selected and calibrated model to predict the measured methane flux independent of any data used to calibrate the model.

3. Estimate the model error as the sum of the differences between predicted and measured fluxes, divided by the number of measurements.

4. The mean error must demonstrate that the model conservatively over-predicts emissions fluxes compared to direct measurement of methane flux.

Predicted emissions fluxes by the selected model from literature must be converted to units of tCO_2e/day, such that they can be used directly in equation [G.11] as described in Section 8.2.2 (for the distinction between units and resolution, see Section 2.5).

If a model(s) from literature is selected, it must be justified at the time of validation and its applicability determined at the first verification event and subsequent baseline reevaluations.

PD Requirements: Methane Models from Literature
The project description must include the following if a model from literature is used to estimate methane flux: **PDR.62** Justification of methane flux model from the literature, per the requirements of Section 9.2.2.1.

Monitoring Requirements: Methane Models from Literature
The monitoring report must include the following if a model from literature is used to estimate methane flux: **MRR.55** Demonstration that the selected model is applicable to the project area per the requirements of Section 9.2.2.1. **MRR.56** Description of how model predictions are converted to tCO_2e/day.

9.2.2.2 Proxy Modeling

Project proponents may develop new proxy models to predict methane flux from wetland ecosystems. In building such a predictive model, the project proponent must measure or collect published data on response variables (methane flux) using the guidance in Appendix B as well as possible covariates, consider a range of alternative models and select a model using statistically sound procedures, and apply the model at each verification event to predict methane flux. Use Sections 9.2.2.2.1, 9.2.2.2.2, 9.2.2.2.3 and 9.2.2.2.4 to develop new proxy models.

Although the possible covariates to methane flux must be reported at the time of validation, the selected model and data used to fit the model must be reported at the time of the first verification event.

Such models must comply with requirements for models set out in the *VCS Standard*.

9.2.2.2.1 Considering Covariates

In developing a statistical model, project proponents should first develop a list of possible covariates and list sources of potential data for those covariates, which may include direct field measurement, remote sensing, peer-reviewed scientific literature, and technical reports completed by government agencies. Covariates to be considered may include but are not limited to soil salinity, water salinity, soil temperature, water temperature, air temperature, flooding, spectral reflectance, elevation, flooding frequency, flooding depth, soil organic carbon, and sulfate concentrations. From the initially considered covariates, identify those whose data availability and expected relationship with methane flux are most relevant to the project needs.

Possible and selected covariates and sources for covariates must be validated.

PD Requirements: Covariates for Proxy Methane Models
The project description must include the following if a proxy model is used to estimate methane flux: **PDR.63** A list of possible covariates and the sources of data available for each. **PDR.64** A list of selected covariates to be used for model fitting.

9.2.2.2.2 Collecting Data for Model Fitting and Response Variables

Data for model fitting may be collected from a combination of direct field measurements (see Appendix B), peer-reviewed scientific literature and/or technical reports issued by government agencies. Field data must be collected to cover the entire range of methane emissions flux potentially expected by the project, as well as the values of covariates that correspond to that range. Additional guidance is provided in Section 4.1.7 of the *VCS Standard v3.3*.

When data are collected directly by the project proponent in the field, a data collection plan (or protocol) must be prepared, detailing the data collection methods and referencing appropriate technical source documents.

Monitoring Requirements: Data Collection for Proxy Methane Model
The first monitoring report must include the following if an proxy model is used to estimate methane flux: **MRR.57** Complete references to the source of any data collected from literature or reports. **MRR.58** Data collection procedures, plans or protocols for any data collected directly from the project area.

9.2.2.2.3 Model Fitting, Selection, and Goodness of Fit

This methodology is not prescriptive with regard to model form and fitting procedures, as various types of models may be appropriate depending on the observed relationship between covariates and response variables. However, the model must be fit using sound and well documented statistical methods. The model must predict methane flux in tCO_2e/day (or units that can be converted appropriately) from some combination of measurable covariates. The project proponents must consider a variety of model forms and data transformations as appropriate to the data collected. During model fitting, attention should be paid to outliers and overly influential data points. Residual plots should be analyzed to confirm that model fitting assumptions have been met. Model selection and goodness of fit must be evaluated as described in Appendix F.

Monitoring Requirements: Model Fit for Methane
The first monitoring report must include the following if a proxy model is used to estimate methane flux: **MRR.59** The form of the selected model. **MRR.60** Summary statistics of the model fit as appropriate to the fitting of the model. **MRR.61** The estimated model parameters. **MRR.62** A description of the range of covariate data with which the model was fit.

9.2.2.2.4 Predicting Methane Flux

When a proxy model is used, measurement of the selected covariates replaces direct measurement of methane flux at each verification event. Covariates must be measured according to the procedures outlined by the project proponent in Section 9.2.2.2.1 and their actual values reported. Use the measured values as inputs to the statistical model. In the case that there is uncertainty about the value of a covariate model input, choose the value that results in the most conservative (ie, largest) estimate of methane emissions flux. Models must not be extrapolated more than 10% (that is, no independent variables that exceed the range from which the model was fit by more than 10% must be input into the model).

Monitoring Requirements: Model Prediction for Methane
The first monitoring report must include the following if an proxy model is used to estimate methane flux: **MRR.63** The values of any measured covariates. **MRR.64** The predicted methane flux.

9.2.2.3 Direct Measurement

Either chamber measurements (Section 9.2.2.3.2), eddy covariance measurements (Section 9.2.2.3.3), or other substantive equivalent techniques must be used. The project proponent must select the measurement method at the time of validation.

Monitoring of gas fluxes is inherently uncertain when aggregated over space and time. This methodology addresses this uncertainty by providing requirements that ensure the fluxes are overestimated, rather than underestimated, using conservativeness as a mediator to accuracy. These requirements include guidelines for stratification, a requirement for making measurements in the stratum expected to have the highest emissions, and guidelines for the points in time during which measurements are made.

To convert monitoring data from flux per acre per day to flux per day as required in Section 8.2.2, use equation [G.10].

Monitoring Requirements: Processed Chamber and Eddy Covariance Flux Data
The monitoring report must include the following: **MRR.65** A table of chamber flux or eddy covariance emission summary statistics of the mean (±1SEM) and number of samples for each mean in tCO_2e/ac/day for each sample location within a stratum.

9.2.2.3.1 Stratification

Stratification must be used to determine the stratum that is likely to yield the greatest methane emissions flux over the course of a year. Appendix A, Section A.1, provides general guidelines for stratifying the project area. Direct measurements must be conducted in the stratum that is likely to yield the greatest methane emissions flux, and may optionally be conducted in other strata as well, using appropriate area weighted stratification estimators as provided in appendix A.

The following factors predominantly affect methane emissions flux:

1. Carbon source: Methane emissions are associated with productive emergent plants that supply labile organic matter for methane producing bacteria. Areas with stressed plants or low plant productivity may have limited emissions over an annual period.

2. Soil saturation or reduction-oxidation potential: Persistent soil saturation or inundation above the wetland surface indicates reduced conditions and a likelihood of enhanced methane emissions. Methane production occurs when the reduction-oxidation potential is less than < 200mV. Optimal methane production occurs when redox is below -200mV.

3. Sulfate (salinity): The absence of sulfate favors methane production. The regular replenishment of sulfate with seawater from tidal action can suppress methane production. Methane production can occur when sulfate is less than 4mM umol (or typically when salinity < 18ppt).

4. Plant traits: 'Shunt' plant species are capable of conducting methane from the soil to atmosphere. A comprehensive list of species is not known, however, candidate genera that contain substantial aerenhymatous roots and shoots includes: *Typha*, *Sagittaria*, *Peltandra*, *Nuphar*, *Nymphaea*, *Phragmites*, and *Cladium* (see Couwenberg 2009).

5. Electron acceptors: In the absence of sulfate and other electron acceptors, such as nitrate and iron, methane production may be enhanced.

These factors must be considered when determining the stratum that is likely to yield the greatest methane emissions flux. The project proponent must justify the selected strata for direct measurement, including time considerations related to cyclical changes in the tidal frame.

Strata boundaries may change over time. If this occurs, the project proponent must ensure that the stratum likely to yield the greatest methane flux is always measured.

PD Requirements: Stratification for Methane Emissions
The project description must include the following if direct measurement is used to estimate methane flux: **PDR.65** Description for how the strata were delineated. **PDR.66** Map(s) of the initial strata boundaries indicating which stratum is likely to yield the greatest methane emissions flux. **PDR.67** Justification per the criteria in Section 9.2.2.3.1 for the stratum that is likely to yield the greatest methane emissions flux.

Monitoring Requirements: Stratification for Methane Emissions
The monitoring report must include the following if direct measurement is used to estimate methane flux: **MRR.66** Map(s) of the current strata boundaries. **MRR.67** A description of changes to the strata boundaries (if applicable).

9.2.2.3.2 Chamber Measurements

If the chamber measurement method is selected, the project proponent must take direct measurements of methane flux using chambers. The project proponent may use the protocols prescribed in Appendix B as the basis for flux measurement in the monitoring plan.

Within stratum, chambers must be located in areas that are likely to yield the greatest methane emissions flux over the course of a year (see factors in Section 9.2.2.3.1).

PD Requirements: Instrumentation for Chambers
The project description must include the following: **PDR.68** Diagram of chamber design.

Monitoring Requirements: Instrumentation for Chambers
The monitoring report must include the following: **MRR.68** Diagram of chamber design. **MRR.69** Map showing the location of chambers in the project area.

9.2.2.3.3 Eddy Covariance Measurements

The project proponent may take direct measurements of methane flux using eddy covariance. The project proponent may use the protocols prescribed in Appendix C as the basis for flux measurement in the monitoring plan.

The footprint of the eddy covariance tower must be more than half in the stratum determined to yield the greatest methane emissions flux over the course of a year (see factors in Section 9.2.2.3.1). The tower must be located in the stratum determined to yield the greatest methane emissions flux over the course of a year. The footprint of the tower must be defined using a published model (eg, Kljun et al. 2004, Kormann and Meixner 2001).

Monitoring Requirements: Instrumentation for Eddy Covariance	
The monitoring report must include the following:	
MRR.70	Diagram or map of eddy covariance tower delineating the selected footprint area where flux was integrated from and the computed mean 80% footprint distance (including the footprint model used) from the tower during the period of analysis. A table of computed estimates for each of the following parameters: σ_w = standard deviation of the vertical velocity fluctuations (m/s) u^*= surface friction velocity (m/sec) z_m= measurement height (m) z_0= roughness length (m) (or canopy height and density to be used to estimate roughness length)
MRR.71	Description of the published model used to define the footprint.
MRR.72	Map showing the location of eddy covariance towers in the project area.
MRR.73	Documentation of adherence to manufacturer-recommended procedures for calibration of the methane analyzer.

The project proponent must use one of the software packages for eddy covariance data processing listed below. An inter-comparison of some of these software packages for eddy covariance data quality control was reviewed by Mauder et al. (2008), and any of these packages must be considered equally acceptable for computing GHG fluxes. Eddy covariance algorithms may be used in other commercial software, such as MatLab, but will require justification from the project proponent.

- EddyPro 4.0 (fully documented, maintained, and supported by LI-COR®, Inc.)
- ECO$_2$S (IMECC-EU)
- EdiRe (Rob Clement, University of Edinburgh)
- TK3 (Matthias Mauder and Thomas Foken, University of Bayreuth)
- ECPack (GNU Public License; Wageningen University);
- EddySoft (Olaf Kolle and Corinna Rebmann, Max-Planck Institute for Biogeochemistry)
- Alteddy (Jan Elbers, Alterra Institute in Wageningen)

The project proponent must plot a time series of 30 min data including methane concentration, surface friction velocity and temperature. Data points must be omitted based on the following thresholds:

- Methane concentration must not be less than ambient (< 1.7 ppm) or the regional average, which is available from the nearest NOAA ERSL laboratory field station.

- Surface friction velocities less than 0.10 m/s or greater than 1.2 m/s.

Upper and lower limits of daily temperature should be within norms of the nearest meteorological station.

Monitoring Requirements: Eddy Covariance Data Processing and Flux Computation
The monitoring report must include the following: **MRR.74** Frequency diagram of wind direction (0-359° with 30° intervals) and velocity (m/s) for the period of analysis. **MRR.75** Summary of the dates of data collection, the selected approach for averaging over each period, explicit formulas used for computing flux, number of 0.5-hr samples used in calculations. **MRR.76** Graphical plot of 0.5-hr GHG concentration (ppmv), wind velocity and direction, and temperature used for the flux calculations **MRR.77** Summary statistics (number of samples, mean, median, variance) of GHG flux for each averaging period.

9.2.2.4 Frequency of Measurement

The project proponent must monitor methane flux periodically during a sampling period. The frequency of measurement is dependent upon the measurement method selection (ie, chamber or eddy covariance).

9.2.2.4.1 Chamber Measurements

The sampling period must be defined by a chamber sampling type selected from Table 13; guidance on the appropriate seasons for sampling activities is given for the northern hemisphere. The chamber sampling type may change from monitoring period to monitoring period, but must never change within a monitoring period. The project proponent must justify their selection of the chamber sampling type every monitoring period.

Table 13: Measurement requirements for chambers

Chamber Sampling Type	Sampling Period	Frequency	Period Flux Calculation (tCO_2e/ac/d)	Annual Flux Calculation (tCO_2e/ac/yr)
Peak	June - August	Minimum of two sampling events. If only two, no less than 30 days between events.	Mean of all measurements during the sampling period.	Mean period flux * 365 days.
Seasonal	October – February (winter) March – May (spring) June – September (summer)	Minimum of four sampling events. Each season must have at least one event and the summer season must have at least two, with no less than 30 days between events.	Mean of all measurements per each sampling season.	SUM of the mean winter season flux * 151 days and the mean spring season flux * 92 days and the mean summer season flux * 122 days.
Monthly	January - December	Minimum of 12 sampling events with no less than seven days between events. Minimum of one event per each calendar month.	Mean of all monthly measurements during the sampling period.	Mean period flux * 365 days.

Methane production from wetland soils predominantly occurs when mean soil and water temperatures exceeds 20°C (Whalen 2005). Because the peak chamber sampling type is during the hottest months in the northern hemisphere, this sampling type is most conservative; it also requires the least amount of sampling. Seasonal and Monthly chamber sampling types may provide a more accurate estimate of seasonal and inter-annual fluxes.

Sampling must occur when water levels are within mean low and mean high water (ie, not during extended low water events).

Monitoring Requirements: Chamber Sampling for Methane	
The monitoring report must include the following:	
MRR.78	Table of sampling event dates for the monitoring period, including the time of day samples were collected, water level relative to the soil surface, soil temperature, and air temperature.
MRR.79	Copy of field data sheets documenting time intervals when samples were collected, sample identification number, and verification of the total number of samples received by the laboratory.

9.2.2.4.2 Eddy Covariance Measurements

The sampling period must be defined by the eddy covariance sampling type and the eddy covariance sampling type must be selected from Table 14; sampling periods are given for the northern hemisphere. The eddy covariance sampling type may change from monitoring period to monitoring period, but must never change within a monitoring period. The project proponent must justify their selection of the eddy covariance sampling type every monitoring period.

Flux measurements must not be verified during the sampling period if the selected eddy covariance sampling type is peak or seasonal.

Table 14: Measurement requirements for Eddy Covariance

Eddy Covariance Sampling Type	Sampling Period	Frequency	Period Flux Calculation ($tCO_2e/ac/d$)	Annual Flux Calculation ($tCO_2e/ac/yr$)
Peak	July 1 – September 30	Minimum of 21 days.	Mean of all measurements during the 21 cumulative days (or more).	Mean period flux * 365 days.
Seasonal	March 1 – May 30 (spring) July 15 – September 15 (summer)	Minimum of 21 days sampled in the spring and minimum of 21 days sampled in the summer.	Mean of all measurements during the 21 cumulative days (or more) per each season.	SUM of the mean spring season flux * 243 days and the mean summer season flux * 122 days.
Monthly	January - December	Minimum of 3 days sampled per calendar month. No less than 7 days between sampling events.	Mean of all measurements during the 36 days (or more).	Mean period flux * 365 days.

The following criteria establish the frequency of measurements within each day:

1) A sample interval is 0.5 hr.

2) A minimum of 12 samples must comprise a daily flux mean.

3) One missing sample between two samples may be linearly interpolated. No interpolation is allowed for time periods greater than 1 hr.

4) A list of interpolated samples must be recorded and provided to the verifier.

PD Requirements: Eddy Covariance Measurement	
The project description must include the following:	
PDR.69	The type of analyzer selected for direct measurements of methane, including a description of the resolution of measurements (in ppb) and the frequency at which measurements are to be taken (in Hz).
PDR.70	A table of meteorological variables selected for measurement. For each variable in the table, justification for its selection, the unit of measurement, resolution of measurement and frequency of measurement.
PDR.71	A description the eddy covariance tower configuration including the distances between sensors (vertical, northward and eastward separation).
PDR.72	A scale diagram of the eddy covariance tower configuration showing the relative location and distance of the anemometer relative to the methane sensor.
PDR.73	Plan view diagram or map of the eddy covariance tower delineating strata and the area of highest anticipated emissions within a 100m radius of the tower. Delineation of any patch vegetation (twice the dominant canopy height and occupying >100m^2 in area) occurring within the estimated 80% footprint area.
PDR.74	Description of dominant plant canopy height (in m) over an annual cycle. An estimate of the 80% flux footprint distance (in m) and parameter estimates, as follows: σ_w= standard deviation of the vertical velocity fluctuations (m/s) u_*= surface friction velocity (m/sec) z_m= measurement height (m) h_m= planetary boundary layer height (m) or 1000m z_m= roughness length (m) or 1/10th of the average canopy height

Monitoring Requirements: Eddy Covariance Measurement
The monitoring report must include the following: **MRR.80** A table of meteorological variables selected for measurement. For each variable in the table, an indication of whether the variable was measured, the make and model of the instrument used for measurement. **MRR.81** For each measured variable, a graphical plot or table of the data with respect to time during the monitoring period. A data table or plot must include at minimum: air temperature, methane concentration, methane flux. A list of interpolated/missing samples. **MRR.82** Documentation of calibration dates and zero checks for methane analyzer. Provide the date of last full calibration (0-10 ppm methane standard). Provide dates of carbon-free air gas checks for methane analyzer.

9.2.3 Monitoring Project Nitrous Oxide Flux

Nitrous oxide may be *de minimis* as determined per Section 8.4.3.2 and current VCS requirements. If it is not *de minimis*, the project proponent must monitor nitrous oxide flux $F_{P\,\Delta\,N20}^{[m]}$ using one of three approaches: applying default values (Section 9.2.3.1), proxy methods developed by the project proponent (Section 9.2.3.2) or direct measurement of flux from the project area (Section 9.2.3.3). All three approaches result in an estimate of flux in units of tCO_2e/day, which is then used in equation [G.13] to predict emissions as a result of project activities (see Section 8.2.3). Specific field methods for measuring nitrous oxide flux are described in Appendix B.

In deciding which monitoring approach to use, it should be kept in mind that direct measurement is usually the most demanding in terms of time and cost. If the project proponent is able to identify a default value or model that meets the requirements herein, these will likely be the most efficient methods.

Once an approach is selected, it cannot be changed after the first verification event.

PD Requirements: Monitoring Nitrous Oxide
The project description must include the following: **PDR.75** The selected approach for monitoring nitrous oxide.

9.2.3.1 Default Values

This section provides peer-reviewed estimates for nitrous oxide emissions flux in a variety of wetland ecosystems in several regions of North America (primarily Louisiana). The values provided in Table 16 may be used to determine a default value for nitrous oxide emissions.

If the project proponent demonstrates that the project area is not located within a direct 'outfall' of a NPDES major discharger (as described in this section) and is not located within a CWA Section 303d designated impaired water, the project proponent may use an applicable default value provided in Table 16 of Section 9.2.3.1.1, taking into consideration the issues described in this section in order to determine if the values in Table 16 are applicable to the project. If the project area is determined to be within the 'outfall' of a NPDES major discharger (ie, affected by external nitrate loading) or is located within a CWA Section 303d designated impaired water, the project proponent must either apply a proxy model (see Section 9.2.3.2) or conduct direct monitoring (see Section 9.2.3.3).

Prior to selecting a default value from Table 16, the project proponent must determine whether there exists an external nitrogen loading that is likely to influence gas fluxes in the project area. The project proponent must provide supporting evidence to show where major point sources of nitrogen are located relative to the project area and to define the hydrologic connections that lead to direct discharge into the project area. Major point sources of nitrogen may include state-authorized NPDES permits (industrial or municipal wastewater effluent) or public works projects resulting in the alteration of surface water flow into wetlands and estuaries (eg wetland restoration projects with freshwater/sediment river diversions). Major non-point nitrogen sources from surface runoff or wastewater – including agricultural, urban and suburban areas, leach fields, and leaking sewer pipes – also must be considered.

Specifically, the project proponent must demonstrate:

1. The project area is not located within a direct 'outfall,' nor is it downstream and in close proximity of a NPDES major discharger (>1 mgd) or public works project (river diversion) discharging elevated nitrogen effluent (>3 mg TN/L);

2. The project area is not located within a CWA Section 303d designated impaired water, where nitrogen (or 'nutrients') is the suspected causal factor of impairment; and

3. The project area does not receive direct surface runoff from agricultural, urban or suburban areas, and is not immediately adjacent to areas with sewer lines or leach fields.

Acceptable sources of supporting documentation to demonstrate the presence or absence of external nitrogen loading may include: state-authorized National Pollutant Discharge Elimination System (NPDES) documentation; Clean Water Act 303d Impaired Waters documentation; watershed-based Total Maximum Daily Load (TMDL) regulations; project-specific monitoring reports; first order, area-based water quality models; and ambient water quality monitoring data.

PD Requirements: Determining Project Area Exposure to Nitrogen Loading
The project description must include the following: **PDR.76** Location of the project area within a minimum definable watershed, using a USGS, EPA or state delineated watershed. **PDR.77** Locations of all NPDES major dischargers and public works projects producing > 1 MGD of elevated nitrogen effluent (>3 mg TN/L) discharging into the project area and located within the minimum definable watershed. **PDR.78** List of EPA CWA Section 303d designated impaired waters for the state.

Alternatively, other peer-reviewed estimates may be used, in which case the project proponent must demonstrate and justify the selected default value. Where default factors are used, they must be consistent with the current version of the VCS Standard's requirements for default factors (currently located in Section 4.5.6 of the VCS Standard version 3.3). The project proponent must calculate the selected default value in terms of tCO_2e/year and apply this calculated default to determine emissions in equation [G.13]. Models must be publicly available, though not necessarily free of charge, from a reputable and recognized source (eg, the model developer's website, IPCC or government agency).

PD Requirements: Default Values for Nitrous Oxide Monitoring
The project description must include the following if a default value is used to estimate nitrous oxide flux: **PDR. 79** Justification for the selected default value.

9.2.3.1.1 Default Factors in Absence of External Nitrate Loading

Under background wetland conditions, defined as those wetland areas not exposed to external nitrate loading sources (eg, a river diversion or wastewater treatment outflows, or other significant point sources), in the Mississippi River delta plain, nitrous oxide emissions flux to the atmosphere is ≤0.1 t CO2e/ac/yr (Smith et al. 1983). Under these conditions, the project proponent may use a value from Table 16, making sure to justify its applicability to the project area.

Table 15 shows annual estimates of nitrous oxide emissions fluxes from vegetated wetland and open water habitats across a salinity gradient in Louisiana (Smith et al. 1983),. The study was done over 2 years with samples taken on ~6 week intervals (17 sampling events) using static flux chambers at sites representative of background conditions for Louisiana wetlands (in the absence of external nitrate loading). The emissions fluxes are presented relative to an anticipated annual sequestration rate of 3 tCO_2e/ac/yr.

Table 15: Background annual nitrous oxide flux values from vegetated wetland and open water habitats across a salinity gradient in Louisiana (Smith et al. 1983)

Wetland Type	Annual mg N20-N/m2/yr	Annual $tCO_2e/ac/yr$	% of Benefit @ 3 $tCO_2e/ac/yr$
Salt marsh	31	0.06	2.0%
open water	10	0.02	
Brackish marsh	48	0.09	3.2%
open water	21	0.04	
Fresh marsh	55	0.11	3.6%
open water	34	0.07	

For projects in Louisiana, the values provided in Table 15 may be used to estimate nitrous oxide flux. For projects outside Louisiana, the project proponent must identify appropriate flux estimates from peer-reviewed literature and must demonstrate that they are applicable to the project.

The effects of river diversions on nitrous emissions flux to the atmosphere are less predictable than background conditions. Nitrous oxide emissions flux from freshwater wetlands near the outfall of river diversions may depend on whether the diversion is operating (positive flux to the atmosphere ~0.4 t CO2e/ac/yr; Yu et al. 2006) or not operating (flux from the atmosphere to the wetland -0.17 t CO2e/ac/yr; Table 15, Yu et al. 2006). The study of Lundberg (2012) conducted along a salinity gradient from the outfall of one river diversion showed that wetland nitrous emissions flux to the atmosphere are relatively low (< 0.07 t CO2e/ac/yr).

9.2.3.1.2 Projects in Presence of External Nitrate Loading

Exposure to high external nitrate loads may result in increased nitrous oxide emissions flux compared to background conditions. For project areas in the presence of external nitrate loading, the project proponent must either apply a proxy model (see Section 9.2.3.2) or conduct direct monitoring (see Section 9.2.3.3).

9.2.3.2 Proxy Modeling

Project proponents may develop new proxy models to predict nitrous oxide flux from wetland ecosystems. In building such a predictive model, the project proponent must measure or collect published data on response variables (nitrous oxide flux) using the guidance in Appendix B as well as possible covariates, consider a range of alternative models and select a model using statistically sound procedures, and apply the model at each verification event to predict nitrous oxide flux. Use Sections 9.2.3.2.1, 9.2.3.2.2, 9.2.3.2.3 and 9.2.3.2.4 to develop new proxy models.

Although the possible covariates to nitrous oxide flux must be reported at the time of validation, the selected model and data used to fit the model must be reported at the time of the first verification event.

9.2.3.2.1 Considering Covariates

In developing a statistical model, project proponents must first develop a list of possible covariates and list sources of potential data for those covariates, which may include direct field measurement, remote sensing, peer-reviewed scientific literature, and technical reports completed by government agencies. From the initially considered covariates, identify those whose data availability and expected relationship with methane flux are most relevant to the project needs.

Possible and selected covariates and sources for covariates must be validated.

PD Requirements: Covariates for Proxy Nitrous Oxide Models
The project description must include the following if an proxy model is used to estimate nitrous oxide flux: **PDR.80** A list of possible covariates and the sources of data available for each. **PDR.81** A list of selected covariates to be used for model fitting.

9.2.3.2.2 Collecting Data for Model Fitting and Response Variables

Data for model fitting may be collected from a combination of direct field measurements (see Appendix B), peer reviewed scientific literature and/or technical reports issued by government agencies. Field data must be collected to cover the entire range of nitrous oxide emissions flux potentially expected by the project, as well as the values of covariates that correspond to that range.

When data are collected directly by the project proponent in the field, a data collection plan (or protocol) must be prepared, detailing the data collection methods and referencing appropriate technical source documents.

Monitoring Requirements: Data Collection for Proxy Nitrous Oxide Model
The first monitoring report must include the following if an proxy model is used to estimate nitrous oxide flux: **MRR.83** Complete references to the source of any data collected from literature or reports. **MRR.84** Data collection procedures, plans or protocols for any data collected directly from the project area.

9.2.3.2.3 Model Fitting, Selection, and Goodness of Fit

This methodology is not prescriptive with regard to model form and fitting procedures, as various types of models may be appropriate depending on the observed relationship between covariates and response variables. However, the model must be fit using sound and well-documented statistical methods. The model must predict nitrous oxide flux in tCO_2e/day (or units that can be converted appropriately) from some combination of measureable covariates. The project proponents must consider a variety of model forms and data transformations as appropriate to the data collected. During model fitting, attention should be paid to outliers and overly influential data points. Residual plots should be analyzed to confirm that model fitting assumptions have been met. Model selection and goodness of fit must be evaluated as described in Appendix F.

PD Requirements: Model Fit for Nitrous Oxide
The project description must include the following if an proxy model is used to estimate nitrous oxide flux: **PDR.82** Justification that the proxy is an equivalent or better method (in terms of reliability, consistency or practicality) to determine the value of interest than direct measurement.

Monitoring Requirements: Model Fit for Nitrous Oxide
The first monitoring report must include the following if an proxy model is used to estimate nitrous oxide flux: **MRR.85** The form of the selected model. **MRR.86** Summary statistics of the model fit as appropriate to the fitting of the model. **MRR.87** The estimated model parameters. **MRR.88** A description of the range of covariate data with which the model was fit.

9.2.3.2.4 Predicting Nitrous Oxide Flux

When a proxy model is used, measurement of the selected covariates replaces direct measurement of nitrous oxide flux at each verification event. Covariates must be measured according to the procedures outlined by the project proponent in Section 9.2.2.2.1 and their actual values reported. Use the measured values as inputs to the statistical model. In the case that there is uncertainty about the value of a covariate model input, choose the value that results in the most conservative (ie, largest) estimate of nitrous oxide emissions flux. Models must not be extrapolated more than 10% (that is, no independent variables that exceed the range from which the model was fit by more than 10% must be input into the model).

Monitoring Requirements: Model Prediction for Nitrous Oxide
The first monitoring report must include the following if an proxy model is used to estimate nitrous oxide flux: **MRR.89** The values of any measured covariates. **MRR.90** The predicted nitrous oxide flux.

9.2.3.3 Direct Measurement

If using direct measurements, the project proponent must measure nitrous oxide flux using chambers. The project proponent may use the protocols prescribed in Appendix B as the basis for flux measurement in the monitoring plan.

Monitoring of gas fluxes is inherently uncertain when aggregated over space and time. This methodology addresses this uncertainty by providing requirements that ensure the fluxes are overestimated, rather than underestimated, using conservativeness as a mediator to accuracy. These requirements include guidelines for stratification, a requirement for making measurements in the stratum expected to have the highest emissions, and guidelines for the points in time during which measurements are made.

To convert monitoring data from flux per acre per day to flux per day as required in Section 8.2.3, use equation [G.12].

9.2.3.3.1 Stratification

Stratification must be used to determine the stratum that is likely to yield the greatest nitrous oxide emissions flux over the course of a year. Appendix A, Section A.1, provides general guidelines for stratifying the project area. Direct measurements must occur in the stratum that is likely to yield the greatest nitrous oxide emissions flux, and may optionally be made in other strata as well, using appropriate area-weighted stratification estimators as provided in Appendix A to determine a weighted-average estimate of flux for the project area. Strata boundaries may change over time. If this occurs, the project proponent must ensure that the stratum likely to yield the greatest nitrous oxide flux is always measured.

PD Requirements: Stratification for Nitrous Oxide Emissions
The project description must include the following if direct measurement is used to estimate nitrous oxide flux: **PDR.83** Description for how the strata were delineated. **PDR.84** Map(s) of the initial strata boundaries indicating which stratum is likely to yield the greatest nitrous oxide emissions flux. **PDR.85** Justification per the criteria in Section 9.2.2.3.1 for the stratum that is likely to yield the greatest nitrous oxide emissions flux.

Monitoring Requirements: Stratification for Nitrous Oxide Emissions
The monitoring report must include the following if direct measurement is used to estimate nitrous oxide flux: **MRR.91** Map(s) of the current strata boundaries. **MRR.92** A description of changes to the strata boundaries (if applicable).

9.2.3.3.2 Chamber Measurements

In most cases, chamber measurements for nitrous oxide flux will be collocated with methane flux. In the event that they are not collocated, the requirements of Section 9.2.2.4.1 must be used to identify the location of chambers for nitrous oxide.

9.2.3.4 Frequency of Measurement

There are two options for the frequency of nitrous oxide flux measurements:

1. In conjunction with chamber samples of methane flux per Section 9.2.2.4.1 (if applicable); or
2. Approximately once per calendar month, a minimum of 12 samples that are no less than seven days apart.

For either option, nitrous oxide flux must be calculated as the mean of all measurements.

Monitoring Requirements: Chamber Sampling for Nitrous Oxide
The monitoring report must include the following: **MRR.93** Table of sampling event dates for the monitoring period, including the time of day samples were collected, water level relative to the soil surface, soil temperature, and air temperature. **MRR.94** Copy of field data sheets documenting time intervals when samples were collected, sample identification number, and verification of the total number of samples received by the laboratory.

9.2.4 Monitoring Project Energy Consumption

Units of energy that are consumed as a result of project activities and monitoring activities must be monitored using the direct measurement approach or the cost approach (see Sections 9.2.4.1 and 9.2.4.2).

Monitoring Requirements: Energy Consumption Measurement Method
The monitoring report must include the following: **MRR.95** The selected approach to monitoring energy consumption.

9.2.4.1 Direct Measurement of Energy Consumption

If direct measurement is used, the project proponent must maintain separate records of energy consumption for each energy type listed in Table 10 (see Section 8.1.1). The total units of energy consumed during the monitoring period for each energy type is recorded as $G_{P\,\Delta\,(ty)}^{[m]}$.

Monitoring Requirements: Direct Measurement of Energy Consumption
The monitoring report must include the following: **MRR.96** Energy consumption for each energy type listed in Section 8.1.1. **MRR.97** References to records of energy consumption.

9.2.4.2 Cost Approach to Energy Consumption

The cost approach to estimating energy consumption assumes that the project proponent does not possess definitive, itemized records of energy expenditures, given that energy and fuel costs often are paid directly by dredging subcontractors and actual energy consumption is not often reported. If the cost approach is used, the project proponent must extrapolate energy consumption based on the project budget and historic energy costs. The project proponent must adhere to the following procedure:

1. Determine the proportion of the dredging budget estimated for fuel (or electricity) purchases,
2. Identify the energy type(s) likely to have been used in the course of dredging, and
3. Calculate the estimated energy consumption by energy type using published historic energy prices (eg, U.S. Energy Information Administration) at the time of dredging activities. The estimate of total units of energy consumed during the monitoring period for each energy type is recorded as $G_{P\,\Delta\,(ty)}^{[m]}$.

The project proponent must justify how the energy prices and proportion allocated to energy type is conservative; the most conservative scenario will always be to assume the lowest energy prices and allocate the highest emission factor for each type.

Monitoring Requirements: Cost Approach to Energy Consumption	
The monitoring report must include the following:	
MRR.98	Justification for the proportion of dredging budget allocated for fuel (or electricity) purchases.
MRR.99	Justification for choice of energy type(s).
MRR.100	Documentation of historic energy costs at the time of dredging activities.
MRR.101	Justification of estimate of energy consumption.

9.2.5 Monitoring Project Sediment Transport

Emissions from energy consumption are based upon the mass of sediment transported as a result of project activities. The mass of sediment transported is given by equation [G.2] where $M_{P\,\Delta}^{[m]}$ is the mass of sediment dredged from the sediment source as a result of project activities during the monitoring period, $V_{P\,\Delta}^{[m]}$ is the volume of transported sediment, and $d_{P\,\Delta}^{[m]}$ is the density of the transported sediment. The estimated volume of transported sediment must be based upon the volume of the catchment area to which dredged sediment is transported. Given that dredged sediment is likely to be a solid-liquid mixture, the density must be measured as equation [G.1].

Monitoring Requirements: Monitoring Sediment Transport	
The monitoring report must include the following:	
MRR. 102	Justification for the estimate of volume of dredged sediment transported.
MRR. 103	Justification for the estimate of the density of dredged sediment.
MRR.104	Estimated mass of sediment transported.

9.2.6 Monitoring Allochthonous Carbon

For projects that do not meet the criteria for the conservative exclusion of allochthonous carbon import (per Section 5.2.1), the project proponent must monitor allochthonous carbon sedimentation. Accretion measurements (ie, with a marker horizon technique) must be used to estimate the fraction of allochthonous mineral-associated carbon with sedimentation.

Based on literature values for the project area, a conservative deduction must be assessed according to the procedures described in Appendix E.6.4 and using equation [E.4]. Using regionally appropriate literature, the project proponent must use a peer-accepted correction factor (typically ≤3% of the mineral content is bound by organic matter, see Andrews et al. 2011) for the type of wetland system (eg, fluvial, non-fluvial) in order to compute the mass of the mineral-associated carbon that must be subtracted from total soil carbon accumulation during the monitoring period.

Monitoring Requirements: Monitoring Allochthonous Carbon	
The monitoring report must include the following:	
MRR.105	Reference(s) to the regionally appropriate literature used to determine the correct factor for mineral-associated carbon.

9.2.7 Monitoring Baseline Methane Flux

Baseline monitoring for methane must be conducted in a suitable reference area (as defined in Section 6.3.1). Methane monitoring (chamber or eddy covariance) must conform to the requirements in Sections 9.2.2 and must use the sampling designs and specifications outlined in Appendices B and C.

9.2.8 Procedures for Quality Control and Assurance

The monitoring plan must specify specific measures for quality control and assurance. These measures must conform to the requirements in Sections 9.2.8.1, 9.2.8.2 and 9.2.8.3.

9.2.8.1 Field Measurements

The project proponent must develop a monitoring plan that includes a detailed field sampling protocol. Field data must be spot-checked for errors in sampling, transcription, and analysis (see Section 9). The project description must describe the type and frequency of training for field personnel responsible for sampling carbon stocks, fluxes, and covariates. The monitoring report must document the type and training field personnel received during the monitoring period.

PD Requirements: Field Training for Field Sampling	
The project description must include the following:	
PDR.86	A description of the type and frequency of training of field personnel responsible for sampling carbon stocks, fluxes, and covariates.

Monitoring Requirements: Field Training for Field Sampling	
The monitoring report must include the following:	
MRR.106	The type and frequency of training of field personnel during the monitoring period.

9.2.8.2 Data Transcription and Analysis

Project proponents must document a procedure for ensuring high quality data is used in determining emissions reductions and removals. This procedure must include methods for recording and archiving data, checking data for errors, and analyzing data in a transparent manner. To the extent possible, analysis methods should be maintained throughout the lifetime of the project (eg, using the same spreadsheets, software, and computer code for all calculations made during the project lifetime). A percentage of any data entered manually should be randomly checked for transcription errors, preferably by a person not involved in the initial entry.

9.2.8.3 Carbon Stock Measurements

All carbon stock data from individual plots must be provided to the validation/verification body, along with all spreadsheets or computer code used to calculate project-level carbon stocks and associated uncertainties. Data analysis should be carefully checked for transcription or calculation errors. The distribution of biomass estimates by plot should be examined and compared to available literature to confirm that reasonable results have been achieved; a similar procedure must be followed for SOC. Any plots with unusually high or low biomass or SOC (ie, outliers) should be examined closely. It is good practice to re-measure a subset of biomass plots to verify the accuracy of field measurements when non-destructive sampling techniques are used. When destructive sampling is used, evidence of calibration of instruments (such as scales) must be provided.

Monitoring Requirements: Carbon Stock Measurements	
The monitoring report must include the following:	
MRR.107	Biomass and SOC carbon stock data for all plots, along with any ancillary spreadsheets or computer code used to generate these predictions.
MRR.108	List of outliers with unusually high or low biomass or SOC, including justification for their continued inclusion.
MRR.109	Results of accuracy assessment if non-destructive sampling techniques are used. Otherwise, justification for why accuracy need not be formally addressed.

9.2.8.4 Eddy Covariance Data

The project proponent must take direct measurements of methane flux using eddy covariance. The project proponent may use the protocols prescribed in Appendix C as the basis for flux measurement in the monitoring plan.. Refer to Section 9.2.2.4.2 for eddy covariance sampling requirements. Requirements for calibration are found in Section C.2.5.

PD Requirements: Quality Control and Assurance of Eddy Covariance Data	
The project description must include the following:	
PDR.87	Any methodology deviations. Such deviations must include the text that is being modified and the proposed new language.

Monitoring Requirements: Quality Control and Assurance of Eddy Covariance Data
The monitoring report must include the following: **MRR.110** Description of processing software used, assumptions, and data quality control measures, which must include the selected method of coordinate rotation, detrending, and density fluctuation correction.

9.2.8.5 Laboratory Analyses

The analysis of methane and/or nitrous oxide from chamber samples (see Sections 9.2.2.3.2 and 9.2.3.3, Appendix B) must meet or exceed USEPA QA/QC requirements. The selected laboratory must provide written pre-analysis sample processing procedures, specific chemistry test methods and detection limits for the analysis.

Sample analyses must follow the EPA Method 3C (Determination of Carbon Dioxide, Methane, Nitrogen, and Oxygen from Stationary Sources). Instrument calibration must comply with EPA Protocol Gaseous Calibration Standards.

Soil samples must be analyzed for bulk density and SOC by a qualified laboratory following the methods of Nelson and Sommers 1996 and Ball 1964, respectively, or comparable methods. The chosen laboratory must have a rigorous Quality Assurance program that meets or exceeds the USEPA QA/QC requirements or similar international standards for laboratory procedures, analysis reproducibility, and chain of custody. The laboratory must also provide a document that defines the pre-analysis sample processing procedures, and the specific chemistry test methods they use at the laboratory, including the minimum detection limits for each constituent analyzed.

Monitoring Requirements: Laboratory Analyses
The monitoring report must include the following if samples are sent to a laboratory: **MRR.111** Documentation of the laboratory QA/QC protocols, the methods of sample analysis, and general calibration procedures used the laboratories conducting the analysis.

9.3 Data and Parameters Available at Validation

Data Unit / Parameter	A_{PA}
Data unit	acre
Description	Size of project area
Equations	[G.10], [G.12]
Source of data	GIS analysis prior to sampling
Justification of choice of data or description of measurement methods and procedures applied	-
Purpose of data	
Comments	

Data Unit / Parameter	$e_{(ty)}$
Data unit	tCO_2e/gal, tCO_2e/scf, tCO_2e/kWh
Description	Emissions coefficient for energy type *ty*
Equations	[G.3], [G.14]
Source of data	Emission factors in Section 8.1.1, Table 10
Justification of choice of data or description of measurement methods and procedures applied	Selected from published values
Purpose of data	
Comments	

Data Unit / Parameter	$g_{B\ (ty)}$
Data unit	gal/tonne, scf/tonne, kWh/tonne
Description	Energy consumed per metric tonne of sediment dredged in the baseline
Equations	[G.3]
Source of data	Documentation provided by project proponent
Justification of choice of data or description of measurement methods and procedures applied	Direct measurement

Purpose of data	
Comments	

Data Unit / Parameter	$p_{B\ (ty)}$
Data unit	proportion (unitless)
Description	Proportion of energy for energy type *ty* consumed in the baseline scenario
Equations	[G.3]
Source of data	Documentation provided by project proponent
Justification of choice of data or description of measurement methods and procedures applied	Calculated from direct measurement
Purpose of data	
Comments	

PD Requirements: Data and Parameters Available at Validation
The project description must include the following: **PDR.88** The value of each variable, data and parameter. **PDR.89** The units, descriptions, source, purpose and comments for each variable reported in the PD.

9.4 Data and Parameters Monitored

Data Unit / Parameter	$C_{P\ CS\ (c)}^{[m]}$
Data unit	tCO_2e
Description	Cumulative project carbon stock in pool *c* at end of monitoring period
Equations	[G.7]
Source of data	Sampling of carbon stocks
Description of measurement methods and procedures to be applied	See Appendix D
Frequency of	At least every five years

monitoring/recording	
QA/QC procedures to be applied	Independent review of equations and check against literature estimates. See Section 9.2.8.3
Purpose of data	
Calculation method	
Comments	

Data Unit / Parameter	$d_{LQD}^{[m]}$
Data unit	kg/m3
Description	Density of liquid in dredged sediment
Equations	[G.1]
Source of data	Direct measurement
Description of measurement methods and procedures to be applied	See Section 9.2.5
Frequency of monitoring/recording	Where sediment is transported, Every monitoring period.
QA/QC procedures to be applied	Compare data from multiple samples. See Section 9.2.8.1
Purpose of data	
Comments	

Data Unit / Parameter	$d_{SLD}^{[m]}$
Data unit	kg/m^3
Description	Density of solids in dredged sediment
Equations	[G.1]
Source of data	Direct measurement
Description of measurement methods and procedures to be applied	See Section 9.2.5
Frequency of monitoring/recording	Where sediment is transported, Every monitoring period
QA/QC procedures to be applied	Compare data from multiple samples. See Section 9.2.8.1
Purpose of data	

Comments	

Data Unit / Parameter	$f_{B\,\Delta\,CH4}^{[m]}$
Data unit	tCO_2e/ac/day
Description	Baseline methane emissions flux per unit area
Equations	[G.5]
Source of data	Static chamber or eddy covariance measurement
Description of measurement methods and procedures to be applied	See Section 9.2.7
Frequency of monitoring/recording	Every monitoring period
QA/QC procedures to be applied	Comparison of data from multiple samples and independent review of calculations. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5
Purpose of data	
Comments	

Data Unit / Parameter	$f_{P\,\Delta\,CH4}^{[m]}$
Data unit	tCO_2e/ac/day
Description	Methane emissions flux per unit area within project area
Equations	[G.10]
Source of data	Static chamber or eddy covariance measurement
Description of measurement methods and procedures to be applied	See Section 9.2.2.3
Frequency of monitoring/recording	Every monitoring period
QA/QC procedures to be applied	Comparison of data from multiple samples and review of monitoring records. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5
Purpose of data	
Comments	

Data Unit / Parameter	$f_{P\,\Delta\,N2O}^{[m]}$

Data unit	tCO_2e/ac/day
Description	Nitrous oxide emissions flux per unit area within project area
Equations	[G.12]
Source of data	Static chamber or eddy covariance measurement
Description of measurement methods and procedures to be applied	See Section 9.2.3.3
Frequency of monitoring/recording	Every monitoring period
QA/QC procedures to be applied	Comparison of data from multiple samples and review of monitoring records. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5
Purpose of data	
Comments	

Data Unit / Parameter	$G_{P\,\Delta\,(ty)}^{[m]}$
Data unit	gal, scf, kW
Description	Energy consumed in project area for energy type *ty* over monitoring period
Equations	[G.14]
Source of data	Direct measurement approach or cost approach
Description of measurement methods and procedures to be applied	See Sections 9.2.4.1 and 9.2.4.2
Frequency of monitoring/recording	Every monitoring period when sediment is transported
QA/QC procedures to be applied	Independent review of calculations and monitoring records. See Sections 9.2.8.1 and 9.2.8.2
Purpose of data	
Comments	

Data Unit / Parameter	${p_{SLD}}^{[m]}$
Data unit	proportion (unitless)
Description	Proportion of solids by weight in the dredged sediment
Equations	[G.1]
Source of data	Direct measurement of dredged sediment

Description of measurement methods and procedures to be applied	See Section 9.2.5
Frequency of monitoring/recording	Every monitoring period when sediment is transported
QA/QC procedures to be applied	Comparison of data from multiple samples and review of monitoring records. See Sections 9.2.8.1 and 9.2.8.2
Purpose of data	
Comments	

Data Unit / Parameter	$t^{[m]}$
Data unit	days
Description	Elapsed time from project start at the end of the monitoring period
Equations	[G.11], [G.13]
Source of data	Monitoring records
Description of measurement methods and procedures to be applied	N/A
Frequency of monitoring/recording	Every monitoring period
QA/QC procedures to be applied	N/A
Purpose of data	
Comments	

Data Unit / Parameter	$t^{[m-1]}$
Data unit	days
Description	Elapsed time from project start at the beginning of the monitoring period
Equations	[G.11], [G.13]
Source of data	Monitoring records
Description of measurement methods and procedures to be applied	N/A
Frequency of	Every monitoring period

monitoring/recording	
QA/QC procedures to be applied	N/A
Purpose of data	
Comments	

Data Unit / Parameter	$V_{P\,\Delta}^{[m]}$
Data unit	m^3
Description	Volume of sediment dredged from the sediment source over monitoring period
Equations	[G.2]
Source of data	Direct measurement
Description of measurement methods and procedures to be applied	See Section 9.2.5
Frequency of monitoring/recording	Every monitoring period when sediment is transported
QA/QC procedures to be applied	Independent review of calculations and monitoring records. See Section 9.2.8.2
Purpose of data	
Comments	

Monitoring Requirements: Data and Parameters Monitored
The monitoring report must include the following: **MRR.112** The value of each variable, data and parameter. **MRR.113** The units, descriptions, source, purpose, references to calculations and comments for each variable reported in the Monitoring Report. **MRR.114** For those variables obtained from direct measurement, a description of measurement methods and procedures. These may simply be references to components of the monitoring plan. **MRR.115** For those variables obtained from direct measurement, a description of monitoring equipment including type, accuracy class and serial number (if applicable). These may simply be references to components of the monitoring plan. **MRR.116** Procedures for quality assurance and control, including calibration of equipment (if applicable).

9.5 Grouped Projects

Grouped projects are allowable in order to permit the expansion of project activities after initial validation. For such projects, project documentation may differ by project activity instance with respect to carbon stock estimation, as stratification and plot location will vary. Otherwise, the same monitoring requirements set out in Section 9 apply.

As per Section 9.2.1.1, during the first verification including new project activity instances, all new plots must be measured.

If the original project area is stratified for SOC or biomass, then subsequent project activity instances must be similarly stratified as well, per Section 9.2.1.2.

Monitoring Requirements: Monitoring Grouped Projects	
The monitoring report must include the following when new project activity instances are added to the project:	
MRR.117	List and descriptions of all project activity instances in the project.
MRR.118	Project activity instance start dates.
MRR.119	Map indicating locations of project activity instances added to the group.
MRR.120	List of additional stratifications used for additional project activity instances; justification for why flux measurements are still located in the most conservative stratum (9.2.2, 9.2.3).
MRR.121	As project activity instances are added, the monitoring plan must be updated to reflect additional monitoring times and plot locations.

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APPENDIX A: DEFAULT STRATIFICATION AND SAMPLE UNIT ALLOCATION METHODS

Stratification, in which a population to be sampled is divided into sub-populations of known size, can be used in measurements of many variables to improve sampling effectiveness, and can help reduce uncertainty when it would be cost-prohibitive to conduct statistical sampling of sufficient density to adequately represent the entire population. The default stratification methods, including guidelines for the stratification criteria of individual variables, are described in Sections 9.1, 9.2.1.2, 9.2.2.3.1, and 9.3.2.3.1. Here, formulas that can be used to estimate means and totals from stratified samples are provided, as well as guidelines for efficiently allocating sampling units to identified strata.

Stratification should always be done prior to measurement, such that the stratum sizes are known exactly. Stratification may be performed prior to any measurement event. Different stratification schemes may be used for estimating different variables according to the preferences of the project proponent.

A.1 Sample Size and Plot Allocation

In stratified random sampling, the following equations may be used to estimate the sample size required to attain a targeted precision level. Note that this methodology does not require that sample size be calculated in this way—these equations are provided solely for the convenience of the user. Estimating sample size as described here requires an estimate of the mean and standard deviation of the variable to be estimated. These quantities may be estimated from literature or from a pilot sample. The project proponent should recognize that actual standard error of a sampled statistic will be subject to random error, and that if the mean and standard deviation used to estimate the sample size differ significantly from those properties in the actual population, the sample size actually required for the targeted precision level will also from that estimated. The most efficient allocation of plots to strata depends on the relative sizes of the strata, the estimated means and within strata variability, and potentially the costs of sampling each stratum. Three methods are available for allocating sample units, which are described below. Actual sampling units within strata should be chosen systematically with a random starting point or randomly.

A.1.1 Proportional Allocation

Proportional allocation allocates sampling units to strata in proportion to their size. Given a targeted precision level, the total required sample size may be calculated as:

$$\hat{n}_{TOTAL} = \frac{1}{\left(\frac{\mathrm{E}\times\bar{x}}{Z\times\hat{\sigma}_{\bar{x}}}\right)^2 + \frac{\mathrm{n}}{\mathrm{N}}}$$ [A.1]	
Variables	E - The allowable degree of error (eg, 0.15 for +/- 15%) $\bar{x}$ - The estimated mean of the quantity to be estimated Z - Z statistic from a normal distribution associated with the desired confidence level (1.96 for 95% confidence). $\hat{\sigma}_{\bar{x}}$ - The estimated standard deviation of the quantity to be estimated $\frac{\mathrm{n}}{\mathrm{N}}$ - The relative size of a sampling unit with respect to the entire population to be sampled (for example, in sampling with fixed area plots, this is the ratio of the plot size to the total project area size)
Section References	9.2.1, Appendix D, Appendix E
Comments	The estimated required sample size

The plots are allocated to strata in proportion to strata size as follows:

$$\hat{n}_{(k)} = \hat{n}_{TOTAL}\frac{a_{(k)}}{A_{PA}}$$ [A.2]	
Variables	$\hat{n}_{TOTAL}$ - The estimated total required number of plots $a_{(k)}$ - The area of stratum *k* A_{PA} - The total project area
Section References	9.2.1, Appendix D, Appendix E
Comments	The number of plots to be allocated to stratum *k*

A.1.2 Neyman Allocation

Sometimes strata differ in their degree of within-stratum variability. In this case, the overall standard error will be minimized if sampling efforts are concentrated toward those strata with highest variability. If estimates of the standard deviation of each stratum are available, the following equations may be used to allocate sampling units:

$$w_{(k)} = \frac{a_{(k)}\hat{\sigma}_{(k)}}{\sum_{(j)\in\mathcal{S}} a_{(j)}\,\hat{\sigma}_{(j)}}$$	[A.3]
Variables	$a_{(k)}$ - The area of stratum *k* $\hat{\sigma}_{(k)}$ - The estimated standard deviation of the quantity to be estimated within stratum $\mathcal{S}$ - The set of all strata $a_{(i)}$ – The area $\hat{\sigma}_{(j)}$ – The standard deviation
Section References	9.2.1, Appendix D, Appendix E
Comments	The proportion of total sample size to be allocated to stratum k

$$\hat{n}_{TOTAL} = \frac{\sum_{(k)\in\mathcal{S}} \frac{a^2_{(k)}\hat{\sigma}^2_{(k)}}{w_{(k)}}}{\left(\frac{\mathrm{E}\times\bar{x}}{\mathrm{Z}} \times \frac{\mathrm{n}}{\mathrm{N}}\right)^2 + \sum_{(k)\in\mathcal{S}} a_{(k)}\, \hat{\sigma}_{(k)}{}^2}$$	[A.4]
Variables	${a^2}_{(k)}$ - $a_{(k)}$ - The area of stratum *k* ${\hat{\sigma}^2}_{(k)}$ - The estimated standard deviation of the quantity to be estimated within stratum $\mathcal{S}$ - The set of all strata E - The allowable degree of error (eg, 0.15 for +/- 15%) $\bar{x}$ - The estimated mean of the quantity to be estimated $w_{(k)}$ – proportion of total sample size to be allocated to stratum k Z - Z statistic from a normal distribution associated with the desired confidence level (1.96 for 95% confidence). $\frac{\mathrm{n}}{\mathrm{N}}$ - The relative size of a sampling unit with respect to the entire population to be sampled (for example, in sampling with fixed area plots, this is the ratio of the plot size to the total project area size)
Section References	9.2.1, Appendix D, Appendix E
Comments	The estimated total required number of plots

$$\hat{n}_{(k)} = \hat{n}_{TOTAL} w_{(k)}$$ [A.5]	
Variables	$w_{(k)}$ – proportion of total sample size to be allocated to stratum k $\hat{n}_{TOTAL}$ - The estimated total required number of plots
Section References	9.2.1, Appendix D, Appendix E
Comments	The number of plots to be allocated to stratum *k*

A.1.3 Optimal Allocation

A third allocation method incorporates both information about within strata variability and the potential for varying costs for sampling different strata:

$$w_{(k)} = \frac{a_{(k)}\hat{\sigma}_{(k)}/\sqrt{c_{(k)}}}{\sum_{(j)\in\mathcal{S}} a_{(j)}\,\hat{\sigma}_{(j)}/\sqrt{c_{(j)}}}$$ [A.6]	
Variables	$a_{(k)}$ - The area of stratum *k* $a_{(j)}$ – The area of stratum *j* $\hat{\sigma}_{(k)}$ - The estimated standard deviation of the quantity to be estimated within stratum $\mathcal{S}$ - The set of all strata E - The allowable degree of error (eg, 0.15 for +/- 15%) $c_{(k)}$ or $c_{(j)}$ - The cost of sampling stratum *k* or *j*
Section References	9.2.1, Appendix D, Appendix E
Comments	The proportion of total sample size to be allocated to stratum k

A.2 Totals and Standard Errors from Stratified Samples

The total of a quantity of interest may be estimated from a stratified sample

$$\hat{T} = \sum_{(k)\in\mathcal{S}} \frac{a_{(k)}}{n_{(k)}} \sum_{(j)\in\mathcal{P}_{(k)}} y_{(j,k)}$$ [A.7]	
Variables	$a_{(k)}$ - The area of stratum *k* $\mathcal{S}$ - The set of all strata $n_{(k)}$ – Number of sampling units in stratum k $\mathcal{P}_{(k)}$ – Set of all sampling units in stratum k $y_{(j,k)}$ - A quantity estimated for or measured on sampling unit j in stratum k
Section References	9.2.1, Appendix D, Appendix E
Comments	The estimated total quantity in the sampled area

$$\sqrt{\sum_{(k)\in\mathcal{S}} \left[\frac{a_{(k)}^2 \hat{\sigma}_{(k)}^2}{\#(\mathcal{P}_{(k)})}\left(\frac{N_{POSSIBLE\ (k)} - \#(\mathcal{P}_{(k)})}{N_{POSSIBLE\ (k)}}\right)\right]}$$ [A.8]	
Variables	$a_{(k)}$ - The area of stratum *k* $\hat{\sigma}_{(k)}^2$ - The estimated within-stratum variance of stratum *k* $\mathcal{S}$ - The set of all strata $\mathcal{P}_{(k)}$ – Set of all sampling units in stratum k $N_{POSSIBLE\ (k)}$ = total number of possible plots in stratum k
Section References	D.1, D.2
Comments	The estimated standard error of the total

APPENDIX B: DEFAULT STATIC CHAMBER MEASUREMENT METHODS

The project proponent may deviate from the methods provided in this appendix per the requirements of Section 9.

GHG emissions fluxes have been measured with the static (closed) or dynamic (with air circulation) chamber techniques on a wide variety of wetland sites (Moore and Roulet 1991). There are a number of chamber techniques that are used to isolate soil respiration or develop carbon budgets and sophisticated soil flux systems are commercially available. While there are acceptable variations in equipment and techniques, this guidance focuses on describing a static chamber method, with discrete time series of gas measurements during each monitoring period, to calculate methane flux for baseline and project monitoring. Nitrous oxide or carbon dioxide fluxes may be sampled in the same manner, depending on project requirements. With attention to minimizing chamber and soil disturbance, periodic sampling with static chambers can provide an estimate of project area GHG emissions on a daily time scale, which is then extrapolated to annual estimates.

The methods described here are specific to herbaceous marshes where vegetation heights are typically less than 1.0 m, and present optimal conditions to sample all contributions of GHG exchange, particularly soil diffusion, ebullition, and plant-mediated transport of methane. Closed chamber methods that only isolate soil processes, by excluding vegetation, may underestimate the contribution of methane release from plants (through xylem transport to the atmosphere), which can be considerable from certain wetland 'shunt' species that have well developed aerenchyma. Therefore, vegetation must not be excluded from wetland-based sampling, but an exception exists when open water sampling may be necessary for quantifying fluxes from this habitat type. Clipping of emergent plants above the water level to accommodate the dimensions of the flux chamber is allowable immediately prior to sampling. The technique of using dynamic chambers with semi-continuous measurements of GHGs may also be used but will require a justification of the technique and description by the project proponent.

B.1 Chamber Description

Chamber size or design must be scaled to accommodate the existing vegetation height and seal the soil surface so that plant-mediated, diffusion, and ebullition fluxes are captured. Chamber design guidelines described here follow that of Yu et al. (2008) and Parkin and Venterea (2010). A cylinder or box chamber must not have a cross-sectional area less than 200 cm^2. The base seals the soil column and is permanently installed and left in the field during the monitoring period. If the base is disturbed by natural or human causes, it must be reinstalled and allowed to equilibrate for a minimum of two weeks prior to additional sample collection.

The chamber top must be less than 1.0 m in vertical height, and is only installed or fit to the permanently installed base during sampling periods. It contains two or more sealed (syringe septa) gas collection ports that allow sampling when water levels are high or low. One port will have a tube that extends lower in the chamber for retrieving samples when water level is low, and the other port(s) must have a shorter tube(s) to collect samples higher in the chamber when water level is high. Where the chamber base and top seal together there must be a gas-impermeable gasket or water trough.

Cylinder or box chamber materials may consist of stainless steel, aluminum, PVC, polypropylene, polyethylene, or plexiglass. Opaque or clear chambers are acceptable. Black material must not be used given its potential for excessive heating of the chamber in sunlight. The chamber base must have drainage ports along its vertical length to eliminate chamber flooding between monitoring periods.

For sampling open water habitats, chamber specifications are the same as above; however, a permanent chamber base or collar is not required. Rather the chamber top may be outfitted with floatation that can form a seal with the water surface.

B.2 Plot Establishment for Chambers

B.2.1 Replication

Within a stratum, there must be a minimum of two plots comprising three replicate chambers per plot. Each plot must occur within a 100 m radius of a randomly chosen sampling location center point.

From the center point, chambers may be randomly located within a 100 m radius of habitat that is representative of the stratum. Factors that must be considered for plot location include dominant vegetation type and marsh surface elevation. In choosing sample locations, project proponents must justify that the locations chosen are conservative – that is, within a stratum, chambers should be located in areas in which methane flux is expected to be greatest (see section 9.2.2.3.1 for a description methane flux indications). Typically, this involves positioning chambers in areas that occupy lower elevations in the landscape that still support dense vegetation coverage. The arrangement of chambers within this radius will be dependent on the marsh topography and a suitable amount of existing habitat to re-locate chamber plots if needed in the future. There are no minimum or maximum distance requirements between replicate chambers but the chambers should be placed such that sampling can occur within the prescribed time intervals.

B.3 Chamber Installation

Most wetland conditions will require the construction of boardwalks to minimize soil disturbance during chamber deployment and subsequent sampling. Site specific conditions (water table depth, soil permeability) will dictate the depth to which the base of the chamber is fitted into the soil; the base should be installed to a depth no lower than the mean water table depth of the site. Installation of chambers may take place anytime of the year and should occur when water levels are at or below the soil surface.

The chamber base is installed to the soil by slicing and excavating a trench that will accommodate its dimensions. The base must capture representative vegetation cover and species and disturbance to vegetation in the chamber area must be minimized. To allow soil/plant disturbance effects to diminish, the chamber must equilibrate for a minimum of two weeks prior to any sampling. Drainage ports will remain open during the equilibration period and between verification events.

PD Requirements: Chamber Description	
The project description must include the following:	
PDR.90	A description of the chamber design, with its dimensions or total volume, and cross-sectional area.
PDR.91	Diagram of chamber plot randomization design and the resulting chamber locations within each stratum, with the chambers identified as replicates. Provide dates when chambers were deployed in each stratum. Provide a justification that the locations chosen are conservative (ie, that they are likely to predict methane emissions flux for the entire stratum for which they are representative.)

B.4 Chamber Sampling

Flux chamber measurements require collecting syringe gas samples of ambient air outside of the chamber, replicate samples within the chamber base prior to sealing with the chamber top, and then successive samples over an incubation period less than 2 hours after sealing the chamber. A minimum of three sample intervals should be collected: time = 0 hours (unsealed chamber), time = 0.5 hours (30 min after chamber sealed), t = 1.0 hours (60 min after chamber sealed). Exact sample times are recorded during sampling.

Steps:

1. Inspect the chamber base for any physical disturbance.
2. Drainage ports that are open to atmosphere are plugged before inserting the chamber top.
3. Sample vials are vacuumed with a 10 ml syringe.
4. Collect one ambient atmosphere gas sample outside of the chamber and inject into the sample vacuum vial.
5. Duplicate (n=2) gas samples are collected inside the chamber base prior to sealing with the top of the chamber.
6. The chamber top is sealed to the base. Stopwatch is started at t=0.
7. With the chamber sealed, duplicate samples are collected at 30 min intervals and injected into vacuum vials. One minute prior to each sample collection, a stirring procedure is done by

inserting a 30 ml syringe into the chamber septa and withdrawing and expelling the full volume twice.

8. After sampling is complete, the chamber top is removed and the drainage ports are unplugged.

Samples must be stored out of direct sunlight during transport to the laboratory. A chain of custody form should be completed by the field lead and submitted to the laboratory with the samples to be maintained with their records. The steps for open water sampling follow those for wetland-based sampling.

B.5 Data Processing and Analysis

Gas concentration data from lab analyses are in volumetric units (L trace gas : L total gas) and are corrected for chamber volume, cross-sectional area and linear change with time to yield flux volume (L trace gas m^{-2} hr^{-1}), according to the following equation:

$$f_v = v_{CHAM} * c_v * 1/a_{CHAM}$$ [B.1]	
Variables	f_v - flux of trace gas (volume basis) in the chamber headspace over the enclosure period, corrected for chamber volume and cross sectional area (L trace gas m^{-2} hr^{-1}) v_{CHAM} - chamber volume (L) c_v - change in gas concentration over the enclosure period, or slope of best fit line calculated from simple linear regression (L trace gas L^{-1} total gas hr^{-1}) a_{CHAM} - cross-sectional area of soil enclosed by the chamber base (m^2).
Section References	9.2.2.3
Comments	Guidance for assessing goodness of fit is provided in section F.3 of Appendix F. Curve fitting methods for non-linear rates of trace gas change are outlined in: Parkin, T.B. and R.T. Venterea. 2010. Sampling protocols. Chapter 3. Chamber–based Trace Gas Flux Measurements. In: Sampling Protocols R. F. Follett, ed. P.3-1 to 3-39. www.ars.usda.gov/research/GRACEnet

To convert from volumetric to mass flux basis, the ideal gas law is used in the following equation:

$$f_{P\,\Delta} = \frac{f_v * P}{R * T} * M * 24 * 0.000001 * GHGcf$$ [B.2]	
Variables	$f_{P\,\Delta}$ - mass of trace gas flux (tCO_2e ac/day) f_v - flux of trace gas (volume basis) (L trace gas m^{-2} hr^{-1}) *P* - barometric pressure (atm) *T* - air temperature (°K) *R* - universal gas constant (0.0820575 L atm/°K mol) *M* - molecular weight of trace gas (g/mol)
Section References	9.2.2.3
Comments	24 = conversion from hr to day 0.000001 = conversion from g to tonnes $GHGcf$ = GHG correction factor to CO2e, use 21 (CH_4) and 310 (N_2O)

With the series of repeated measures of gas concentration from a chamber, simple linear regression is used to compute the slope of gas concentration with time (c_t), which represents one replicate of gas flux (see equation [B.1]). A minimum of three replicate chambers (or plots) must be used to compute a mean flux (±1SEM) for a given location within a stratum for each verification event or sample date. Refer to Section 9.2.2.3 for chamber flux calculations.

APPENDIX C: DEFAULT EDDY COVARIANCE MEASUREMENT METHODS FOR METHANE

The project proponent may deviate from the methods provided in this appendix per the requirements of Section 9.

Eddy covariance or eddy correlation is a widely accepted micrometeorological technique to estimate flux of heat, water, atmospheric trace gases and pollutants and relies on turbulence to calculate fluxes. The semi-continuous nature of sampling allows for diurnal, seasonal, and annual budgets of energy and GHGs between the biosphere and atmosphere. Measuring carbon fluxes with the eddy covariance method has the advantage of covering broader space and more continuous measurements, unlike chamber flux techniques. The two methods may be used in concert in a heterogeneous landscape to evaluate flux contribution of distinct landforms (hummocks, hollows, ditches, open water; Teh et al. 2011, Baldocchi et al. 2011) to create a more accurate landscape or project area GHG budget.

Standard operating procedures for designing flux studies and data analyses are being unified by global and regional bio-meteorological communities, such as FLUXNET and AMERIFLUX, respectively. The information presented here draws from their basic guidelines for eddy covariance methods. Open source software is increasingly available for computing GHG fluxes that have been validated by a 'Gold Standard' (see AMERIFLUX, http://public.ornl.gov/ameriflux/sop.shtml) and a selection of the available software is given in Section 9.2.8.4.

Eddy flux is equivalent to the mean dry air density, multiplied by the mean covariance of instantaneous deviations of vertical wind velocity and the mixing ratio of a constituent (methane and carbon dioxide) in air. These covariances are corrected for density fluctuations due to water vapor (Baldocchi et al. 2011).

The eddy covariance technique, while applied in many different ecosystems, is most easily applied in areas where the canopy is relatively homogeneous and the terrain is horizontal. Thus herbaceous wetlands lend themselves well to this technique. Caution is needed when deploying eddy covariance stations, so that vertical disruptions (canopy height changes, trees, buildings) to the boundary layer of interest are minimized. The seven main assumptions for eddy covariance technique are outlined here (from Burba and Anderson 2007) and specific requirements to satisfy these assumptions are described throughout this appendix.

1. Measurements at a point represent an upwind area
2. Measurements are collected in the layer of interest (eg, constant flux layer)
3. The fetch is assumed to be adequate and measures the area of interest
4. Flux is fully turbulent
5. Terrain is horizontal
6. Average of vertical fluctuations is zero, density fluctuations are negligible, and flow convergence and divergence does not occur.

7. Instruments are capable of detecting small changes and measuring at a high frequency (>10 Hz).

There are sources of error that can affect flux computations; however, these errors, such as time lags in measurements and unleveled instruments, are adjusted according to accepted methods during data processing (see Section 9.2.8.4).

C.1 Eddy Covariance Instrumentation

Direct measurements of methane at high frequencies (10-20 Hz) are needed for eddy covariance calculations. For methane, laser absorption spectroscopy is common, and suitable instrumentation is equivalent to those of the closed path Los Gatos tunable diode laser spectrometer (DLT-100 Fast Methane Analyzer), the open path LICOR 7700 (Wave Modulated Spectroscopy), and the Campbell Scientific Trace Gas Analyzers. The chosen methane analyzer must have a resolution of ≤5 ppb methane at 10 Hz (@ 2000 ppb methane) and measurement frequencies must not be less than 10 Hz.

In addition to methane, other meteorological variables must be measured at a frequency (≥10 Hz) equivalent to the gas measurements, including wind and turbulence (three-dimensional sonic anemometer), water vapor, and air temperature. The chosen water vapor analyzer must have a resolution ≤ 0.005 mmol H20/mol air (@ 10 mmol H20/mol air). The sonic anemometer must have a resolution ≤ 0.01 m/sec (@ standard velocity of 12 m/sec). Water vapor measurements will be used to correct for air density fluctuations.

C.2 Tower Configuration

C.2.1 Orientation of Sensors and Equipment

A single tower must be used with the elevated array of eddy covariance instruments contained within a 3 m radius from the center of the tower. If a platform is used, the maximum footprint of the platform and support equipment (solar panels, flow modules, batteries) must not exceed a 5 m radius from the center of the tower base.

High frequency measurements of air properties for eddy covariance require short distances between sensors to minimize time response errors. Instrumentation on the tower must be integrated (ie, trace gas analyzers, anemometer, and temperature sensors) such that distance and orientation between sensors sample the representative air mass properties and allow frequency response corrections.

While configurations may vary depending on the wind direction of interest, the maximum horizontal distance of methane sensor or water vapor intake must not exceed 1.0 m from the center of the anemometer, unless the project proponent provides justification. The distance of the intake sensor for air density and methane sensor must be measured and recorded for elevation, in addition to the northward and eastward separation relative to the center of the sonic anemometer.

C.2.2 Landscape Location of Tower

For conservative project emissions estimates, a primary requirement is to locate the tower within the strata where the highest emissions are anticipated, and at least one-half of the footprint area (as defined by the 80% mean footprint distance) must include the highest emitting strata (see Section 9.2.2.3.1, which defines criteria for determining areas likely to have highest emissions).

The slope of the site must not exceed 1% (1 m vertical /100 m horizontal distance) in any direction within a 200m radius of the eddy covariance tower. The tower may be positioned in the landscape to capture specified wind direction(s) or it may be centrally placed within a homogeneous habitat with adequate fetch to measure all wind directions. In either case, the terrain must be homogeneous with respect to the *mean 80% footprint distance*. Homogeneous terrain here is defined as an area that contains no more than 25% areal coverage of patch vegetation that exceeds twice the dominant plant canopy height. A patch is defined as ≥100 m^2 of species (twice the dominant plant canopy height) covering >70% of the 100 m^2.

C.2.3 Sensor Height

As a general rule a sensor height of 1.0 m above the canopy can integrate fluxes from 100 m upwind under turbulent conditions. Sensor height above the canopy must be no less than one and one-half greater than the dominant plant canopy height in the footprint area. It is permissible to increase or decrease sensor height on the tower to accommodate changes in plant canopy height, as long as the sensor height is maintained above twice the canopy height. Alternately, during data post-processing vegetation canopy height may be adjusted without changing sensor height. Physical changes in sensor height must be recorded and incorporated as offsets during data processing.

C.2.4 Fetch and Flux Footprint

Fetch is described as the horizontal extent from the tower where flux is sampled, whereas the flux footprint describes how much of the measured flux comes from an area at a given horizontal distance. Sufficient fetch is needed to develop an internal boundary layer where fluxes are constant with height (Baldocchi et al. 2001). For every 1.0 m increase in vertical plant structure above an effective surface, approximately 100 m of fetch is needed to readjust the internal boundary layer (Businger 1986, in Baldocchi et al. 1988). To provide adequate fetch, the effective surface (dominant canopy height of interest) must be provided by the project proponent and the sensor height must be twice the dominant canopy height within a minimum radius of 100 m from the tower. If patch vegetation is present it must not exceed the 25% area threshold identified in Section C.2.2.

C.2.4.1 Footprint Distance Estimation

The *mean 80% footprint distance* provides the verifier with information to confirm that flux measurements are being collected within an area that is homogeneous. Here, *mean 80% footprint distance* can be estimated with a predictive model and using daytime turbulence parameters that are typical of the region (ie, from a nearby meteorological station) and the characteristics of the site.

The predicted *mean 80% footprint distance* must be estimated by the project proponent based on the methodology by Klujn et al. (2004), which uses turbulence parameters to predict the location or distance that influences a percentage of the flux. In this case, the project proponent must provide parameter estimates and the results of the predicted footprint distance with 80% flux contribution (online footprint parameterization, http://footprint.kljun.net/varinput.php) to the verifier, based on data known for the project site or estimates from local meteorological stations for the time period of measurement. The parameter estimates must include:

σ_W = standard deviation of daytime vertical velocity fluctuations (m/s)
u_* = surface friction velocity (m/sec)
z_m = measurement height (m)
h_m = planetary boundary layer height (m) or 1000 m
z_m = roughness length (m) or 1/10th of the average canopy height

C.2.5 Calibration

Calibration of methane sensors must be performed by the factory or user according to manufacturer guidelines. When LICOR equipment is used, the intervals for checks and calibration are provided here, while detailed calibration/zero instructions can be accessed via the LICOR website. The methane analyzer (LI-7700) must be fully calibrated spanning a 0 and 10 ppm methane concentration standard at least once annually with standard gases (1% accuracy). Zero and 10 ppm checks of the methane analyzer with hydrocarbon-free and 10 ppm standard gases (accuracy for zero gases = <0.1 ppm Total Hydrocarbon Concentration; accuracy for 10 ppm methane = <0.5 ppm methane) must be conducted at a minimum of twice every six months over one year of data collection. The LI-7200, which measures water vapor and carbon dioxide, must be returned to the factory at least once every three years to confirm the stability of coefficient values on the factory drift table.

C.3 Scale to Project Area

Project field monitoring designs may fall into one of several general approaches that may embrace one uniform habitat type or multiple habitat types in a single location, periodic habitat sampling, or multiple eddy covariance towers contemporaneously measuring different habitats.

1. Stationary single habitat: The simplest case is restricting long-term measurements to a single location that maximizes flux estimates from a homogeneous habitat across seasonal atmospheric and environmental events. The assumption of this approach is that the range of project-scale variability in GHG emissions is adequately characterized over an annual period.

2. Stationary multiple habitats: The eddy covariance tower may be placed a single location that generates information from different habitats that have different source/sink effects. In this case,

data are isolated by the wind direction or quadrant that corresponds to the habitat (open water, scrub-shrub, herbaceous).

3. Complete or periodic coverage of multiple habitats: For project areas with diverse habitats, each habitat type is individually instrumented and measuring simultaneously for valid inter-habitat comparisons. Another approach is to make periodic movements to different habitats with an eddy covariance tower. The degree to which periodic deployments in different locations approximate average conditions must be demonstrated by the project proponent.

Regardless of the method chosen above to scale from the tower location to the project area, project proponents must justify that the tower locations selected result in conservative estimates of methane emissions flux. To do this, project proponents must:

1. Stratify the project area based on measureable factors expected to impact methane emissions flux. These factors may include but are not limited to elevation, vegetation cover, and salinity.

2. Calculate the percentage of the total project area that falls into each methane emissions flux stratum.

3. Using the mean 80% footprint distance defined above, calculate the percentage of the expected tower footprint that falls within each stratum.

4. Demonstrate that, if the proportion of the tower footprint area that falls within each stratum differs from the proportion of the total project area that falls within each stratum, the tower footprint area contains a proportionally greater area of strata expected to have high methane emissions flux. For example, if two strata are identified (low and high emissions flux), and the project area is 40% low and 60% high, a tower footprint that includes 70% high emissions flux strata and 30% low is acceptable, while a footprint that includes 55% high emissions flux strata and 45% low is not. If evidence can be presented that a tower footprint is completely homogenous and all strata are sampled separately, this requirement can be considered satisfied.

$$f_{P\,\Delta\,CH4} = (\,\overline{\rho a}\,\overline{w's'}) \times 5.61 \times 10^{-3} \times 21$$ [C.1]	
Variables	$f_{P\,\Delta\,CH4}$ = CH_4 daily flux (tCO_2e/ac/day) $\overline{\rho a}$ - mean air density for a 0.5 hour sample interval (μmol air/m^3) $\overline{w's'}$ - mean covariance of instantaneous vertical wind velocity and mixing ratio of CH_4 in air w' - instantaneous vertical wind velocity (m/sec) s' - instantaneous mixing ratio of CH_4 in air (μmol gas/μmol air)
Section References	9.2.2.3
Comments	5.61×10^{-3} = unit conversion of μmol CH_4/m^2/s to tCH_4/ac/day 21 = conversion of tCH4 to tCO_2e

C.4 Data Processing and Analyses

Decades of eddy covariance methodology research has resulted in some widely accepted sequences of processing steps and corrections that should be applied. As an evolving science, however, there are debatable topics under discussion. The traditional steps in eddy covariance data processing are outlined below and the project proponent is responsible for specifying how data processing conforms to accepted methods (adapted from Burba and Anderson 2007).

Table 16: Steps to eddy covariance data processing

	Step	Accepted methods	References
1.	**Raw data unit conversion**	- raw voltage to unit conversion	
2.	**Despike**	-signals greater than 6 times the standard deviation for a given averaging period (30 min) must be removed for vertical wind velocity and gas concentration	
3.	**Calibration coefficients**	-may be done during data post processing; or, -user input corrections embedded in the instrument software and metadata	
4.	**Coordinate rotation**	- rotation to mean vertical velocity is equal to zero over a 30 min sample interval; or, -planar fit method; or, -sonic tilt correction algorithms	
5.	**Detrending**	-30 min block averaging must be used -linear and non-linear de-trending should be justified by project proponent	
6.	**Frequency response corrections**	-corrections may include: sensor separation, scalar path averaging, high-low pass filtering.	Moore, C.J. 1986. Frequency response corrections for eddy correlation systems. Boundary Layer Meteorology, 37:17-35.
7.	**Density fluctuation**	WPL correction applied to uncorrected covariances or final fluxes.	Webb, E.K., Pearman, G., and Leuning, R. 1980. Correction of flux measurements for density effects due to heat and water vapor transfer. Quarterly Journal of the Royal Meteorological Society, 106:85-100.

C.5 Flux Footprint Calculations

Flux footprint calculations must employ one of the following methods: Klujn et al. 2004 or Kormann and Meixner 2001. With either method, the project proponent must provide a summary table describing the measured meteorological conditions and the mean 80% footprint distance for the monitoring period. See equation [C.1].

APPENDIX D: DEFAULT BIOMASS MEASUREMENT METHODS

The project proponent must develop a detailed sampling protocol for the purposes of field crew consistency and documentation. The project proponent may deviate from the methods provided in this appendix per the requirements of Section 9.

D.1 Above Ground Tree Biomass

Above ground tree (AGT) biomass includes only trees above a specified diameter and is estimated using allometric equations. For each tree within a given measurement plot, diameter at breast height (dbh) is measured and input into an equation to yield an estimate of above ground biomass. Some equations may also require tree height and/or wood density. Tree biomass is then summed for each plot, and plot biomass estimates are extrapolated across the entire project area to estimate total carbon stocks in AGT biomass.

Project proponents must choose plot size and design. For example, a nested plot configuration may be utilized in order to decrease sampling size necessary to obtain an acceptable level of error. The sampling protocol should reflect the selected sampling scheme.

In each plot, required measurements are taken on every tree falling within the plot based on the sampling protocol. The sampling protocol should explain how to determine whether a given tree is “in” or “out.” The project proponent may decide whether to collect height or wood density based on which metrics are required by selected allometric equations.

When a list of tree species present in the project area is available, allometric equations are to be compiled. Equations may be obtained from peer-reviewed scientific journals or developed by the project proponent, and may be species-specific, genus-specific, or generic form equations. Equations must be validated. When form equations are used, the project proponent must justify that they are conservative for species considered in the project. Since small errors in equations can lead to significant error in the biomass estimate across the entire project, it is important that equations are representative of the trees for which they are utilized—species, locale, and diameter range used to develop the equations should be considered when making selections. If equations require wood density, the project proponent may choose to employ species- or genus-specific values from peer-reviewed scientific journals instead of using field-collected data.

After field measurements are complete, the following steps are taken to calculate total project area carbon stocks in AGT:

- Using Equation [D.1], apply the appropriate allometric equation and convert the resulting biomass to carbon stocks for each tree.
- Using Equation [D.2], AGT carbon stocks are summed for each plot then divided by plot area to yield plot-wide carbon stock density.
- Using Equation [D.4], carbon stocks in each stratum are extrapolated from plot-wide carbon stock density and summed across all strata to yield average AGT carbon stocks for the project.

- Using Equations [A.8], calculate standard error of the average project carbon stock estimate.

D.2 Above Ground Non-Tree Biomass

Grasses, sedges, other herbaceous plants, shrubs, and trees smaller than the AGT pool minimum diameter are included in above ground non-tree (AGNT) biomass. Woody plants (small trees and shrubs) may be measured using either destructively-sampled clip plots or allometric equations, while herbaceous plants, if included, must be measured using clip plots. If a distinction in sampling is made between woody and herbaceous plants, a procedure to ensure that each plant is counted only once must be outlined in the sampling protocol.

Plot size will be chosen by the project proponent and will likely be much smaller than AGT plots. Though plots for AGNT sampling are separate measuring units from AGT plots, they may exist within AGT plots.

D.2.1 Destructive Sampling – Clip Plots

In the destructive sampling method, all plants in the sampling frame within a plot are cut and weighed to measure plot-wide AGNT biomass. Plants should be cut at a consistent height as close to the ground as possible. To aid in determining the extent of the plot, a sampling frame of the desired plot size must be laid on the ground and all plants within must be cut. If possible, biomass must be refrigerated as soon as possible after clipping in order to avoid mass loss due to respiration.

If the project proponent desires, woody and herbaceous plants may be destructively sampled separately, with a smaller plot size for herbaceous plants to improve sampling efficiency.

After harvest, all biomass should be placed in a drying oven at 70° C and weighed periodically until weight is static, indicating that drying is complete. Weigh all dry biomass to determine plot-wide dry weight.

Alternatively, the project proponent may elect to measure wet weight of all biomass in the field and collect a representative and well mixed subsample of which to measure dry weight. The ratio of dry-to-wet weight determined by the subsample would then be multiplied by the plot-wide wet weight to determine plot-wide dry weight.

After measurements are complete, the following steps must be taken to calculate total project area carbon stocks in AGNT:

- Using Equation [D.3], AGNT biomass is converted to carbon stocks and then divided by plot area to yield plot-wide carbon density.
- Using Equation [D.4], carbon stocks in each stratum are extrapolated from plot-wide carbon stock density and summed across all strata to yield average AGNT carbon stocks for the project.
- Using Equations [A.8], calculate standard error of the average project carbon stock estimate.

D.2.2 Allometric Equations

Allometric equations may be used to estimate biomass of trees smaller than the AGT minimum and small shrubs. It is not only less important but also potentially impractical for equations to be specific to the species level in this scenario. The project proponent may wish to destructively sample a subset of shrubs in order to develop one or more allometric equations since doing so for shrubs is far easier than for trees.

The same procedure used to estimate biomass through allometric equations used for AGT biomass must be used to find AGNT; refer to the AGT section. Note that shrub equations may use a different metric such as diameter near root collar (drc) as the independent variable.

D.3 Below ground Biomass

Below ground biomass must be estimated using proportional relationships between above ground and below ground biomass (ie, root-shoot ratios) or by SOC measurement, but not both.

D.3.1 Coarse roots

Coarse roots are defined as roots ≥ 2 mm in diameter, the IPCC suggested minimum diameter for below ground biomass. In partially or wholly forested wetlands, below ground biomass may be estimated with either root-shoot ratios or SOC measurement. In herbaceous wetland creation projects, carbon stock in coarse roots (> 2 mm) is captured by SOC measurement (see Appendix E); root-shoot ratios may not be used to calculate coarse root carbon stock in herbaceous wetlands.

D.3.1.1 Estimation using root-shoot ratios

Carbon stocks in below ground biomass may be estimated by applying a root-shoot ratio to the estimate of above ground tree and/or non-tree biomass yielded in Equation [D.4]. Root-shoot ratios from peer-reviewed literature (eg, Vadeboncoeur, Hamburg, & Yanai, 2007) in a comparable ecosystem and latitude must be used when available. If not available, the root-shoot ratios from the IPCC 2006 Guidelines may be used if appropriate for the ecosystem. The carbon concentration of roots may be determined by taking samples from roots leaving the tree base, using 50% carbon content, or by using the carbon content of above ground biomass.

If this approach is utilized, roots ≥ 2 mm must be removed from soil samples prior to analysis (see Appendix E).

D.3.1.2 SOC Measurement

In the case of herbaceous wetlands—and in forested wetlands, if the project proponent prefers—carbon stocks in coarse root biomass may be included in the SOC pool. If this approach is utilized, root-shoot ratios must not be used.

D.3.2 Fine roots

The carbon stock in fine roots (< 2 mm) is included in the SOC pool (see Appendix E).

D.4 Biomass Measurement Equations

$$x_{(i,j,k)} = \frac{44}{12} \times \frac{1}{1{,}000} \times f_{SPC}(\bullet) \times p_{(SPC)CF}$$ [D.1]	
Variables	$f_{SPC}(\bullet)$ - allometric equation for species SPC, with output in kg $p_{(SPC)CF}$ - carbon fraction for species SPC
Section References	D.1
Comments	Carbon stocks in the i^{th} tree in plot j in stratum k (tCO_2e). $\frac{44}{12}$ is the ratio of the mass of carbon dioxide to the mass of carbon and is used to convert to CO2e units. $\frac{1}{1{,}000}$ represents a conversion from kg to tonnes.

$$y_{(j,k)} = \frac{1}{a_{(j,k)}} \sum_{i \in \mathcal{X}_{(j,k)}} x_{(i,j,k)}$$ [D.2]	
Variables	$a_{(j,k)}$ - area of plot j in stratum k (ac) $x_{(i,j,k)}$ - estimated carbon stocks in the i^{th} tree in plot j in stratum k (tCO_2e) $\mathcal{X}_{(j,k)}$ - set of all measurements of a type in plot j in stratum k
Section References	D.1
Comments	Carbon stock density in above ground tree biomass in plot j in stratum k (tCO_2e/ac).

$$y_{(j,k)} = \frac{44}{12} \times \frac{1}{1{,}000} \times \frac{p_{(SPC)CF} \times md_{(j,k)}}{a_{(j,k)}}$$ [D.3]	
Variables	$p_{(SPC)CF}$ - carbon fraction for species SPC $md_{(j,k)\_}$ - dry mass of non-tree sample harvested from clip plots in plot j, stratum k (kg) $a_{(j,k)}$ - area of plot j in stratum k (ac)
Section References	D.2.1
Comments	Carbon stock density in above ground non-tree biomass in plot j in stratum k (tCO_2e/ha).

$$C_{P\ CS\ (c)} = \sum_{k \in \mathcal{S}} \frac{A_{(k)}}{n_{(k)}} \sum_{j \in \mathcal{P}_{(k)}} y_{(j,k)}$$ [D.4]	
Variables	$A_{(k)}$ - the area of stratum k (ac) $n_{(k)}$ - number of plots in stratum k $y_{(j,k)}$ - Carbon stock density in plot j in stratum k (tCO_2e/ac) $\mathcal{S}$ - set of all strata for monitoring period m $\mathcal{P}_{(k)}$ - set of all plots in stratum k
Section References	D.1, D.2
Comments	Carbon stocks in pool c in the sampled area (tCO_2e).

$$c_{BG\ (p,i)} = c_{AG\ (p,i)} \times r/s$$ [D.5]	
Variables	$c_{(p,i)AGx}$ - carbon in above ground biomass in pool p in stratum i for a given monitoring period r/s – root-shoot ratio selected
Section References	D.3
Comments	Carbon stock in below ground biomass for a given pool in stratum i.

APPENDIX E: DEFAULT SOC MEASUREMENT METHODS

Wetland soil carbon can comprise elemental (charcoal, soot), inorganic (carbonates) and organic states (dead and living plant-animal tissue). The organic form is dominant in alluvial soils which are typically poor in carbonate or calcite content. Elemental analyzers can provide direct measurements of total soil carbon, whereas the loss on ignition technique of organic matter combustion can provide an estimate of organic carbon. Chemical oxidation of organic carbon may also be used (Nelson and Sommers 1996).

Soil organic carbon (OC) in mature gulf coast wetlands is relatively constant with depth and averages 26 mg/ml (Gosselink and Hatton 1984). This vertical consistency develops as soils are saturated for extended periods and compaction/oxidation is minimal. Once wetland creation projects attain full plant coverage and long-duration hydroperiods, the process of organic matter vertical accumulation can proceed rapidly (1.0 cm/yr) both above the soil surface (via litter deposition and adventitious root growth) and within the emplaced soil (via root growth). Wetland creation projects will typically begin with a mineral-based soil that is homogeneous in elevation, soil texture, and relatively low in carbon content. The created wetland surface, or original project soil surface, becomes a long-lived marker where carbon accumulation rates can be estimated by measuring changes: (1) within the original project soil, and (2) in vertical accretion above the original project soil surface.

Accretion above the surface and within the original project soil compartments may have carbon infilling (via root growth) and vertical accretion rates. With time, the wetland soil in general may reach an equilibrium point with regards to carbon density. When this happens, changes in soil carbon stocks largely take the form of increasing vertical accretion and not necessarily increasing soil carbon density. A combined approach of soil coring and artificial marker horizons (such as feldspar clay; Knaus and Cahoon 1990) or reference devices (such as sediment reference pins; Steiger et al. 2003; USACE 1993) may be used to account for changes in carbon stocks within both compartments.

E.1 Sampling Design

Project proponents must choose plot size and design. For example, a nested plot configuration may be utilized in order to decrease sampling size necessary to obtain an acceptable level of error. The sampling protocol should reflect the selected sampling scheme.

Guidance for the design, allocation, and demarcation of core locations within a soil measurement plot is provided in VCS Module VMD0021: Estimation of Stocks in the Soil Carbon Pool.

E.2 Description of Soil Compartments

Two soil compartments may be monitored for changes in carbon stocks with time: (1) the original project soil, and (2) newly accreted material above the original project soil surface.

The project proponent may monitor both compartments, or choose to monitor stock changes only within a fixed soil sample depth, for the project lifetime. The project proponent must identify prior to the project start date either of these two methods:

1) fixed soil sample depth; or,

2) fixed soil sample depth *plus* accretion depth.

If for any reason during a monitoring event accretion measurements become unreliable, the fixed soil sample depth becomes the basis for detecting stock changes for the monitoring period.

E.2.1 Original Project Soil

Prior to the project start date, the project proponent must specify a fixed soil sample depth for the original project soil, and this depth will be fixed for the life of the project. The fixed soil sample depth must not exceed 100 cm. The fixed soil sample depth must be sampled in a manner to inventory carbon and bulk properties on a mass- volume basis. There is no requirement on the number of additional depth intervals from the original project soil that must be sampled and analyzed separately.

E.2.2 Accretion above the Original Project Soil Surface

Artificial marker horizons (described in Section E.4) must be used to assess the vertical depth ($d_{accretion}$) of material that has accreted above the original project soil from $t^{[m-1]}$ to $t^{[m]}$. Marker horizons must be deployed at a minimum of once every five years.

E.3 Coring Devices

When soils are sampled for carbon and bulk property analyses, coring devices must be used that are adequate to retrieve volumetrically intact samples. Accretion depth measurements may be taken on soil samples that are excavated with a knife or slicing instrument, but the accretion layer must be collected with a volumetrically controlled corer for carbon and bulk property analysis.

Soil density largely determines the smallest diameter corer than can be used without creating significant compaction. Highly compressible organic soils (bulk density ≤0.20 g/ cm^3) should be collected with a core tube diameter ≥7.6 cm. Soils with a bulk density >0.20 g/cm^3 can be sampled with a core tube diameter < 7.6 cm. Corer materials may consist of but are not limited to aluminum, stainless steel, PVC, or acrylic.

Core devices must allow inspection/measurement of vertical compaction of sample versus field condition. Piston corers should have a sampling base that limits the sample collection to the specified depth. McCauley peat augers may be used to collect organic soils and are designed to minimize compaction.

E.4 Artificial Marker Horizon Establishment

Marker horizons may be established with a feldspar marker technique (Knaus and Cahoon 1990; Folse et al. 2012), which consists of a 1-cm layer of white feldspar clay that is evenly sprinkled on the wetland sediment surface to create a white layer which is easily distinguishable from the natural substrate and can be used to measure surface accretion of sediments over time. Plot size must be approximately 0.25 m^2 or greater. A minimum of three marker horizon plots must be deployed in each stratum.

E.5 Soil Sample Collection

Soil from the accretion layer and the original project soil may be collected as one unit unless discrete horizons are identifiable within the sampling depth found in the original project soil, in which case the soil must be sampled in sub-increments of the sampling depth. However, the accretion layer formed from $t^{[m-1]}$ to $t^{[m]}$ must be separated from the original project soil. The accretion layer and the original project soil must be analyzed for bulk density and carbon content separately, except when an accretion layer is < 1.0 cm, in which case the accretion layer may be incorporated and analyzed for bulk density and carbon content with the original project soil. To properly adjust coring depth, a mean accretion estimate from a stratum must be known prior to sampling soil from the fixed soil sample depth. Thus, there are two soil sampling depth options available for monitoring.

- Soil Sampling Depth Option 1: fixed soil sample depth
- Soil Sampling Depth Option 2: fixed soil sample depth plus accretion depth.

Specific methods for efficient sampling will depend on local soil conditions, so prescriptive requirements for sample size, volume, and sampling depth are not provided in this methodology. Rather, project proponents must develop a locally appropriate sampling plan. In developing this plan, care must be taken that the sampling procedures employed across the depth profile do not bias the estimation of soil organic carbon. In the case that discrete soil horizons can be identified within the selected fixed soil sample depth, each horizon must be sampled separately. The volume of each soil sample taken should be large enough to capture inherent soil structure variability across the depth range represented by the sample.

In the case that a single sample is used to represent a depth range, the sample must be well homogenized prior to analysis, and care must be taken that the sample used for organic carbon determination and bulk density determination are representative of the same depth range. If multiple samples are taken across a vertical soil profile (such as by division of a core into segments), a weighted average should be used to estimate the mean carbon content across the entire depth profile, where the weights are proportional to the percentage of the total sample depth range represented by each subsample.

Refer to the most recent version of VCS Module VMD0021: Estimation of Stocks in the Soil Carbon Pool, the IPCC Good Practice Guidance for Land Use, Land Use Change, and Forestry, and Nelson and Sommers (1996) for more detailed guidance on establishing appropriate sampling protocols.

E.5.1 Accretion above the Original Project Soil Surface

The accretion depth will be measured from a minimum of three feldspar plots per sampling location within a stratum. The mean of the individual measurements from each plot will represent ($d_{accretion}$). The accretion depth from the marker horizons may be sampled by conventional coring, knife excavation, or cryogenic coring techniques. Regardless of technique, at least three measurements of the material thickness above the marker horizon must be taken with calipers or a ruler to the nearest 1.0 mm and recorded on a data sheet. The mean accretion depth will inform the total depth of subsequent soil sampling. The accretion depth must be known prior to determining the overall depth required for soil coring.

E.5.2 Original Project Soil

The original project soil must be sampled with a coring tube of an appropriate diameter (as described in Section E.3). The thickness of ($d_{accretion}$) sediment accretion above the original project soil must be accounted for, when applicable. Otherwise the original project soil is sampled to the fixed soil sample depth defined for the project.

Soil Coring Process:

1. Locate pre-determined sample plot. Remove emergent vegetation by clipping to the soil surface. Insert core tube and drive approximately 5-10 cm deeper than the fixed soil sample depth or the sum of the fixed depth and accretion depth.

2. Measure the vertical height of the soil surface relative to top of the core tube, both inside and outside of core tube to calculate compaction. If height difference is ≥ 10% of the sample depth, remove the core tube and re-sample. If height difference ≤ 10%, remove the core, aided by a cap on the top of the core tube to create a vacuum, or by inserting a hand at the base of the core tube. The core compaction estimate must be documented.

3. Transfer core to an extruding base, which may consist of a 'Meriwether extruder' (Folse et al. 2012) or equivalent device that permits extrusion from the base of the core, such that the upper soil is sectioned first, and deeper layers thereafter.

4. If the accretion depth ($d_{accretion}$) is ≤1 cm, it must be considered to be conservative to include this layer within the original project soil (ie, only core to the original fixed soil sample depth). If the accretion layer is > 1 cm, record the layer thickness as $d_{accretion}$.

5. Extrude the core to the mean accretion depth ($d_{accretion}$) as defined by the marker horizon technique (described in Section E.4 and E.5.1). The soil from this sample depth is removed and placed in a plastic bag labeled with sample location information and the sample depth to the nearest 1.0 cm.

6. After the surface accretion layer has been removed, continue the extrusion process to the original fixed soil sample depth, sectioning at the pre-defined intervals of the original project soil (as described in section E.2.1). Place the sample in a plastic bag with sample location information and deposit depth to the nearest 1.0 cm.

E.6 Soil Sample Analyses

All soil samples must be stored on ice following collection and during transport. A chain of custody form should be completed by the field lead and submitted to the laboratory with the samples to be maintained with their records.

Soil samples must be analyzed for bulk density and SOC by a qualified laboratory following the methods of Nelson and Sommers 1996 and Ball 1964, respectively, or comparable methods.

The chosen laboratory must have a rigorous Quality Assurance program that meets or exceeds the USEPA QA/QC requirements or similar international standards for laboratory procedures, analysis reproducibility, and chain of custody. The laboratory must also provide a document that defines the pre-analysis sample processing procedures, and the specific chemistry test methods they use at the laboratory, including the minimum detection limits for each constituent analyzed.

If root-shoot ratios are used to estimate carbon stocks in coarse roots (≥ 2 mm), such roots must be removed from soil samples prior to analysis. In this case, note that although coarse roots do not count toward mass or carbon content in SOC calculations, their volume should still contribute to soil core volume.

E.6.1 Bulk Density

For bulk density determination, core samples of known volume are collected in the field and oven dried to a constant weight at 105°C (for a minimum of 48 hours). The total sample is then weighed.

The bulk density of the soil core is estimated as:

$$\rho_{SOIL} = M_{soil} / V_{soil}$$ [E.1]	
Variables	M_{soil} - oven-dried mass of sample soil core (g) V_{soil} - volume of soil core (cm^3)
Section References	
Comments	Bulk density of soil core *j* in stratum *k* (g/cm^3)

Further guidance is provided in Nelson and Sommers (1996).

E.6.2 Direct Carbon Determination

For direct soil carbon determination, individual core samples collected in the field are oven dried to a constant weight at 105°C (for a minimum of 48 hours). Dried samples must be homogenized or ground with a Wiley Mill or ball grinder.

The prepared sample is analyzed for percent organic carbon or g C/g soil (cf_{soil}) using either dry combustion using a controlled-temperature furnace (eg, LECO CHN-2000, LECO RC-412 multi-carbon analyzer, or equivalent), dichromate oxidation with heating, or Walkley-Black method. Further guidance is provided in the IPCC LULUCF Good Practice Guidance (2003) and in Nelson and Sommers (1996).

E.6.3 Indirect Carbon Determination

Indirect carbon estimation techniques may be substituted for direct determination. Organic carbon (OC) can be estimated reliably with the loss-on-ignition (LOI) method, which combusts organic matter from a soil sample, leading to a direct relationship between soil organic matter content and organic carbon content. LOI lab techniques should adhere to those of described in Ball 1964 or Henri et al. 2001. While some variability may exist among samples, OC content should not exceed 50% of the OM content. Table 17 presents the relationships that are acceptable for converting from organic matter to organic carbon.

Table 17: Default equations for estimating organic carbon content from organic matter content with soil samples analyzed with the loss-on-ignition technique

Region	Relationship (OC and OM on a percent dry basis)	Reference
Atlantic	OC= 0.40 * OM + 0.0025 *OM^2	Craft et al. 1991
Gulf of Mexico	OC= 0.4541 * OM	Steyer et al. 2012
Pacific	OC= 0.38 * OM + 0.0012 *OM^2	Callaway et al. 2012

$$c_{SOC\ j} = \left[\sum_{l}^{1-x}\left(cf_{soil,l} * \rho_{soil,l} * \ d_{soil,l}\right) + \sum_{l}^{1-x}\left(cf_{soil,l} * \rho_{soil,l} * \ d_{accretion,l}\right)\right] * \frac{44}{12} * 40.47 - \ c_{alloch,j} \quad [E.2]$$

Variables	$c_{SOC\ j}$ = total soil carbon measured at plot *j* (tCO₂e ac⁻¹) *x* =number of soil layers *l* = soil layer cf_{soil} = organic carbon content of the soil sample in plot *j* in stratum *k* (g C/g soil) ρ_{soil} = soil bulk density of sample in plot *j* in stratum *k* (g/cm3) d_{soil} = depth of a soil sample collected below the surface of the original project soil surface in plot *j* in stratum *k* (cm) $d_{accretion}$ = depth of soil sample collected above a marker horizon (feldspar) or control rod or pin in plot *j* in stratum *k* (cm) $c_{alloch,j}$ = allochthonous soil carbon measured at plot *j* (tCO2e/ac). This quantity is zero if the project meets the criteria in section 5.2.1.
Section References	
Comments	$\frac{44}{12}$ is the ratio of the mass of carbon dioxide to the mass of carbon and is used to convert to CO2e units. 40.47= conversion to t/ac

$$C = \sum_{k \in \mathcal{S}} \frac{A_{(k)}}{n_{(k)}} \sum_{j \in \mathcal{P}_{(k)}} y_{(j,k)}$$	[E.3]
Variables	$A_{(k)}$ - the area of stratum k $n_{(k)}$ - number of plots in stratum k $y_{(j,k)}$ - a quantity estimated for or measured on plot j in stratum k $\mathcal{S}$ - set of all strata for monitoring period m $\mathcal{P}_{(k)}$ - set of all plots in stratum k
Section References	D.1
Comments	Estimated total SOC stock in the sampled area

E.6.4 Allochthonous Carbon Determination

Allochthonous carbon is estimated using a marker horizon technique in order to determine the amount of mineral matter that has been deposited over the monitoring period. The mineral-associated carbon is the component that is classified as allochthonous carbon.

1. Measure the total amount of soil accumulation (accretion depth) during the monitoring period.
2. From the accretion depth, collect soil sediment samples and analyze the samples for bulk density.
3. Calculate the mineral fraction of the soil sample.
4. Use a correction factor to estimate the amount of mineral-associated carbon (allochthonous carbon) to be deducted from the carbon stocks associated with recently deposited sediment.

Core samples of known volume are collected in the field, homogenized in the laboratory, and the homogenized material is sub-sampled for combustion (with the loss-on-ignition technique, described in Section E.6.3), which removes the organic matter/carbon. (The dry bulk density of total sample is measured first; then the organic and mineral content are separated by combustion.) The total remaining material is mineral, and mineral density of the sample is calculated from the original soil sample volume.

The mass of allochthonous carbon of the soil sample above the marker horizon is estimated as:

$$c_{alloch,j} = \sum_{l}^{1-x} (mcf_{soil,l} * \rho_{minsoil,l} * \ d_{accretion,l}) * \frac{44}{12} * 40.47$$	[E.4]
Variables	$c_{alloch,j}$- allochthonous soil carbon measured at plot *j* (tCO2e/ac) *x* =number of soil layers *l* = soil layer mcf_{soil} – mineral-associated carbon fraction of the soil sample in plot j in stratum k (%) $\rho_{minsoil}$ – mineral density of sample in plot j in stratum k (g cm^{-3}) $d_{accretion}$- depth of soil sample collected above a marker horizon (feldspar) or control rod or pin in plot j in stratum k (cm)
Section References	9.2.6
Comments	$\frac{44}{12}$ is the ratio of the mass of carbon dioxide to the mass of carbon and is used to convert to CO2e units. 40.47= conversion to t/ac Mineral associated carbon fraction of estuarine soils is typically less than 3% and a locally relevant data source may be used, or see, Andrews JE, Jickells TD, Adams CA, Parkes DJ, and Kelly SD (2011) Sediment Record and Storage of Organic Carbon and the Nutrient Elements (N, P, and Si) in Estuaries and Near-Coastal Seas. In: Wolanski E and McLusky DS (eds.) Treatise on Estuarine and Coastal Science, Vol 4, pp. 9–38. Waltham: Academic Press)

APPENDIX F: MODEL ASSESSMENT REQUIREMENTS

The project proponent may not deviate from the methods provided in this appendix because these methods are not related to monitoring or measurement. This appendix must be followed to select and assess proxy models from sections 9.2.2.2 and 9.2.3.2.

All models must be fit using a sample size of at least 30 measurements.

F.1 Model Selection

A candidate set of models to predict methane or nitrous oxide flux (the response) must be fit using an unbiased estimator of model parameters. All models must be fit to the same response data and covariate data. An estimate of Akaike Information Criterion (AIC) must be used for model selection. The model with the lowest AIC must be used to predict methane and nitrous oxide flux.

F.2 Checking Assumptions

The assumptions of the statistical methods used to fit the selected model must be listed. If ordinary least squares (OLS) is used to fit the model, this statistical method assumes the following:

1. Residuals are uncorrelated.
2. Residuals are homoscedastic.
3. Residuals are independent of each other.
4. Residuals are normally distributed.

The assumptions of the statistical method must be confirmed on the basis of sampling design, statistics and diagnostic plots. Diagnostic plots must be used to check for 'outlier' data points, which must be included in the model fitting unless they are determined to be erroneous. If the assumptions of the statistical method are not confirmed, then in some cases, a correction factor may be required. The correction factor must be applied from peer-reviewed literature or a statistical publication.

The selected model must not be used if the assumptions of the model are unconfirmed or if an appropriate correction factor has not been applied.

F.3 Determining Goodness of Fit

Goodness of fit must be determined based on the parameter values of the selected model. The parameter estimates must be unbiased and predictions must be monotonic on the interval of the range of plausible predicted emissions. The covariate and response data used to parameterize the model must be obtained per the requirements of Sections 9.2.2.3 or 9.2.3.3 to ensure conservativeness of model predictions. Because data for the parameterization of the model is derived from conservative measurements as described in these sections, there are no requirements on the precision of the model predictions or parameter estimates.

F.3.1 Estimates of Parameter Bias

Leave-one-out cross validation must be used to estimate the bias of parameter estimates. The estimated bias must not exceed 15% of the estimated parameter value, on average across parameters.

F.3.2 Confirmation of Monotonicity

In order to confirm that the selected model is conservative, the project proponent must provide graphical plots of the model predictions across the range of plausible input covariate values. Within this range, the function must be monotonic—that is, predictions must not change concavity and be increasing throughout the range of plausible predicted emissions. For example, if the function is increasing at a decreasing rate, it must continue to increase at a decreasing rate across the interval of plausible predicted emissions.

APPENDIX G: EQUATIONS IN METHODOLOGY

$$d_{P\,\Delta}^{[m]} = p_{SLD}{}^{[m]} d_{SLD}^{[m]} + (1 - p_{SLD}{}^{[m]}) d_{LQD}^{[m]}$$	[G.1]
Variables	$\boldsymbol{d_{P\,\Delta}^{[m]}}$, $\boldsymbol{p_{SLD}{}^{[m]}}$, $\boldsymbol{d_{SLD}^{[m]}}$, $\boldsymbol{d_{LQD}^{[m]}}$
Section References	9.2.5
Comments	Density of sediment dredged from sediment source.

$$M_{P\,\Delta}^{[m]} = \frac{V_{P\,\Delta}^{[m]} d_{P\,\Delta}^{[m]}}{1000}$$	[G.2]
Variables	$\boldsymbol{M_{P\,\Delta}^{[m]}}$, $\boldsymbol{V_{P\,\Delta}^{[m]}}$, $\boldsymbol{d_{P\,\Delta}^{[m]}}$
Section References	9.2.5
Comments	Mass of sediment dredged from the sediment source as a result of project activities.

$$E_{B\,\Delta\,EC}^{[m]} = -M_{P\,\Delta}^{[m]} \sum_{(ty)\in\mathcal{T}_{B\,EC}} e_{(ty)}\, g_{B\,(ty)}$$	[G.3]
Variables	$\boldsymbol{E_{B\,\Delta\,EC}^{[m]}}$, $\boldsymbol{M_{P\,\Delta}^{[m]}}$, $\boldsymbol{e_{(ty)}}$, $\boldsymbol{g_{B\,(ty)}}$
Section References	8.1.1
Comments	Total baseline emissions from energy consumption in the monitoring period (tCO_2e).

$$F_{B\,\Delta\,CH4}^{[m]} = A_{PA} \times f_{B\,\Delta\,CH4}^{[m]}$$ [G.4]	
Variables	$\boldsymbol{F_{B\,\Delta\,CH4}^{[m]}}$, A_{PA}, $\boldsymbol{f_{B\,\Delta\,CH4}^{[m]}}$
Section References	8.1.2, 9.2.2
Comments	Baseline methane emissions flux (tCO_2e/day).

$$E_{B\,\Delta\,CH4}^{[m]} = -\left(t^{[m]} - t^{[m-1]}\right)F_{B\,\Delta\,CH4}^{[m]}$$ [G.5]	
Variables	$\boldsymbol{E_{B\,\Delta\,CH4}^{[m]}}$, $\boldsymbol{t^{[m]}}$, $\boldsymbol{t^{[m-1]}}$, $\boldsymbol{F_{B\,\Delta\,CH4}^{[m]}}$
Section References	8.1.2
Comments	Total baseline methane emissions from methane over monitoring period (tCO_2e).

$$E_{B\,\Delta}^{[m]} = E_{B\,\Delta\,EC}^{[m]} + E_{B\,\Delta\,CH4}^{[m]}$$ [G.6]	
Variables	$\boldsymbol{E_{B\,\Delta}^{[m]}}$, $\boldsymbol{E_{B\,\Delta\,EC}^{[m]}}$, $\boldsymbol{E_{B\,\Delta\,CH4}^{[m]}}$
Section References	8.1
Comments	Total baseline emissions over monitoring period (tCO_2e). (If dredging is not included in the baseline scenario, emissions from energy consumption are zero (see section 6.2); if methane ebullition is not included in the baseline scenario, methane emissions are zero.)

$$C^{[m]}_{P\ CS} = \sum_{(c)\in\mathcal{C}} C^{[m]}_{P\ CS\ (c)}$$ [G.7]	
Variables	$\boldsymbol{C^{[m]}_{P\ CS}}$, $\boldsymbol{C^{[m]}_{P\ CS\ (c)}}$
Section References	9.2.1, 9.2.1.1
Comments	Cumulative carbon stocks in project area at end of monitoring period.

$$E^{[m]}_{P\ \Delta\ CS} = C^{[m]}_{P\ CS} - C^{[m-1]}_{P\ CS} - 0.131 E^{[m]}_{P\ \Delta\ CH4}$$ [G.8]	
Variables	$E^{[m]}_{P\ \Delta\ CS}$, $\boldsymbol{C^{[m]}_{P\ CS}}$, $\boldsymbol{C^{[m-1]}_{P\ CS}}$, $\boldsymbol{E^{[m]}_{P\ \Delta\ CH4}}$,
Section References	8.2.1
Comments	Total carbon stock emissions or emissions reductions and/or removals in the project area for the monitoring period (tCO_2e). For the first monitoring period $C^{[m-1]}_{P\ CS} = C^{[m=0]}_{P\ CS}$ or the carbon stocks in the project area prior to the project start date. Last term in equation ($0.131 E^{[m]}_{P\ \Delta\ CH4}$) is included in order to avoid double-counting of sequestered carbon that subsequently was released as a methane flux. The coefficient (0.131) represents a conversion for the differences in mass (44 CO_2 = 16 CH_4) and global warming potential (1 CO_2 = 21 CH_4): 1 ton CO2 = (44/16)*(1/21) = 0.131.

$$E^{[m]}_{P\,\Delta\,CS} = -0.131 E^{[m]}_{P\,\Delta\,CH4} + \sum_{(i)\in\mathcal{G}} C^{[m]}_{P\,CS\,(i)} - C^{[m-1]}_{P\,CS\,(i)}$$ [G.9]	
Variables	$\boldsymbol{E^{[m]}_{P\,\Delta\,CH4}}$, $\boldsymbol{C^{[m-1]}_{P\,CS}}$, $\boldsymbol{C^{[m]}_{P\,CS}}$ $\boldsymbol{E^{[m]}_{P\,\Delta\,CS}}$
Section References	8.2.1
Comments	Total carbon stock emissions or emissions reductions and/or removals in the project area for the monitoring period for project activity instances in a grouped project (tCO_2e). First term in equation ($0.131 E^{[m]}_{P\,\Delta\,CH4}$) is included in order to avoid double-counting of sequestered carbon that subsequently was released as a methane flux. The coefficient (0.131) represents a conversion for the differences in mass (44 CO_2 = 16 CH_4) and global warming potential (1 CO_2 = 21 CH_4): 1 ton CO2 = (44/16)*(1/21) = 0.131.

$$F^{[m]}_{P\,\Delta\,CH4} = A_{PA} \times f^{[m]}_{P\,\Delta\,CH4}$$ [G.10]	
Variables	$\boldsymbol{F^{[m]}_{P\,\Delta\,CH4}}$, $\boldsymbol{A_{PA}}$, $\boldsymbol{f^{[m]}_{P\,\Delta\,CH4} F^{[m]}_{P\,\Delta\,CH4}}$
Section References	8.2.2, 9.3.2.3
Comments	Methane emissions flux within project area (tCO_2e/day).

$$E_{P\,\Delta\,CH4}^{[m]} = -\left(t^{[m]} - t^{[m-1]}\right)F_{P\,\Delta\,CH4}^{[m]}$$ [G.11]	
Variables	$\boldsymbol{E_{P\,\Delta\,CH4}^{[m]}}$, $\boldsymbol{t^{[m]}}$, $\boldsymbol{t^{[m-1]}}$, $\boldsymbol{F_{P\,\Delta\,CH4}^{[m]}}$
Section References	8.2.2, 9.2.2, 9.2.2.1
Comments	Total methane emissions in project area over monitoring period (tCO_2e).

$$F_{P\,\Delta\,N2O}^{[m]} = A_{PA} \times f_{P\,\Delta\,N2O}^{[m]}$$ [G.12]	
Variables	$\boldsymbol{F_{P\,\Delta\,N2O}^{[m]}}$, $\boldsymbol{A_{PA}}$, $\boldsymbol{f_{P\,\Delta\,N2O}^{[m]}}$
Section References	9.3.3.3
Comments	Nitrous oxide emissions flux within project area (tCO_2e/day).

$$E_{P\,\Delta\,N2O}^{[m]} = -\left(t^{[m]} - t^{[m-1]}\right)F_{P\,\Delta\,N2O}^{[m]}$$ [G.13]	
Variables	$\boldsymbol{E_{P\,\Delta\,N2O}^{[m]}}$, $\boldsymbol{t^{[m]}}$, $\boldsymbol{t^{[m-1]}}$, $\boldsymbol{F_{P\,\Delta\,N2O}^{[m]}}$
Section References	8.2.3, 9.2.3, 9.2.3.1
Comments	Total nitrous oxide emissions in project area over monitoring period (tCO_2e).

$$E_{P\,\Delta\,EC}^{[m]} = -\sum_{(ty)\in\mathcal{T}_{P\,EC}} G_{P\,\Delta\,(ty)}^{[m]} e_{(ty)}$$	[G.14]
Variables	$\boldsymbol{E_{P\,\Delta\,EC}^{[m]}}$, $\boldsymbol{G_{P\,\Delta\,(ty)}^{[m]}}$, $e_{(ty)}$
Section References	8.2.4
Comments	Total emissions from energy consumption in project area over monitoring period (tCO_2e).

$$E_{P\,\Delta}^{[m]} = E_{P\,\Delta\,CS}^{[m]} + E_{P\,\Delta\,CH4}^{[m]} + E_{P\,\Delta\,N2O}^{[m]} + E_{P\,\Delta\,EC}^{[m]}$$	[G.15]
Variables	$\boldsymbol{E_{P\,\Delta}^{[m]}}$, $\boldsymbol{E_{P\,\Delta\,CS}^{[m]}}$, $\boldsymbol{E_{P\,\Delta\,N2O}^{[m]}}$, $\boldsymbol{E_{P\,\Delta\,CH4}^{[m]}}$, $\boldsymbol{E_{P\,\Delta\,EC}^{[m]}}$
Section References	8.2
Comments	Total emissions or emissions reductions and/or removals in project area over monitoring period (tCO_2e).

$$E_{GER\,\Delta}^{[m]} = E_{P\,\Delta}^{[m]} - E_{B\,\Delta}^{[m]}$$	[G.16]
Variables	$\boldsymbol{E_{GER\,\Delta}^{[m]}}$, $\boldsymbol{E_{B\,\Delta}^{[m]}}$, $\boldsymbol{E_{P\,\Delta}^{[m]}}$
Section References	8.4.1
Comments	Total gross emissions reductions and/or removals over monitoring period (tCO_2e).

$$E_{GER}^{[m]} = \sum_{m \in \mathcal{M}} E_{GER\ \Delta}^{[m]}$$ [G.17]	
Variables	$\boldsymbol{E_{GER}^{[m]}}$, $\boldsymbol{E_{GER\ \Delta}^{[m]}}$ $\boldsymbol{E_{GER\ \Delta}^{[m]}}$
Section References	8.4.1.1
Comments	Cumulative gross emissions reductions and/or removals over monitoring period (tCO_2e).

$$U_{P\ CS}^{[m]} = \sqrt{\sum_{(c) \in \mathcal{C}} \left(U_{P\ CS\ (c)}^{[m]}\right)^2}$$ [G.18]	
Variables	$\boldsymbol{U_{P\ CS}^{[m]}}$, $\boldsymbol{U_{P\ CS\ (c)}^{[m]}}$
Section References	8.4.2.1
Comments	Total standard error of carbon stocks over monitoring period (tCO_2e).

$$E_{U\ \Delta}^{[m]} = E_{GER\ \Delta}^{[m]} \left[\frac{1.645 \times U_{P\ CS}^{[m]}}{C_{P\ CS}^{[m]}} - 0.15\right]$$ [G.19]	
Variables	$\boldsymbol{E_{U\ \Delta}^{[m]}}$, $\boldsymbol{E_{GER\ \Delta}^{[m]}}$, $\boldsymbol{U_{P\ CS}^{[m]}}$, $\boldsymbol{C_{P\ CS}^{[m]}}$
Section References	8.4.2.1
Comments	Confidence deduction for monitoring period (tCO_2e). This quantity must be greater than or equal to zero.

$$E^{[m]}_{BA\,\Delta} = b^{[m]} E^{[m]}_{P\,\Delta\,CS}$$ [G.20]	
Variables	$\boldsymbol{E^{[m]}_{BA\,\Delta}}$, $\boldsymbol{b^{[m]}}$, $\boldsymbol{E^{[m]}_{P\,\Delta\,CS}}$
Section References	8.4.2.2
Comments	Total emissions reductions and/or removals allocated to AFOLU pooled buffer account over monitoring period.

$$E^{[m]}_{NER\,\Delta} = E^{[m]}_{GER\,\Delta} - E^{[m]}_{U\,\Delta} - E^{[m]}_{BA\,\Delta} + E^{[m]}_{BR\,\Delta}$$ [G.21]	
Variables	$\boldsymbol{E^{[m]}_{NER\,\Delta}}$, $\boldsymbol{E^{[m]}_{GER\,\Delta}}$, $\boldsymbol{E^{[m]}_{U\,\Delta}}$, $\boldsymbol{E^{[m]}_{BA\,\Delta}}$, $\boldsymbol{E^{[m]}_{BR\,\Delta}}$
Section References	8.4.2
Comments	Total net emissions reductions and/or removals over monitoring period (tCO_2e).

APPENDIX H: SUPPORTING INFORMATION ON DEVELOPMENT OF POSITIVE LIST

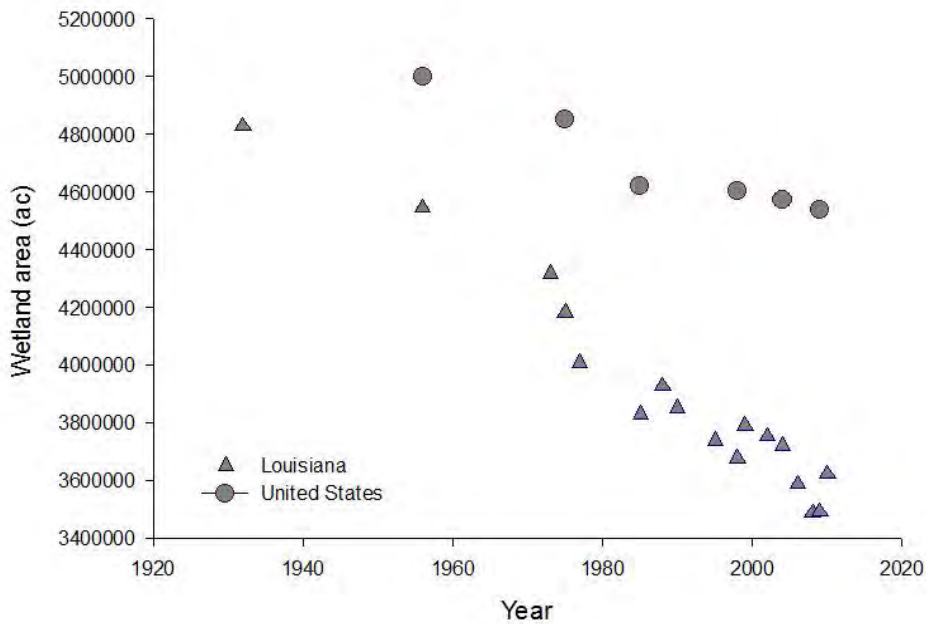
The methodology specifies a positive list for additionality based on activity penetration in specific geographic scopes. The level of activity penetration for a project activity in a given geographic region is determined using appropriate credible data, including from federal agencies (eg, USACE, USGS, USFWS). In order to define the activity and geographic scope for the positive list, the methodology developer demonstrated both the maximum adoption potential and the observed adoption of the project activity (eg, the number and extent of the activity which has been implemented). The calculated level of activity penetration of RWE project activities is currently determined to be less than 5 percent and the level of activity penetration of ARR+RWE project activities meeting the applicability conditions of this methodology is negligible.

The maximum adoption potential takes into account the relevant factors affecting the adoption of the activity within the applicable geographic scope, including implementation potential (ie, the extent of wetland loss within the geographic scope), resource availability (ie, the local supply of dredged sediments), technological capacity (ie, the amount of locally available dredging equipment), level of service (ie, the availability of dredging equipment), socio-economic conditions (ie, the presence of competing economic activities occurring in the coastal zone), and climatic conditions (ie, the incidence of hurricanes and extreme tidal fluctuations). In the case of socio-economic conditions and competing economic activities (eg, oyster farming), the methodology developers concluded that such competing activities are not common enough to limit or displace coastal wetland reestablishment activities, and moreover such economic activities do not vary significantly among regions within the geographic scope. The methodology developers also considered the spatial heterogeneity of climate conditions across the geographic scope, and concluded that regardless of the likelihood of such extreme climate events, the project proponent must demonstrate a long-term trend of wetland loss (see section 6.1). Further, once a project has been established, the methodology ensures that the impacts of a climate event will be captured by the monitoring activities and will be reflected in the carbon accounting. Maximum adoption potential does not consider cost of adoption, cultural or behavioral barriers, and laws, statues, regulatory frameworks or policies.

H.1 Synopsis

This methodology deems project activities as additional, and qualifies them for a positive list based on low rates of adoption in the United States. The total need or adoption potential for coastal wetland creation is conservatively ~1.482 million ac, based on historic loss in the lower 48 states since the 1930's (Figure 1). Approximately 2.7% (39,834) ac of the total coastal wetlands lost in the U.S. has been rebuilt. Therefore, creation of wetlands as described in this methodology, for both RWE and ARR+RWE projects, is deemed additional in accordance with VCS requirements.

Figure 1: Estimates of estuarine vegetated wetland in the U.S. and coastal land area in Louisiana



The following sections—*Analysis* and *Supporting Technical Information*—present the adoption potential analysis and summaries of national and region-specific wetland changes and creation efforts.

H.2 Analysis

This analysis demonstrates that the level of "activity penetration" for creation of coastal wetlands is currently much less than 5%. Substantial needs exist for rebuilding of wetlands lost due to various direct and indirect anthropogenic factors. However, due to funding constraints only a small fraction of the need has been satisfied as of the completion of this methodology.

The positive list for activities established under this methodology is based on a demonstration that the project activities have achieved a low level of penetration relative to their maximum adoption potential, in accordance with VCS requirements. This activity penetration level is estimated using the following equation:

$$AP_y = OA_y / MAP_y$$

Where,

AP_y = Activity penetration of the project activity in year y (percentage)

OA_y = Observed adoption of the project activity in year y (eg, total number of instances installed at a given date in year y, or amount of energy supplied in year y)

MAP_y = Maximum adoption potential of the project activity in year y (eg, total number of instances that potentially could have been installed at a given date in year y, or the amount of energy that potentially could have been supplied in year y)

The following analysis estimates penetration level, current as of 2012, for the conterminous United States. Since a key location for application of this methodology is Louisiana, it will also be demonstrated using state-specific data.

Given adequate time and funding, adequate supplies of sediment for wetland are available, either from rivers or nearshore/offshore locations where they are routinely dredged. Resource availability is not a constraint. As an ecosystem restoration activity, total demand, market access, and market price are not relevant factors in this analysis. Implementation potential is the need for wetland restoration and is therefore considered equal to maximum adoption potential.

In order to arrive at a conservative estimate for the maximum adoption potential, data from two studies are used. The first (Couvillion et al. 2012) provides data from Louisiana only and indicates that total coastal wetland loss in Louisiana amounted to 1,205,120 ac. This study provides a comprehensive and detailed estimate of wetland loss, including both coastal fresh and saltwater wetlands. The second is a national level study (Dahl 2000, 2006, 2011) that estimates total U.S. wetland loss of 461,000 ac, but includes only estuarine vegetated wetlands, thus excluding the losses of tidal freshwater wetlands. Because coastal Louisiana loss is commonly accepted to be 40% of the national total, the national vegetated estuarine wetland loss excluding Louisiana was estimated at 276,000 ac. Adding in the long-term historic wetland loss in Louisiana of 1,205,120 ac with the less-comprehensive national estimate of 276,000 ac yields 1,481,720 ac. The two studies used to derive the maximum adoption potential are described in more detail below.

Based on USGS data (Couvillion et al. 2012), approximately 1.205 million acres of Louisiana's coastal wetlands have been lost and converted to open water since the 1930's. Louisiana's Coastal Protection and Restoration Authority (CPRA) has tracked engineered wetland creation projects by the State, in addition to USACE beneficial use projects. CPRA estimates that approximately 16,137 acres have been created since 2005, including both the State's projects and USACE beneficial use projects (Table H3, *Supporting Technical Information*). Therefore, the current level of activity penetration in Louisiana is approximately 1.3% (16,137 ac created/1,205,000 ac lost).

At a national scale, the U.S. Fish & Wildlife Service Status & Trends reports (Dahl 2000, 2006, 2011) estimate that 461,000 acres of vegetated estuarine wetlands have been lost since the 1950s (Table H2, *Supporting Technical Information).* This estimate excludes the losses of tidal freshwater wetlands, which results in a conservative (underestimate) of total tidal and estuarine wetland loss (tidal freshwater wetlands are now reported as 'Palustrine,' which typically includes all inland freshwater systems). For example, a more detailed analysis by Stedman and Dahl (2008) showed that the *coastal watersheds* of the Gulf of Mexico and the Atlantic states lost a total of 370,760 ac and 14,980 ac, respectively, of freshwater and saltwater wetlands.

Given that total coastal wetland creation as described in Section H.3.5 was 39,834 ac and the maximum adoption potential is 1,481,720 ac, the resulting activity penetration level is approximately 2.7%. With observed adoption less than the need for replacement of wetlands, adoption potential is below the 5% threshold set by VCS requirements. Therefore, coastal wetland creation projects are deemed additional.

H.3 Supporting Technical Information

H.3.1 Estuarine Vegetated Wetland Loss in the United States

Estuarine vegetated wetland loss in the United States since the 1950's to 2009 has been estimated at approximately 461,000 ac (Table H1). Based on the most recent analysis from 2004-2009 (Dahl 2011), approximately 111,000 ac of estuarine vegetated wetlands were lost over the 4.5 year period, or approximately 25,000 ac/yr.

Wetland loss prior to the 1980's may have included direct conversion of wetlands to agriculture and coastal development. Since the 1980's, however, conversion of wetlands to deep open water has been responsible for wetland losses, as excerpted from Dahl's analyses:

> "[The 1998-2004 rate of loss] *was consistent with the rate of salt marsh loss recorded from 1986 to 1997 (Dahl 2000). Urban and rural development activities, and the conversion of wetlands to other upland land uses, accounted for an estimated loss of 1,732 acres (700 ha) or about 3.0 percent of all losses of estuarine emergent wetland. Most of the losses of estuarine emergent wetland were due to loss to deep salt water and occurred in coastal Louisiana*." (Dahl 2006)
>
> "[The 2004-2009 rate of loss] *of intertidal emergent wetland increased to three times the previous loss rate between 1998 and 2004. The majority of these losses (83%) was to deepwater bay bottoms or open ocean.*"

H.3.2 Vegetated Wetland Loss in Coastal Watersheds in the Atlantic and Gulf of Mexico

An analysis of *coastal watershed* vegetated wetland changes in the eastern United States (1998-2004) (Stedman and Dahl 2008) showed that the Gulf of Mexico and Atlantic states had net wetland losses in coastal watersheds totaling 370,760 ac and 14,980 ac, respectively, when including both fresh and saltwater wetlands. Total saltwater vegetated wetland loss was 64,970 ac, of which 96% (or 62,370 ac) was conversion to open saltwater.

Table H1: Historic and contemporary estimates of estuarine vegetated wetland acreage since the mid-1950's for the United States and Atlantic/Gulf of Mexico regions based on similar mapping techniques

Time period	**Conterminous US** Estuarine vegetated wetland (ac) (Dahl 2006, Dahl 2011)	**Atlantic Coastal Watershed** Vegetated wetland (ac) (Stedman and Dahl 2008)	**GOM Coastal Watershed** Vegetated wetland (ac) (Stedman and Dahl 2008)
1950's	5,000,000		
1970's	4,854,000		
1980's	4,623,000		
1998	4,604,200	1,842,320	3,108,110
2004	4,571,700	1,822,780	3,062,680
2009	4,539,700		
Notes	US wetland loss (1950's-2009) 461,000 ac	Atlantic wetland loss (98-04) 19,540 ac	GOM wetland loss (98-04) 45,430 ac

H.3.3 Wetland Loss in Louisiana

The most recent study by Couvillion et al. (2012) summarized wetland loss during 1932-2010 and intervals in between. Cumulative wetland loss in Louisiana from 1932-2010 was estimated at 1,205,120 ac. Trend analyses of comparable satellite imagery were limited to the 1985-2010[4] time period, which showed a loss rate of 10,605 ac/yr.

H.3.4 Proportion of Coastal Wetland Loss in Louisiana Compared to the U.S.

Based on a number of analyses, Louisiana wetland loss has been commonly accepted to be ~ 40% of the national total. This is supported by the recent analyses by Couvillion et al. (2012) and Dahl (2011), which showed that the annual loss rate in Louisiana (-10,605 ac/yr, from 1985-2010) was 42% of the national rate (-25,000 ac/yr 2004-2009).

[4] The calculation of wetland loss rates in Louisiana is sensitive to water level during imagery acquisition. More recent and frequent satellite imagery has allowed for a large number of images to be analyzed and reduced uncertainty.

H.3.5 Wetland Creation in the United States and Louisiana

The most significant nationwide wetland creation effort has been accomplished with beneficial placement of dredged sediments by the USACE (Table H2). More recently, a state wetland creation program has been developed in Louisiana by the Coastal Protection and Restoration Authority (CPRA) (Table H3).

Including Louisiana, marsh creation and nourishment by the USACE has totaled approximately 32,355 ac from 2007-2012 (Table H2). There are several reasons why these data produce a conservative overestimate of actual wetland creation. First, the USACE presents both wetland 'creation' and 'nourishment' together. Second, there are 11 non-coastal districts which are included in the statistics presented in Table H2 (although the non-coastal districts comprise only 5 percent of the total dredging conducted by the USACE). Third, the assumed conversion value of 1 ac = 6,250 CY may be low for some areas. For example, the actual CY of sediment needed for an acre of wetland creation ranges from approximately 6,000 CY to 16,000 CY (calculated from data in Table H3).

In Louisiana, engineered wetland creation projects have been tracked more precisely than USACE nationwide projects. Based on CPRA's data set, approximately 7,479 ac of wetlands have been created in Louisiana during FY 2005-2012 Table H3), not including the USACE's beneficial use projects (which are included in Table H2).

Combining both data sets results in an estimate of 39,834 ac (nationwide USACE = 32,355 ac; Louisiana state projects = 7,479 ac) of wetland creation and nourishment that has occurred nationwide through efforts of the USACE and the State of Louisiana, which comprise the most significant sources of wetland creation with dredged material.

Table H2: Estimated nationwide USACE wetland creation and nourishment from both coastal and non-coastal areas of the U.S. Acreage estimates are derived from dredge disposal statistics from the USACE Navigation Data Center: http://www.navigationdatacenter.us/dredge/drgdisp.htm (Disposal Type = Wetland Creation and Nourishment). For more information, contact U.S. Army Corps of Engineers, CEIWR-NDC, 7701 Telegraph Road, Casey Bldg., Alexandria, Virginia 22315-3868, point of contact: NDC (703) 428-9061**.**

Year	Contracts	Cubic Yards (Bid)	Dollars (Bid)	Estimated Acres[5]
2007	9	38,075,031	$69,878,722	6,092
2008	9	49,108,000	$55,467,694	7,857

[5] Assumes that 6,250 CY of sediment is needed to create one acre of wetland, based on USACE, 2006, Louisiana Coastal Area Beneficial Use of Dredge Material: http://www.lca.gov/Studies/budmat.aspx.

2009	7	25,582,361	$56,902,237	4,093
2010	9	37,481,966	$107,437,192	5,997
2011	6	17,705,385	$28,221,454	2,833
2012	8	34,263,868	$94,759,277	5,482
			Estimated Total	32,355 ac

Table H3: Wetland creation acreage constructed in Louisiana during FY2005-2012 by CPRA and USACE (data courtesy of CPRA)

	Louisiana (Federal/State/Other)		Louisiana (USACE Beneficial Use)		Total
Year	CY	AC	CY	AC	AC
2004-2005	244,441	26	14,686,790	515	541
2005-2006	0	0	9,286,170	604	604
2006-2007	6,099,372	920	16,018,350	1,228	2,148
2007-2008	1,593,629	262	8,726,625	522	784
2008-2009	11,653,148	1,350	8,134,849	248	1,598
2009-2010	21,303,000	3,483	19,613,374	1,591	5,074
2010-2011	6,300,000	94	27,325,000	2,514	2,608
2011-2012	16,764,560	1,344	15,125,000	1,437	2,781
Total	63,958,150	7,479	118,916,158	8,658	**16,137**

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APPENDIX I: JUSTIFICATION FOR THE EXCLUSION OF ALLOCHTHONOUS CARBON IN THE LOUISIANA COASTAL ZONE

I.1 Introduction

Many estuarine wetlands are exporters or sources of carbon to the continental shelf, typically termed 'carbon outwelling'. Net burial of carbon in tidal wetland soils is usually on the order of <200 g C/m^2/yr (McLeod et al. 2011), while an excess of 100-200 g C/m^2/yr of carbon is exported to inshore and offshore areas (Nixon 1980; also see Table 1). The source, transport and fate of carbon along the estuary-offshore gradient are complicated processes, but largely, estuarine wetland systems are typically understood as carbon sources to estuarine-offshore systems. High energy, macrotidal salt marshes may receive substantial mineral sediments (and associated carbon) near the mouth of the estuary. The source of carbon may come from upland habitats, which may be replenished, or within the estuarine system as wetlands are eroded or reworked.

Stevenson et al. (1988) raised the consideration of sea level rise and sediment supply as to why estuaries—especially southern microtidal systems—are susceptible to wetland loss. In addition to sea level rise, the authors maintain that sediment starvation through reductions in terrigenous sediment sources is a key factor of undernourishment of wetlands:

> From Stevenson et al. 1988*: Differences in tidal dynamics, seasonal changes in sea levels and higher temperatures may help explain why, in the U.S., southern marshes are more susceptible to export and eventual erosion than northern marshes. We hypothesize that another factor, the recent reductions of terrigenous sediment inputs from the southern river systems of the U.S., may also be critical. Sediment starvation may have led to undernourishment of wetland systems of the coastal zone over the last half century which may be reflected in the net export measured in the tidal marshes in this region. Furthermore, we postulate that changes in sediment inputs are more important than eustatic sea level rise in causing the past losses of marshes which are now undergoing mass erosion.*

There has been a systemic reduction in sediment delivery to coastal wetlands nationwide due to changes in land-use (European settlement and land clearing) and expansion of dam building on major rivers (Syvitski et al. 2009). The Chesapeake Bay area and Louisiana delta serve as examples of the observed modern sediment-driven degradation of wetlands to open water (Kirwan et al. 2011).

I.2 Support from the Literature

The literature from coastal Louisiana broadly supports the understanding that its wetlands are sources of carbon to the Gulf of Mexico (see estimates in Table I.1). Moreover, in the last century there has been a systematic reduction in allochthonous mineral sediment (with its associated carbon) to the wetlands due to construction of levees along the Mississippi River (Blum and Roberts 2009). As a consequence, the estuaries are not receiving substantial external sources of sediments or carbon. The following summary provides a description on carbon exchange in Louisiana estuaries and provides the rationale as to why accounting for the import of carbon to created wetlands projects is not relevant for the coastal region of Louisiana. Namely, there is an absence of real external sources of carbon to the coastal basins, most of the carbon is exchanged among habitats in the coastal basins, and any import of carbon in the project area will be substantially offset by the carbon that the project will export.

1. *Export of Carbon from Louisiana Estuaries*: Louisiana estuaries are ebb-dominated systems exhibiting a consistent pattern of exporting of Particulate Organic Carbon (POC) and Total Organic Carbon (TOC) to the Gulf of Mexico. This has been shown for most of the Louisiana coastal areas, including: Barataria Basin (Li et al. 2011; Das et al. 2010, 2011; Wilson and Allison 2008; Feijtel et al. 1985; Happ et al. 1977), Breton Sound (Wilson and Allison 2008), and Fourleague Bay (Stern et al. 1991; Madden et al., 1988; Perez et al. 2000). Wilson and Allison (2008) estimated that Barataria and Breton Sound estuaries export 3.7×10^4 and 4.6×10^4 MT POC annually, respectively, and the magnitude of these estimates was corroborated by Das et al. 2011. The magnitude of Dissolved Organic Carbon (DOC) that is exported is six fold greater than particulate forms (Das et al. 2011).

2. *External Sediment Supply Constraints to Louisiana Wetlands*: An allochthonous sediment deficit to Louisiana coastal wetlands occurred following the levee construction along the Mississippi River and persists today (Blum and Roberts 2009). In a review paper of mineral and organic contributions to tidal freshwater wetland accretion from Maine to Louisiana, Neubauer (2008) showed that Louisiana freshwater wetlands exhibited the lowest mineral accumulation rates. Much of the contemporary sediment deposition in Louisiana wetlands is a result of the redistribution of sediment and organic matter within the system. Organic matter (or carbon) can come from upper basin wetlands and be deposited in downstream project areas, or may arrive at the project site from lower in the basin with storms and fronts (Reed 1989). In any case, the source of the carbon comes from either the natural export of surrounding healthy wetlands or from shoreline erosion. DeLaune et al. (2013) described one example of how non-restored wetland erosion can serve as a source of sediments that are transported through the estuary: “as marshes degrade and erode, there is a loss of material through net transport of mineral and organic matter through tidal inlets to the coastal ocean (Li et al 2009, 2011). The translocation of organic and mineral material from the marsh to the coastal waters further exacerbates coastal land loss.”

3. *Carbon Quality, Storage, and Averting Emissions*: Das et al. (2011) proposed that “the fate of carbon from eroded wetlands remains incompletely known” but evidence from their study as well as another recent study (Wilson and Allison, 2008) “potentially suggest that about 40% of POC released from eroding marshes is exported to the coastal Gulf of Mexico”. Thus, organic matter storage is occurring within the estuary’s wetlands and bays. While the fate and transformation of organic matter from interior wetlands to the offshore environment isn’t entirely certain, there is reasonable evidence that the source of allochthonous carbon to a project area in Louisiana will be similar in quality to that which will be released from the project area (Wilson and Allison, 2008). That is, the source of carbon is largely derived within the system. There is also increasing

evidence that Mississippi River water, which could enter from the mouth of adjacent estuaries in Louisiana, has a higher fraction of labile carbon than previously assumed (Mayer et al. 2008).

The design and location of wetland creation projects offer benefits in the form of capturing organic sediments that could otherwise be lost offshore or potentially oxidized in shallow bay waters. The decay of organic matter in the emergent wetland environment is slower than the estuarine open water setting due to the presence of anaerobic conditions, acidic porewater, and the presence of decay inhibitors (secondary metabolic compounds or humic acids) (Bianchi et al. 2011). Along the terrestrial to marine gradient, the likelihood of emissions with organic matter decay is increased as exposure or residence time under oxic conditions is prolonged, a process termed 'diagenetic oxygen exposure time' (Bianchi et al. 2011). The combination of physical energy, photo-degradation, oxygen exposure, and strong ionic gradients can accelerate the carbon decay process along the estuarine-offshore gradient. Thus, under the project condition, allochthonous carbon has a greater likelihood of preservation in the wetland system.

In summary, for Coastal Louisiana, it can be conservatively assumed that transport of organic matter will not cause carbon accretion estimates to be significantly overestimated, and thus allochthonous carbon may be neglected.

Table I.1: Summary of carbon export from estuaries, with special consideration of Louisiana estuaries

Location	Carbon Export[6]	Habitat Type	Source
Review of estuaries	100-200	Salt marshes	Nixon 1980
Barataria Bay, LA	165	Forested upland-estuary interface	Hopkinson and Day 1979
Barataria Bay, LA	150-250	Entire estuary	Feijtel et al. 1985
Barataria Bay, LA	25-540 (150)[7]	Entire estuary	Happ et al. 1977
Barataria Bay, LA	57	Estuary open water area	Das et al. 2010

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[6] Units: g C m^{-2} yr^{-1}

[7] Considering the magnitude of errors involved in the assumptions upon which the calculations were based, the study reported an organic carbon export of 25 to 540 g C m^{-2} yr^{-1} to inshore waters, with the most probable value around 150 g C m^{-2} yr^{-1}.

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APPENDIX J: LIST OF VARIABLES

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
A_{PA}	acre	Area of project area	GIS analysis prior to sampling		[G.10], [G.12]	-	-
$b^{[m]}$	%	Buffer withholding percentage calculated as required by the VCS AFOLU Non-Permanence Risk Tool	VCS AFOLU Non-Permanence Risk Tool	N/A	[G.20]	Every monitoring period	N/A
$C_{P\ CS}^{[m]}$	tCO_2e	Cumulative project carbon stocks at end of current monitoring period	Sampling activities	[G.7]	[G.8], [G.9], [G.19]	At least every five years	Independent review of equations and check against literature estimates. See Section 9.2.8.3
$C_{P\ CS}^{[m-1]}$	tCO_2e	Cumulative project carbon at beginning of current monitoring period	Sampling activities	[G.7]	[G.8], [G.9]	At least every five years	Independent review of equations and check against literature estimates. See Section 9.2.8.3
$C_{P\ CS\ (c)}^{[m]}$	tCO_2e	Cumulative project carbon in pool *c* at end of current monitoring period	Sampling activities	Appendix D	[G.7]	At least every five years	Independent review of equations and check against literature estimates. See Section 9.2.8.3

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
$d_{LQD}^{[m]}$	kg/m³	Density of liquid in dredged sediment	Monitoring records, direct measurement	9.2.5	[G.1]	Every monitoring period when sediment is transported	Compare data from multiple samples. See Section 9.2.8.1
$d_{SLD}^{[m]}$	kg/m³	Density of solids in dredged sediment	Monitoring records. direct measurement	9.2.5	[G.1]	Every monitoring period when sediment is transported	Compare data from multiple samples. See Section 9.2.8.1
$d_{P\,\Delta}^{[m]}$	kg/m³	Density of sediment dredged from sediment source	Monitoring records, direct measurement	9.2.5	[G.2], [G.1]	Every monitoring period when sediment is transported	Compare data from multiple samples. See Section 9.2.8.1
$E_{BA\,\Delta}^{[m]}$	tCO_2e	Emissions reductions and/or removals allocated to AFOLU pooled buffer account over current monitoring period	Monitoring records	8.4.2	[G.21], [G.20]	Every monitoring period	Independent review of equations and monitoring records. See Section 9.2.8.2
$E_{B\,\Delta}^{[m]}$	tCO_2e	Total baseline emissions over current monitoring period	Monitoring records	8.1	[G.6], [G.16]	Every monitoring period	Independent review of equations and monitoring records. See Section 9.2.8.2

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
$E_{B\,\Delta\,CH4}^{[m]}$	tCO_2e	Total baseline emissions from methane over current monitoring period	Monitoring records	8.1.2	[G.5]	Every monitoring period	Independent review of equations and monitoring records. See Section 9.2.8.2
$E_{B\,\Delta\,EC}^{[m]}$	tCO_2e	Total baseline emissions from energy consumption over current monitoring period	Monitoring records	8.1.1	[G.6], [G.3]	Every monitoring period when sediment is transported	Independent review of equations and monitoring records. See Section 9.2.8.2
$E_{BR\,\Delta}^{[m]}$	tCO_2e	Total emissions reductions and/or removals for buffer release over current monitoring period	Monitoring records	8.4.2	[G.21]	Every monitoring period	Independent review of calculations and monitoring records. See Section 9.2.8.2
$E_{GER}^{[m]}$	tCO_2e	Cumulative gross emissions reductions and/or removals at end of current monitoring period	Monitoring records	8.4.1.1	[G.17]	Every monitoring period	Independent review of GER calculations. See Section 9.2.8.2
$E_{GER\,\Delta}^{[m]}$	tCO_2e	Total gross emissions reductions and/or removals over current monitoring period	Monitoring records	8.4.1, 8.4.2	[G.16],[G.17], [G.19], [G.20], [G.21]	Every monitoring period	Independent review of GER calculations. See Section 9.2.8.2
$E_{NER\,\Delta}^{[m]}$	tCO_2e	Total net emissions reductions and/or removals over current monitoring period	Monitoring records	8.4.2	[G.21]	Every monitoring period	Independent review of NER calculations. See Section 9.2.8.2

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
$E_{P\,\Delta}^{[m]}$	tCO_2e	Total project area emissions/ emissions removals over current monitoring period	Monitoring records	8.2	[G.15], [G.16]	Every monitoring period	Independent review of calculations and monitoring records. See Section 9.2.8.2
$E_{P\,\Delta\,CH4}^{[m]}$	tCO_2e	Total methane emissions in project area over current monitoring period	Monitoring records	8.2.2	[G.15],[G.8], [G.9], [G.11]	Every monitoring period	Independent review of calculations and monitoring records. See Section 9.2.8.2
$E_{P\,\Delta\,CS}^{[m]}$	tCO_2e	Total carbon stock emissions or emissions reductions and/or removals in project area over current monitoring period	Monitoring records	8.2.1	[G.15], [G.8], [G.9],	Every monitoring period	Independent review of calculations and monitoring records. See Sections 9.2.8.2 and 9.2.8.3
$E_{P\,\Delta\,EC}^{[m]}$	tCO_2e	Total emissions from energy consumption in project area over current monitoring period	Monitoring records	8.2.4	[G.15], [G.14]	Every monitoring period when sediment is transported	Independent review of calculations and monitoring records. See Section 9.2.8.2
$E_{P\,\Delta\,N2O}^{[m]}$	tCO_2e	Total nitrous oxide emissions within project area over current monitoring period	Monitoring records	8.2.3,	[G.15], [G.13]	Every monitoring period	Independent review of calculations. See Section 9.2.8.2

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
$e_{(ty)}$	tCO_2e /gal, tCO_2e /scf, tCO_2e /kWh	Emissions coefficient for energy type *ty*	Emission factors in Section 8.1.1, Table 10	Selected from published values	[G.3], [G.14]		
$E_{U\,\Delta}^{[m]}$	tCO_2e	Confidence deduction for current monitoring period	Monitoring records	8.4.2.1	[G.19], [G.21]	Every monitoring period	Independent review of calculations and monitoring records. See Section 9.2.8.2
$f_{B\,\Delta\,CH4}^{[m]}$	tCO_2e /ac/day	Baseline methane emissions flux per unit area	Monitoring records and static chamber or eddy covariance measurement	9.2.7	[G.5]	Every monitoring period	Comparison of data from multiple samples and independent review of calculations. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5
$F_{B\,\Delta\,CH4}^{[m]}$	tCO_2e /day	Baseline methane emissions flux	Monitoring records and static chamber or eddy covariance measurement	9.2.7	[G.5]	Every monitoring period	Comparison of data from multiple samples and review of monitoring records. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
$f_{P\,\Delta\,CH4}^{[m]}$	tCO_2e /ac/day	Methane emissions flux per unit area within project area	Monitoring records and static chamber or eddy covariance measurement	9.2.2.3	[G.10]	Every monitoring period	Comparison of data from multiple samples and review of monitoring records. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5
$f_{P\,\Delta\,N2O}^{[m]}$	tCO_2e /ac/day	Nitrous oxide emissions flux per unit area within project area	Monitoring records and static chamber or eddy covariance measurement	9.2.3.3	[G.12]	Every monitoring period	Comparison of data from multiple samples and review of monitoring records. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5
$F_{P\,\Delta\,CH4}^{[m]}$	tCO_2e /day	Methane emissions flux within project area	Monitoring records and static chamber or eddy covariance measurement	9.2.2.3	[G.11], [G.10]	Every monitoring period	Comparison of data from multiple samples and independent review of calculations. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
$F^{[m]}_{P\,\Delta\,N2O}$	tCO_2e /day	Nitrous oxide emissions flux within project	Monitoring records and direct measurement, default values, or proxy values developed by the project proponent	9.2.3	[G.13], [G.12]	Every monitoring period	Comparison of data from multiple samples and independent review of calculations. See Sections 9.2.8.1, 9.2.8.4, and 9.2.8.5
$g_{B\,(ty)}$	gal/tonne, scf/tonne, kWh/tonne	Energy consumed per metric tonne of sediment dredged in the baseline	Documentation provided by proponent	Direct measurement	[G.3]	-	-
$G^{[m]}_{P\,\Delta\,(ty)}$	gal, scf, kW	Energy consumed in project area for energy type *ty* over current monitoring period	Monitoring records and direct measurement or cost approach	8.2.4	[G.14]	Every monitoring period when sediment is transported	Independent review of calculations and monitoring records. See Sections 9.2.8.1 and 9.2.8.2
$M^{[m]}_{P\,\Delta}$	tonnes	Mass of sediment dredged from the sediment source over current monitoring period	Monitoring records	8.1.1, 9.2.5	[G.3], [G.2]	Every monitoring period when sediment is transported	Project verification and independent review of calculations. See Section 9.2.8.2

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
$p_{B\,(ty)}$	proportion (unitless)	Proportion of energy for energy type *ty* consumed in the baseline scenario	Documentation provided by proponent	Calculated from direct measurement	[G.3]	-	-
${p_{SLD}}^{[m]}$	proportion (unitless)	Proportion of solids by weight in the dredged sediment	Sampling activities, direct measurement	9.2.5	[G.1]	Every monitoring period when sediment is transported	Comparison of data from multiple samples and review of monitoring records. See Sections 9.2.8.1 and 9.2.8.2
$t^{[m]}$	days	Elapsed time from project start at the end of the current monitoring period	Monitoring records	N/A	[G.11], [G.13]	Every monitoring period	N/A
$t^{[m-1]}$	days	Elapsed time from project start at the beginning of the current monitoring period	Monitoring records	N/A	[G.11], [G.13]	Every monitoring period	N/A
$U_{P\,CS}^{[m]}$	tCO_2e	Total standard error in project carbon stocks measured during the current monitoring period	Monitoring records	N/A	[G.19], [G.18]	Every monitoring period	Independent review of calculations and monitoring records. See Section 9.2.8.2

Data / Parameter	Unit	Description	Source of Data	Measurement Method	Used in Equations	Frequency of Monitoring/ Recording	QA/QC
$U_{P\ CS\ (c)}^{[m]}$	tCO_2e	Total standard error in project carbon stocks for pool *c* measured during the current monitoring period	Monitoring records	[A.8]	[G.18]	Every monitoring period	Independent review of calculations and monitoring records. See Section 9.2.8.2
$V_{P\ \Delta}^{[m]}$	m^3	Volume of sediment dredged from the sediment source over current monitoring period	Monitoring records	9.2.5	[G.2]	Every monitoring period when sediment is transported	Independent review of calculations and monitoring records. See Section 9.2.8.2

APPENDIX K: SUMMARY OF PROJECT DESCRIPTION REQUIREMENTS

PDR#	Category	Requirements
PDR.1	Applicability Conditions	For each applicability condition, credible evidence in the form of analysis, documentation or third-party reports to satisfy the condition.
PDR.2	GHG Sources	A list of the included GHG sources.
PDR.3	Carbon Pools	A list of the selected carbon pools.
PDR.4	Allochthonous Carbon in Soil Carbon Pool	Narrative justification that the import of organic matter will not cause carbon accretion estimates to be significantly overestimated including citations to case studies, literature or models.
PDR.5	Allochthonous Carbon in Soil Carbon Pool	Description of the dominant sources of sediments with respect to external (ie, fluvial) inputs or internal (within estuary or tidal freshwater wetland) recycling.
PDR.6	Allochthonous Carbon in Soil Carbon Pool	Proximity of the project area with respect to direct fluvial inputs or near-shore sediment sources.
PDR.7	Allochthonous Carbon in Soil Carbon Pool	An annual mass estimate of the total carbon imported or exported from the estuary or tidal freshwater wetland where the project is located.
PDR.8	Allochthonous Carbon in Soil Carbon Pool	Description of the project area with respect to tidal energy (such as flood- or ebb-dominated) or tidal dispersive flux.
PDR.9	Delineating Spatial Boundaries	GIS-based maps of the project area with, at a minimum, the features listed above.
PDR.10	Delineating Spatial Boundaries	Documentation that the entire project area is/was open water at the project start date.
PDR.11	Delineating Spatial Boundaries	Evidence that the project area meets the definition of tidal or estuarine open water wetlands which once supported emergent wetland vegetation.
PDR.12	Delineating Spatial Boundaries	Evidence that the project area is compliant with the most current version of the VCS AFOLU Requirements regarding the clearing of native ecosystems.
PDR.13	Delineating Spatial Boundaries	If emissions from methane are included in the baseline scenario, an estimate of the average water depth in the project area prior to the implementation of project activities (see Section 6.3).
PDR.14	Delineating Spatial Boundaries	Documentation that the project proponent has control over the project area as described in most recent version of the VCS AFOLU Requirements, Section 3.4.
PDR.15	Delineating Spatial Boundaries	Documentation of the assessment of effects to hydrologically connected areas as further

		described in Section 8.3.1.
PDR.16	Delineating Spatial Boundaries	Documentation of projected sea level rise in the vicinity of the project area, evidence that existing landforms or constructed features are expected to withstand project sea level rise, and a description of the post-construction soil surface elevation relative to mean sea level.
PDR.17	Temporal Project Boundaries	The project start date.
PDR.18	Temporal Project Boundaries	The project crediting period start date and length.
PDR.19	Temporal Project Boundaries	The date by which mandatory baseline reassessment must occur after the project start date.
PDR.20	Temporal Project Boundaries	A timeline including the first anticipated monitoring period showing when project activities will be implemented.
PDR.21	Temporal Project Boundaries	A timeline for anticipated subsequent monitoring periods.
PDR.22	Grouped Projects	A list and descriptions of all enrolled project activity instances in the group at the time of validation.
PDR.23	Grouped Projects	A map of the designated geographic area within which all project activity instances in the group may be located, indicating that all instances are in the same region.
PDR.24	Grouped Projects	A list of eligibility criteria for project activity instances.
PDR.25	Baseline Scenario	Results of a comparative assessment of the implementation barriers and net benefits faced by the project and its alternatives, and justification for the most plausible baseline scenario.
PDR.26	Baseline Scenario	Documentation to demonstrate that the project area previously met the definition of a wetland before converting to open water or similar degraded state. Documentation must include hydrological data to show evidence of long-term patterns of wetland loss.
PDR.27	Baseline Scenario	The selected method for demonstrating the baseline scenario in the project area (regional land use change or spatial analysis).
PDR.28	Regional Land Use Change For Baseline Scenario	A reference to the document providing evidence of continued land loss or static condition in the basin for a period of 10 years prior to the project start date.
PDR.29	Regional Land Use Change For Baseline Scenario	A summary of the referenced document indicating where in the document the evidence is provided.
PDR.30	Regional Land Use Change For Baseline Scenario	Documentation of water management activities (eg, river diversions) that could influence the baseline scenario.
PDR.31	Spatial Analysis for Baseline Scenario	A report describing how the analysis was conducted, including data sources and dates, demonstration of conformance with the requirements listed in Section 6.1.2, and justification

		for the selection of the region in which the analysis was conducted.
PDR.32	Spatial Analysis for Baseline Scenario	A map of the region in which the analysis was conducted.
PDR.33	Spatial Analysis for Baseline Scenario	The quantified change in water area.
PDR.34	Determination of Dredging	Determination (yes or no) whether dredging is included in the baseline scenario.
PDR.35	Determination of Dredging	If dredging is included in the baseline scenario, a description of the single event or programmatic dredging projects, including the likely fate of dredged sediments in the baseline scenario.
PDR.36	Demonstration of Navigability	Map of dredging activities, including justification for planned dredging locations.
PDR.37	Demonstration of Navigability	Documents that demonstrate dredging would have occurred.
PDR.38	Determination of Baseline Energy Consumption	For each energy type in Table 11, the estimate of the unit of energy consumed per metric tonne of sediment dredged.
PDR.39	Determination of Baseline Energy Consumption	Description of equipment types and method or process of sediment dredging, transport, disposal, re-handling, sediment production rates, duration of operations and conveyance distances.
PDR.40	Determination of Baseline Energy Consumption	Estimates of cumulative sediment quantity excavated and re-handled, including temporary disposal and displacement activities, if applicable.
PDR.41	Determination of Baseline Energy Consumption	Source of procedures or data on which these estimates are based.
PDR.42	Determination of Baseline Methane Emissions	Description and justification for the selected reference area.
PDR.43	Demonstration of Project Additionality	Demonstration that pertinent laws and regulations have been reviewed and that none mandate the project activities.
PDR.44	Demonstration of Project Additionality	Evidence that project activities comply with all applicability conditions set out under Section 4.
PDR.45	Emissions or Emissions Reductions and/or Removals Events in Project Area	The selected definition of a significant disturbance.
PDR.46	Hydrologic Effects	Description of the expected impacts on hydrologically connected areas, and the agency process which is expected to take place prior to the commencement of project activities.
PDR.47	Monitoring Plan	A summary of carbon stock sampling procedures for the project area, with a copy of a sampling protocol used by field personnel to carry out measurements.
PDR.48	Monitoring Plan	A summary of flux measurement procedures for the project area, with a copy of a flux

		measurement protocol used by field personnel to carry out measurements.
PDR.49	Monitoring Plan	A reference to the monitoring plan.
PDR.50	Monitoring Plan	Any methodology deviations. Such deviations must include the text that is being modified and the proposed new language.
PDR.51	Stratification	Justification for not stratifying carbon stocks.
PDR.52	Stratification for SOC	Description for how the strata were delineated.
PDR.53	Stratification for SOC	Map(s) of the initial strata boundaries.
PDR.54	Stratification for Biomass	Description for how the strata were delineated.
PDR.55	Stratification for Biomass	Map(s) of the initial strata boundaries.
PDR.56	Measuring Carbon Stocks	Proposed method for allocating plots to stratum.
PDR.57	Measuring Carbon Stocks	Description of plot sizes and layout (such as the use of nests and their sizes) for each carbon pool.
PDR.58	Soil Plot Design	Diagram of a soil plot showing the locations of artificial marker horizons and core samples within the plot over time.
PDR.59	Soil Plot Design	Description of the fixed soil sample depth.
PDR.60	Frequency of Carbon Stock Measurements	The anticipated frequency of monitoring for each plot and flux measurement location – all carbon stock plots should be measured for the first verification.
PDR.61	Monitoring Methane	The selected approach for monitoring methane.
PDR.62	Methane Models from Literature	Justification of methane flux model from the literature, per the requirements of Section 9.2.2.1.
PDR.63	Covariates for Proxy Methane Models	A list of possible covariates and the sources of data available for each.
PDR.64	Covariates for Proxy Methane Models	A list of selected covariates to be used for model fitting.
PDR.65	Stratification for Methane Emissions	Description for how the strata were delineated.
PDR.66	Stratification for Methane Emissions	Map(s) of the initial strata boundaries indicating which stratum is likely to yield the greatest methane emissions flux.
PDR.67	Stratification for Methane Emissions	Justification per the criteria in Section 9.2.2.3.1 for the stratum that is likely to yield the greatest methane emissions flux.
PDR.68	Instrumentation for Chambers	Diagram of chamber design.

PDR.69	Eddy Covariance Measurements	The type of analyzer selected for direct measurements of methane, including a description of the resolution of measurements (in ppb) and the frequency at which measurements are to be taken (in Hz).
PDR.70	Eddy Covariance Measurements	A table of meteorological variables selected for measurement. For each variable in the table, justification for its selection, the unit of measurement, resolution of measurement and frequency of measurement.
PDR.71	Eddy Covariance Measurements	A description the eddy covariance tower configuration including the distances between sensors (vertical, northward and eastward separation).
PDR.72	Eddy Covariance Measurements	A scale diagram of the eddy covariance tower configuration showing the relative location and distance of the anemometer relative to the methane sensor.
PDR.73	Eddy Covariance Measurements	Plan view diagram or map of the eddy covariance tower delineating strata and the area of highest anticipated emissions within a 100m radius of the tower. Delineation of any patch vegetation (twice the dominant canopy height and occupying >100m^2 in area) occurring within the estimated 80% footprint area.
PDR.74	Eddy Covariance Measurements	Description of dominant plant canopy height (in m) over an annual cycle. An estimate of the 80% flux footprint distance (in m) and parameter estimates, as follows: σw= standard deviation of the vertical velocity fluctuations (m/s) $u *$= surface friction velocity (m/sec) zm= measurement height (m) hm= planetary boundary layer height (m) or 1000m zm= roughness length (m) or 1/10th of the average canopy height
PDR.75	Monitoring Nitrous Oxide	The selected approach for monitoring nitrous oxide.
PDR.76	Determining Project Area Exposure to Nitrogen Loading	Location of the project area within a minimum definable watershed, using a USGS, EPA or state delineated watershed.
PDR.77	Determining Project Area Exposure to Nitrogen Loading	Locations of all NPDES major dischargers and public works projects producing > 1 MGD of elevated nitrogen effluent (>3 mg TN/L) discharging into the project area and located within the minimum definable watershed.
PDR.78	Determining Project Area Exposure to Nitrogen Loading	List of EPA CWA Section 303d designated impaired waters for the state.
PDR. 79	Default Values for Nitrous Oxide Monitoring	Justification for the selected default value.
PDR.80	Covariates for Proxy Nitrous Oxide Models	A list of possible covariates and the sources of data available for each.
PDR.81	Covariates for Proxy Nitrous Oxide Models	A list of selected covariates to be used for model fitting.

PDR.82	Model Fit for Nitrous Oxide	Justification that the proxy is an equivalent or better method (in terms of reliability, consistency or practicality) to determine the value of interest than direct measurement.
PDR.83	Stratification for Nitrous Oxide Emissions	Description for how the strata were delineated.
PDR.84	Stratification for Nitrous Oxide Emissions	Map(s) of the initial strata boundaries indicating which stratum is likely to yield the greatest nitrous oxide emissions flux.
PDR.85	Stratification for Nitrous Oxide Emissions	Justification per the criteria in Section 9.2.2.3.1 for the stratum that is likely to yield the greatest nitrous oxide emissions flux.
PDR.86	Field Training for Field Sampling	A description of the type and frequency of training of field personnel responsible for sampling carbon stocks, fluxes, and covariates.
PDR.87	Quality Control and Assurance of Eddy Covariance Data	Any methodology deviations. Such deviations must include the text that is being modified and the proposed new language.
PDR.88	Data and Parameters Available at Validation	The value of each variable, data and parameter in Appendix I.
PDR.89	Data and Parameters Available at Validation	The units, descriptions, source, purpose and comments for each variable reported in the PD.
PDR.90	Chamber Description	A description of the chamber design, with its dimensions or total volume, and cross-sectional area.
PDR.91	Chamber Description	Diagram of chamber plot randomization design and the resulting chamber locations within each stratum, with the chambers identified as replicates. Provide dates when chambers were deployed in each stratum. Provide a justification that the locations chosen are conservative (ie, that they are likely to predict methane emissions flux for the entire stratum for which they are representative.)

APPENDIX L: SUMMARY OF MONITORING REPORT REQUIREMENTS

MRR#	Category	Requirements
MRR.1	Project Activities	Plan for establishment of permanent wetland plant community after project construction. Plan must include tracking aerial extent of emergent vegetation long-term monitoring of such communities, as well as plans for continued maintenance if necessary. This documentation must demonstrate that the project activity results in the accumulation or maintenance of soil carbon stock and that, upon completion of the project activities, the project area must meet the definition of a wetland.
MRR.2	Project Activities	Evidence that the project engineering and design takes into account local water level elevation, tidal range, geotechnical characteristics, sea level rise projections, and the range of plant growth within those constraints.
MRR.3	Substrate Establishment	Post-construction report, including an as-built drawing showing plan view and cross section of the project area along with an estimate of post-construction sediment elevation relative to a geodetic or tidal datum.
MRR.4	Substrate Establishment	Aerial image of the project area within three years prior to construction and an aerial image within one year post-construction.
MRR.5	Vegetation Establishment	A description of the quantity, species, date and location of vegetation establishment, and photographs of the operation. This documentation must demonstrate that the project activity results in the accumulation or maintenance of soil carbon stock.
MRR.6	Vegetation Establishment	Aerial image of the project area indicating where species were established.
MRR.7	Temporal Project Boundaries	The project start date.
MRR.8	Temporal Project Boundaries	The project crediting period start date and length.
MRR.9	Temporal Project Boundaries	Evidence of the start of monitoring per the frequency requirements described in Sections 5.4, 9.2.1.1, 9.2.2.4, and 9.2.3.4.
MRR.10	Grouped Projects	A list and description of all project activity instances in the group, including project activity instance start dates.
MRR.11	Grouped Projects	A map of the boundaries of all project activity instances in the group demonstrating that all instances are in the designated geographic region.
MRR.12	Baseline Emissions	Calculations of current baseline emissions $EB\ \Delta m$ as of the monitoring period.
MRR.13	Baseline Emissions	Calculations of baseline emissions $EB\ \Delta m - 1$ from prior monitoring periods.

MRR.14	Emissions Coefficients	Source and date of the emission coefficient.
MRR.15	Emissions Coefficients	Reference to the exact page number or worksheet cell in the source.
MRR.16	Project Emissions or Emissions Reductions and/or Removals	Calculations of current project emissions or emissions reductions and/or removals $EP\ \Delta m$ as of the monitoring period.
MRR.17	Project Emissions or Emissions Reductions and/or Removals	Calculations of project emissions or emissions reductions and/or removals $EP\ \Delta m - 1$ from prior monitoring periods.
MRR.18	Emissions or Emissions Reductions and/or Removals Events in Project Area	The selected definition of a significant disturbance.
MRR.19	Emissions or Emissions Reductions and/or Removals Events in Project Area	A map of the boundaries of any significant disturbance in the project area during the monitoring period.
MRR.20	Emissions or Emissions Reductions and/or Removals Events in Project Area	Evidence that plots were installed into these disturbed areas and were measured per Section 9.2.1.
MRR.21	Hydrologic Effects	Documentation that the project will not have a significant negative impact on hydrologically connected areas. This may include a Clean Water Act permit issued by the USACE, NEPA decision (ROD or FONSI) issued by the appropriate lead federal agency, or compliance documentation from local floodplain management agencies.
MRR.22	Quantification of GERs	Quantified GERs for the monitoring period including references to calculations.
MRR.23	Quantification of GERs	Quantified GERs for the prior monitoring period.
MRR.24	Quantification of GERs	A graph of GERs by monitoring period for all monitoring periods to date.
MRR.25	Quantification of NERs	Quantified NERs for the monitoring period including references to calculations.
MRR.26	Quantification of NERs	Quantified NERs for the prior monitoring period.
MRR.27	Quantification of NERs	A graph of NERs by monitoring period for all monitoring periods to date.
MRR.28	Confidence Deduction	The calculated confidence deduction and supporting calculations.
MRR.29	Confidence Deduction	Any methodology deviations. Such deviations must include the text that is being modified and the proposed new language.

MRR.30	AFOLU Pooled Buffer Account	Reference to the VCS requirements used to determine the AFOLU pooled buffer account allocation.
MRR.31	AFOLU Pooled Buffer Account	Reference to calculations used to determine the AFOLU pooled buffer account allocation.
MRR.32	Buffer Release	Reference to the VCS requirements used to determine the release from the AFOLU pooled buffer account.
MRR.33	Buffer Release	Reference to calculations used to determine the buffer release.
MRR.34	Vintages	Quantified NERs by vintage year for the monitoring period including references to calculations.
MRR.35	Project Performance	Comparison of NERs presented for verification relative to those from *ex-ante* estimates.
MRR.36	Project Performance	Description of the cause and effect of differences from *ex-ante* estimates.
MRR.37	Monitoring Plan	Documentation of training for field measurement crews.
MRR.38	Monitoring Plan	Documentation of data quality assessment.
MRR.39	Monitoring Plan	References to plot allocation for carbon stock measurement.
MRR.40	Monitoring Plan	List of plot GPS coordinates for plots and flux measurement devices.
MRR.41	Monitoring Plan	Description and diagram of flux measurements devices for methane and/or nitrous oxide.
MRR.42	Monitoring Plan	The estimated carbon stock, standard error of the total for each stock, and the sample size for each stratum in the project area.
MRR.43	Monitoring Plan	Any methodology deviations. Such deviations must include the text that is being modified and the proposed new language.
MRR.44	Monitoring Plan	Frequency of monitoring for each plot and flux measurement location – all carbon stock plots should be measured for the first verification.
MRR.45	Stratification for SOC	Map(s) of the current strata boundaries.
MRR.46	Stratification for SOC	A description of changes to the strata boundaries (if applicable).
MRR.47	Stratification for Biomass	Map(s) of the current strata boundaries.
MRR.48	Stratification for Biomass	A description of changes to the strata boundaries (if applicable)
MRR.49	Measuring Carbon Stocks	Method for allocating plots to stratum.
MRR.50	Measuring Carbon Stocks	Map of the location of plots within strata.
MRR.51	Measuring Carbon Stocks	Description of plot sizes and layout (such as the use of nests and their sizes) for each carbon pool.

MRR.52	Soil Plot Design	For each measured soil plot, a diagram showing the location of installed artificial marker horizons and sampled cores.
MRR.53	Soil Plot Design	Field report describing soil sample depths (accretion depth and fixed soil sample depth) and coring devices used to collect samples. The report must also include number of soil samples and their identification in a chain of custody form submitted to the laboratory.
MRR.54	Frequency of Carbon Stock Measurements	List of plots measured during the monitoring period – all carbon stock plots should be measured for the first verification.
MRR.55	Methane Models from Literature	Demonstration that the selected model is applicable to the project area per the requirements of Section 9.2.2.1.
MRR.56	Methane Models from Literature	Description of how model predictions are converted to tCO_2e/day.
MRR.57	Data Collection for Proxy Methane Model	Complete references to the source of any data collected from literature or reports.
MRR.58	Data Collection for Proxy Methane Model	Data collection procedures, plans or protocols for any data collected directly from the project area.
MRR.59	Model Fit for Methane	The form of the selected model.
MRR.60	Model Fit for Methane	Summary statistics of the model fit as appropriate to the fitting of the model.
MRR.61	Model Fit for Methane	The estimated model parameters.
MRR.62	Model Fit for Methane	A description of the range of covariate data with which the model was fit.
MRR.63	Model Prediction for Methane	The values of any measured covariates.
MRR.64	Model Prediction for Methane	The predicted methane flux.
MRR.65	Processed Chamber and Eddy Covariance Flux Data	A table of chamber flux or eddy covariance emission summary statistics of the mean (±1SEM) and number of samples for each mean in tCO_2e/ac/day for each sample location within a stratum.
MRR.66	Stratification for Methane Emissions	Map(s) of the current strata boundaries.
MRR.67	Stratification for Methane Emissions	A description of changes to the strata boundaries (if applicable).
MRR.68	Instrumentation for Chambers	Diagram of chamber design.

MRR.69	Instrumentation for Chambers	Map showing the location of chambers in the project area.
MRR.70	Instrumentation for Eddy Covariance	Diagram or map of eddy covariance tower delineating the selected footprint area where flux was integrated from and the computed mean 80% footprint distance (including the footprint model used) from the tower during the period of analysis. A table of computed estimates for each of the following parameters: σ_w = standard deviation of the vertical velocity fluctuations (m/s) u^*= surface friction velocity (m/sec) z_m= measurement height (m) z_0= roughness length (m) (or canopy height and density to be used to estimate roughness length)
MRR.71	Instrumentation for Eddy Covariance	Description of the published model used to define the footprint.
MRR.72	Instrumentation for Eddy Covariance	Map showing the location of eddy covariance towers in the project area.
MRR.73	Instrumentation for Eddy Covariance	Documentation of adherence to manufacturer-recommended procedures for calibration of the methane analyzer.
MRR.74	Eddy Covariance Data Processing and Flux Computation	Frequency diagram of wind direction (0-359° with 30° intervals) and velocity (m/s) for the period of analysis.
MRR.75	Eddy Covariance Data Processing and Flux Computation	Summary of the dates of data collection, the selected approach for averaging over each period, explicit formulas used for computing flux, number of 0.5-hr samples used in calculations.
MRR.76	Eddy Covariance Data Processing and Flux Computation	Graphical plot of 0.5-hr GHG concentration (ppmv), wind velocity and direction, and temperature used for the flux calculations
MRR.77	Eddy Covariance Data Processing and Flux Computation	Summary statistics (number of samples, mean, median, variance) of GHG flux for each averaging period.
MRR.78	Chamber Sampling for Methane	Table of sampling event dates for the monitoring period, including the time of day samples were collected, water level relative to the soil surface, soil temperature, and air temperature.
MRR.79	Chamber Sampling for Methane	Copy of field data sheets documenting time intervals when samples were collected, sample identification number, and verification of the total number of samples received by the laboratory.
MRR.80	Eddy Covariance Measurement	A table of meteorological variables selected for measurement. For each variable in the table, an indication of whether the variable was measured, the make and model of the instrument used for measurement.
MRR.81	Eddy Covariance Measurement	For each measured variable, a graphical plot or table of the data with respect to time during the monitoring period. A data table or plot must include at minimum: air temperature, methane concentration, methane flux. A list of interpolated/missing samples.

MRR.82	Eddy Covariance Measurement	Documentation of calibration dates and zero checks for methane analyzer. Provide the date of last full calibration (0-10 ppm methane standard). Provide dates of carbon-free air gas checks for methane analyzer.
MRR.83	Data Collection for Proxy Nitrous Oxide Model	Complete references to the source of any data collected from literature or reports.
MRR.84	Data Collection for Proxy Nitrous Oxide Model	Data collection procedures, plans or protocols for any data collected directly from the project area.
MRR.85	Model Fit for Nitrous Oxide	The form of the selected model.
MRR.86	Model Fit for Nitrous Oxide	Summary statistics of the model fit as appropriate to the fitting of the model.
MRR.87	Model Fit for Nitrous Oxide	The estimated model parameters.
MRR.88	Model Fit for Nitrous Oxide Covariance Data	A description of the range of covariate data with which the model was fit.
MRR.89	Model Prediction for Nitrous Oxide	The values of any measured covariates.
MRR.90	Model Prediction for Nitrous Oxide	The predicted nitrous oxide flux.
MRR.91	Stratification for Nitrous Oxide Emissions	Map(s) of the current strata boundaries.
MRR.92	Stratification for Nitrous Oxide Emissions	A description of changes to the strata boundaries (if applicable).
MRR.93	Chamber Sampling for Nitrous Oxide	Table of sampling event dates for the monitoring period, including the time of day samples were collected, water level relative to the soil surface, soil temperature, and air temperature.
MRR.94	Chamber Sampling for Nitrous Oxide	Copy of field data sheets documenting time intervals when samples were collected, sample identification number, and verification of the total number of samples received by the laboratory.
MRR.95	Energy Consumption Measurement Method	The selected approach to monitoring energy consumption.
MRR.96	Direct Measurement of Energy Consumption	Energy consumption for each energy type listed in Section 8.1.1.
MRR.97	Direct Measurement of Energy Consumption	References to records of energy consumption.
MRR.98	Cost Approach to Energy	Justification for the proportion of dredging budget allocated for fuel (or electricity) purchases.

	Consumption	
MRR.99	Cost Approach to Energy Consumption	Justification for choice of energy type(s).
MRR.100	Cost Approach to Energy Consumption	Documentation of historic energy costs at the time of dredging activities.
MRR.101	Cost Approach to Energy Consumption	Justification of estimate of energy consumption.
MRR. 102	Monitoring Sediment Transport	Justification for the estimate of volume of dredged sediment transported.
MRR. 103	Monitoring Sediment Transport	Justification for the estimate of the density of dredged sediment.
MRR.104	Monitoring Sediment Transport	Estimated mass of sediment transported.
MRR.105	Monitoring Allochthonous Carbon	Reference(s) to the regionally appropriate literature used to determine the correct factor for mineral-associated carbon.
MRR.106	Field Training for Field Sampling	The type and frequency of training of field personnel during the monitoring period.
MRR.107	Carbon Stock Measurements	Biomass and SOC carbon stock data for all plots, along with any ancillary spreadsheets or computer code used to generate these predictions.
MRR.108	Carbon Stock Measurements	List of outliers with unusually high or low biomass or SOC, including justification for their continued inclusion.
MRR.109	Carbon Stock Measurements	Results of accuracy assessment if non-destructive sampling techniques are used. Otherwise, justification for why accuracy need not be formally addressed.
MRR.110	Quality Control and Assurance of Eddy Covariance Data	Description of processing software used, assumptions, and data quality control measures, which must include the selected method of coordinate rotation, detrending, and density fluctuation correction.
MRR.111	Laboratory Analyses	Documentation of the laboratory QA/QC protocols, the methods of sample analysis, and general calibration procedures used the laboratories conducting the analysis.
MRR.112	Data and Parameters Monitored	The value of each variable, data and parameter in Section 9.4.
MRR.113	Data and Parameters Monitored	The units, descriptions, source, purpose, references to calculations and comments for each variable reported in the Monitoring Report.
MRR.114	Data and Parameters Monitored	For those variables obtained from direct measurement, a description of measurement methods and procedures. These may simply be references to components of the monitoring plan.

MRR.115	Data and Parameters Monitored	For those variables obtained from direct measurement, a description of monitoring equipment including type, accuracy class and serial number (if applicable). These may simply be references to components of the monitoring plan.
MRR.116	Data and Parameters Monitored	Procedures for quality assurance and control, including calibration of equipment (if applicable).
MRR.117	Monitoring Grouped Projects	List and descriptions of all project activity instances in the group.
MRR.118	Monitoring Grouped Projects	Project activity instance start dates.
MRR.119	Monitoring Grouped Projects	Map indicating locations of project activity instances added to the group.
MRR.120	Monitoring Grouped Projects	List of additional stratifications used for additional project activity instances; justification for why flux measurements are still located in the most conservative stratum (9.2.2, 9.2.3).
MRR.121	Monitoring Grouped Projects	As project activity instances are added, monitoring plan must be updated to reflect additional monitoring times and plot locations.

APPENDIX M: SOURCE OF EMISSIONS FACTORS FOR ENERGY CONSUMPTION

		CO2		CH4		N20				
Fuel Type	Proponent reports as:	Emissions (kg/MMBtu)	tCO2 / MMBtu	Emissions (kg/MMBtu)	tCO2e / MMBtu	Emissions (kg/MMBtu)	tCO2e / MMBtu	Total Emissions (tCO2e/MMBtu)	Energy Content (MMBtu/unit)	**Emission Coefficient**
Diesel	gal	73.96	0.07396	0.003	0.000063	0.0006	0.000186	0.07421	0.138	**0.010241**
Gasoline	gal	70.22	0.07022	0.003	0.000063	0.0006	0.000186	0.07047	0.125	**0.008809**
Biodiesel	gal	73.84	0.07384	0.0011	0.0000231	0.00011	0.0000341	0.07390	0.128	**0.009459**
CNG	scf	53.02	0.05302	0.001	0.000021	0.0001	0.000031	0.05307	0.001028	**0.000055**
Electricity	kWh	see eGRID regional emissions factor								

Sources:

- Emissions factors and energy content for fuels: EPA Final Mandatory Reporting of Greenhouse Gases Rule Table C-1, C-2 (http://www.epa.gov/ghgreporting/documents/pdf/2009/GHG-MRR-FinalRule.pdf). Emissions in kg/MMBtu are taken directly from the EPA Mandatory reporting Rule. Emissions in tCO2e/MMBtu apply a unit conversion to tons (1 ton = 1,000 kg) and multiply by the appropriate global warming potential (1 for CO_2, 21 for CH_4, 310 for N_2O – the project proponent must confirm the global warming potentials per the current version of VCS Standard). Total emissions are a simple sum of the emissions in tCO2e/MMBtu of each of the three covered gases. The emission coefficient is calculated as the product of the total emissions and the energy content of the fuel type.
  For updates to these factors, refer to the EPA website (http://www.epa.gov/ghgreporting/reporters/subpart/c.html) or the federal regulations (40 C.F.R. § 98, Subpart C, Tables C-1 and C-2).
- eGRID regional emissions factors for electricity: http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2012V1_0_year09_GHGOutputrates.pdf ('annual total output emission rates'). Note the unit conversions required to calculate the emissions from electricity usage in terms of tCO_2e, given that eGRID factors are stated in terms of lb/MWh and lb/GWh, and in terms of CH_4 and N_2O emissions (vs. CO_2e).
  For the current version of emissions factors, refer to http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html. Locate the eGRID GHG output summary file for the correct emission year (eg, eGRID2012 provides actual generation data from 2009). Because there is typically a lag of several years, if data for the current year or recent years are not available, use the most recent data (eg, if eGRID2012 is the most recent data available in 2013, then eGRID2012 with 2009 data should be used for all years 2009-2013). In the GHG summary file, use data for the appropriate eGRID subregion for 'annual total output emission rates.'

DOCUMENT HISTORY

Version	Date	Comment
v1.0	30 Jan 2014	Initial version released

VERIFIED CARBON STANDARD
A Global Benchmark for Carbon

Approved VCS Methodology VM0025

Version 1.0, 12 February 2014
Sectoral Scopes 1 and 3

Campus Clean Energy and Energy Efficiency

The methodology was developed by Climate Neutral Business Network (CNBN) in collaboration with Bonneville Environmental Foundation based upon generous support from Chevrolet.

Authors:
Sue Hall, CEO CNBN (sue@climateneutral.com, +1 541 490 2860)

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ACKNOWLEDGEMENTS

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Chevrolet's Environmental Advisory Board
Bob Wilkinson, UCSB
Eban Goodstein, Bard College
Janet Peace, CECS
Mark Kenber, The Climate Group
Bob Sheppard, formerly CACP
Andy Stevenson, formerly NRDC
Snehal Desai, Dow
Chevrolet
David Tulauskas, GM Sustainability
Bill Devine, Chevrolet Marketing

Bonneville Environment Foundation
Pat Nye, Senior Associate
Angus Duncan, President

UCGBC
Chris Pyke, VP R&D USGBC
Jaime Van Mourik, USGBC

AASHE
Paul Rowland, President
Meghan Fay Zahniser, STARS
Chris Pelton, STARS

College Campuses
Bahar Armaghani, University of Florida
Kevin Bright, Harvard University
Bob Koester, Ball State University
James Lowe, Ball State University
Will Frayer, Ball State University
Randy Howard, Ball State University
Jordan Sager, UCSB
Mo Lovegreen, UCSB
Bruce Tiffney, UCSB
Noel Mingo, Portland State University
Jennifer McNamara, Portland State University
Dan Roth, Cornell University
Robert Bland, Cornell University
Jeremy Friedman, New York University
Beth Morningstar, New York University
John Bradley, New York University
Christopher James, New York University
Carol Dollard, Colorado State University
Nifoghale Ovuworie, Ohio State University
Aparna Dial, Ohio State University
Laurie Husted, Bard College

Second Nature
Tony Cortese, former President Second Nature
George Dyer, former VP Second Nature
Toni Nelson, Second Nature
Michele Madia, Second Nature

Other Non-Profits
Derik Broekhoff, Climate Action Reserve
Roger Stephenson, CACP
Jennifer Andrews, CACP
Ruben Aronin, formerly Global Green
Kathleen Rogers, Earth Day Network

Energy Efficiency Services
Ash Awad, McKinstry
Cameron Hamilton, McKinstry
Nancy Hamilton, McKinstry
Vaibhas Potnis, McKinstry

Government Agencies
Steve Jurovics, Cadmus Group, on behalf of US EPA
Einar Telnes, NORAD
Michael Armstrong, City of Portland Sustainability Office

Other
Kristin Zimmerman, formerly GM

1 SOURCES

The methodology uses the latest version of the following tools and guidance:

- VMD0038, Campus-Wide Module
- VMD0039, LEED-Certified Buildings Module
- US Environmental Protection Agency's ENERGY STAR Portfolio Manager® program[1]
- US Environmental Protection Agency's ENERGY STAR Target Finder tool[2]
- Clean Air Cool Planet Campus Carbon Calculator[3]
- CDM-EB67-A06-GUID Guidelines for sampling and surveys for CDM project activities and programme of activities

The methodology is based on approaches used in the following methodologies:

- VM0008 Weatherization of Single and Multifamily Homes (version 1.1)
- NM0302 Emission reductions in the cement production facilities of Holcim Ecuador S.A. (proposed CDM methodology)

The follow have also supported the development of the methodology:

- The American College and University Presidents' Climate Commitment (ACUPCC) GHG inventory reports[4]
- Efficiency Valuation Organization's International Performance Measurement and Verification Protocol (IPMVP) for guidance on methods determining energy savings (EVO-1000-1, 2010)[5]
- USGBC's LEED certification protocols[6]
- Portfolio Manager supporting documentation[7]

[1] EPA. 2013: http://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager
[2] EPA. 2013: http://www.energystar.gov/index.cfm?c=new_bldg_design.bus_target_finder
[3] CACP. Aug, 2013: http://cleanair-coolplanet.org/campus-carbon-calculator/
[4] ACUPCC. 2013: http://rs.acupcc.org/
[5] EVO. 2010: http://www.evo-world.org/index.php?option=com_content&view=article&id=272&Itemid=379&lang=en
[6] USGBC. 2013: http://new.usgbc.org/leed[7] EPA. Nov, 2011. "Methodology for Greenhouse Gas Inventory Calculations" http://www.energystar.gov/ia/business/evaluate_performance/Emissions_Supporting_Doc.pdf?f655-cb13
[7] EPA. Nov, 2011. "Methodology for Greenhouse Gas Inventory Calculations"
http://www.energystar.gov/ia/business/evaluate_performance/Emissions_Supporting_Doc.pdf?f655-cb13
EPA. Mar, 2011. "ENERGY STAR Performance Ratings – Technical Methodology"
http://www.energystar.gov/ia/business/evaluate_performance/General_Overview_tech_methodology.pdf?9d9b-0c2d
EPA. Jul, 2013. "Portfolio Manager Technical Reference: ENERGY STAR Score"
http://www.energystar.gov/buildings/tools-and-resources/portfolio-manager-technical-reference-energy-star-score
http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager_model_tech_desc

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology provides the procedures for quantifying reductions in scope 1 stationary combustion emissions and scope 2 electricity emissions achieved by college, university and school campuses in the United States. The methodology consists of two modules: *VMD0038, Campus-Wide Module*; and *VMD0039, LEED-Certified Buildings Module*, as follows:

1) Campus-Wide Module

   This module applies to projects targeting campus-wide emission reductions on existing college and university campuses in the United States (but does not apply to K-12 schools). Campuses may implement project activities that reduce scope 1 stationary combustion emissions and/or scope 2 electricity emissions. Campuses must meet the relevant additionality performance benchmark by applying a series of additionality benchmark tests. Emission reductions are quantified based on data from third-party GHG reporting programs (eg, ACUPCC, STARS and The Climate Registry) for each year relative to a three to five year adjusted baseline.

Additionality and Crediting Method	
Additionality	Performance Method
Crediting Baseline	Project Method

2) LEED-Certified Buildings Module

   This module applies to projects targeting emission reductions from LEED-certified New Construction or LEED-certified Existing Buildings located on college and university campuses and K-12 schools. The building must meet the relevant additionality performance benchmark. Emission reductions are quantified based on data generated using EPA's Target Finder tool for each year relative to a crediting benchmark or a three to five year adjusted baseline.

Additionality and Crediting Method	
Additionality	Performance Method
Crediting Baseline	Performance Method for New Construction and Existing Buildings B; Project Method for Existing Buildings A

This standardized methodology establishes multiple performance benchmarks which US colleges and schools can use to determine whether they have achieved a superior level of performance that would qualify as additional (additionality benchmark) and to quantify baseline emissions (crediting benchmark). Unlike project methods, performance methods are designed to identify the levels of performance (in terms of GHG emission reductions) in a given sector to allow for sector-wide benchmarking. Through extensive analyses of historical performance (outlined in the modules), this methodology establishes performance benchmarks for campus-wide emission reductions and LEED-certified building emission reductions that allow for a series of simple tests to be conducted to determine additionality and a crediting baseline. Stakeholder consultation was an important part of the development of this methodology, and the process and participants are described in Appendix 2.

Each module provides the detailed procedures for the given type of project activities, adding to the common requirements provided in this document. Each module has distinct specifications for applicability conditions, project boundary, baseline scenario, additionality, quantification of emission reductions, and monitoring. Where both campus-wide and building reductions are sought in combination for the same campus, both modules must be applied separately, and the relevant emission reductions netted out, as described in Section 8 below. Figure 1 below provides a conceptual route map illustrating how this methodology and its two modules are applied.

Projects must demonstrate right of use for any GHG emission reductions generated by the project, in accordance with the *VCS Standard* (for definition of *right of use* see VCS program document *Program Definitions*). Where right of use cannot be demonstrated for particular emission reductions (eg, for scope 2 emissions addressed by the project), the project proponent may choose to include only those emission reductions for which it can demonstrate right of use (eg, only include scope 1 emissions for LEED certified building projects). Emission reductions arising from a campus's third-party customer's use (eg, emission reductions achieved by a neighboring hospital which purchases energy from campus on-site energy generation) must be excluded from the project. Note that the consumption of energy services provided by off-site suppliers (eg, local industry) must be excluded from the scope 1 emissions and included in scope 2 emissions.

Where projects generate other forms of environmental credit (eg, renewable energy certificates (RECs)), the project must meet VCS rules and guidance on double counting (see *VCS Standard, Registration and Issuance Process,* and VCS guidance on double counting). For example GHG emission reductions that arise from the installation of renewable energy systems located on a campus, whose GHG-related attributes have been sold as RECs to other third parties must also be excluded from the quantification of emission reductions. Similarly, where RECs from off-site renewable installations are purchased by the campus, the lower GHG emissions or the respective grid emission factors associated with the RECs cannot be used to decrease project emissions in the quantification of emission reductions.

Emission reduction generated within a region subject to a carbon cap (eg, campuses' whose electricity emissions are included within a regulatory cap and trade program such as that in California) must meet the VCS rules regarding emission trading programs and other binding limits (ie, double counting) set out in the *VCS Standard*.

Where emission reductions are verified and intend to be issued as VCUs, project proponents must ensure that such VCUs are accurately reported in accordance with any procedures set out under any applicable third-party GHG reporting program under which the campus reports. The sale, transfer or retirement of any VCUs must be accurately reported to any applicable third-party GHG reporting program during the period where such sale, transfer or retirement occurs.

Figure 1: Conceptual Route Map for Methodology

Select project activities and determine appropriate module(s):

I. Campus-wide module for campus-wide activities
II. LEED-certified building module for LEED-certified building activities
III. Both modules for campus-wide *and* LEED-certified building activities

Campus-Wide	**LEED-Certified Buildings**
Applicability Conditions Determine whether activities qualify (eg, ACUPCC Carnegie classification of campus, use of third-party GHG reporting program, and activities implemented)	Applicability Conditions Determine whether activities qualify (LEED New Construction (NC), Existing Buildings A (EB-A), or Existing Building B (EB-B) and building classification higher education, higher education laboratory or K-12 School)
Project Boundary Determine the GHG sources, sinks and reservoirs for the project and whether new site areas can be excluded from the project boundary	Project Boundary Determine the GHG sources, sinks and reservoirs for the project
Baseline Scenario Determine the baseline scenario for the scope of GHG emission reductions that are additional, accounting for variance in square footage during the baseline period	Baseline Scenario Determine the baseline scenario for each building in the project by applying a crediting benchmark for NC and EB-B, or a historical baseline adjusted for energy efficiency improvements for EB-A
Additionality Determine which scope of emission reductions (ie, scope 1 stationary combustion emissions and/or scope 2 electricity emissions) are additional for the given project year, applying the regulatory surplus and performance benchmark tests, which account for variance in square footage during the baseline period and weather variances where necessary	Additionality Determine which buildings are additional for the given project year, applying the regulatory surplus and performance benchmark tests
GHG Emission Reductions Quantify the reductions for the relevant scope of emission reductions, adjusting for variance in square footage during the baseline period and project crediting period where necessary	GHG Emission Reductions Quantify the reductions for all additional buildings in the project using results generated from EPA's Target Finder tool anchored upon the appropriate property type and property use details

Monitoring Plan

Identify the data and parameters that need to be determined at validation, and those that need to be determined at each verification event.

Describe the plan for obtaining, recording, compiling and analyzing monitored data and parameters. Where both the campus-wide and LEED-certified buildings modules are applied, create a single monitoring plan.

Net GHG Emission Reductions

Where both the campus-wide and LEED-certified buildings modules are applied, quantify the net reductions by subtracting relevant LEED-certified building reductions from the campus-wide total.

3 DEFINITIONS

Definitions are specified in each of the modules referenced by this methodology.

4 APPLICABILITY CONDITIONS

This methodology applies to project activities that reduce emissions through the implementation of clean energy and/or energy efficiency activities at college and school campuses in the United States.

Projects applying this methodology must use the latest versions of one, or both, of the following modules:

1) VMD0038, Campus-Wide Module

2) VMD0039, LEED-Certified Buildings Module

Where the project applies one of these modules (ie, is implementing campus-wide activities *or* LEED-certified building activities), the project must meet the applicability conditions specified in the relevant module. Where the project applies both modules (ie, is implementing both campus-wide *and* LEED-certified building activities), the campus-wide activities must meet the applicability conditions set out in the campus-wide module, while the LEED-certified building activities must meet the applicability conditions set out in the LEED-certified buildings module.

Note that this methodology applies a standardized method and therefore must be used in preference to project methods (methodologies) available for the same project activities. Appendix 1 provides an indicative (non-exhaustive) list of project methods available for clean energy and energy efficiency projects.

5 PROJECT BOUNDARY

The procedures in the module being applied must be followed.

6 BASELINE SCENARIO

The procedures in the module being applied must be followed.

7 ADDITIONALITY

The procedures in the module being applied must be followed.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

The procedures in the module being applied must be followed.

Where both campus-wide and building reductions are sought in combination from the same campus (ie, both the campus-wide and LEED modules have been applied), then the building reductions must be subtracted from the campus-wide reductions, as follows:

$$ER_y = ER_{y,cw} - ER_{y,lcb} \quad (1)$$

Where:

ER_y = Net GHG emission reductions in year y for the project
$ER_{y,cw}$ = Net GHG emission reductions in year y from campus-wide module
$ER_{y,lcb}$ = Net GHG emission reductions in year y from LEED-certified building module

Only the relevant scope of emissions used in the quantification of campus-wide emission reductions must be subtracted (ie, only stationary combustion emissions reductions from LEED-certified buildings must be subtracted from projects quantifying campus-wide stationary combustion emission reductions). The LEED certification documents contain all the relevant information regarding the contributions that each source of energy (ie, stationary combustion or scope 2 electricity) contributed to the building's total energy consumption. These may be used, if sub-metering of the LEED-certified building is not accessible, to assess the total portion of the emission reductions from LEED-certified buildings that should be subtracted. For example, if a project sought emission reductions from both campus-wide stationary combustion and LEED-certified buildings, and the stationary combustion energy sources represent 40% of the LEED-certified building's energy consumption, then 40% of the LEED-certified building's emission reductions must be deducted from the campus-wide emission reductions.[8]

9 MONITORING

For campus-wide activities, the monitoring procedures set out in the campus-wide module must be followed. For LEED-certified building activities, the monitoring procedures set out in the LEED-certified buildings module must be followed. Where both modules are applied, monitoring procedures from both modules must be followed to provide a single monitoring approach for the project.

10 REFERENCES

None

[8] Given that LEED-certified building emission reductions will be small compared to a campus-wide emission reductions, this represents a reasonable estimation process, recognizing that the percent contribution of a given scope of energy emissions to the total is a reasonable proxy for the proportion of reductions that it contributed to a LEED-certified building emission reductions total.

APPENDIX 1: SIMILAR PROJECT METHODS

Standardized methods are designed to identify superior performance within a given sector and the performance benchmarks within the methodology have been developed to ensure such environmental integrity. Where project activities meet the applicability conditions of this methodology and its respective modules, such projects should apply the methodology in preference to project methods available for the same project activities. Project proponents should contact the VCSA at secretariat@v-c-s.org if additional guidance or clarification is necessary when selecting an appropriate methodology.

Table 1 below lists the identified approved and pending methodologies under VCS and approved GHG programs that target project activities that could be included under the *Campus Clean Energy and Energy Efficiency* methodology (ie, such methodologies may also be applicable to certain subsets of project activities covered by this methodology). Note that this is provided for indicative purposes only and does not necessarily represent an exhaustive list.

Table 1: Methodologies Targeting Similar Project Activities

Methodology	Title	GHG Program
AMS-I.A.	Electricity generation by the user	CDM
AMS-I.D.	Grid connected renewable electricity generation	CDM
AMS-I.F.	Renewable electricity generation for captive use and mini-grid	CDM
AMS-I.J.	Solar water heating systems (SWH)	CDM
AMS-II.C.	Demand-side energy efficiency activities for specific technologies	CDM
AMS-II.E.	Energy efficiency and fuel switching measures for buildings	CDM
AMS-II.J.	Demand-side activities for efficient lighting technologies	CDM
AMS-II.K.	Installation of co-generation or tri-generation systems supplying energy to commercial building	CDM
AMS-II.L.	Demand-side activities for efficient outdoor and street lighting technologies	CDM
AMS-II.M.	Demand-side energy efficiency activities for installation of low-flow hot water savings devices	CDM
AMS-II.N.	Demand-side energy efficiency activities for installation of energy efficient lighting and/or controls in buildings	CDM
AMS-II.Q.	Energy efficiency and/or energy supply projects in commercial buildings	CDM
AMS-II.R	Energy efficiency space heating measures for residential buildings	CDM
AMS-III.AC.	Electricity and/or heat generation using fuel cell	CDM

AMS-III.AE.	Energy efficiency and renewable energy measures in new residential buildings	CDM
AMS-III.AR.	Substituting fossil fuel based lighting with LED/CFL lighting systems	CDM

APPENDIX 2: STAKEHOLDER CONSULTATION SUMMARY

The development of the methodology was generously sponsored by Chevrolet. Chevrolet's Carbon Reduction Initiative Environmental Advisory Board was instrumental in developing a draft white paper outlining the core framing and assumptions which would become this methodology. As part of this advisory board, a diverse group of stakeholders were consulted to refine the white paper and develop the performance benchmarks. This extensive stakeholder group included a diverse group of experts including AASHE, campus experts, environmental experts, college-focused NGO's, college sustainability officers, college business officers, carbon experts, and energy efficiency experts. A list of the experts involved with the stakeholder consultation is provided at the end of this appendix.

During the stakeholder consultation process many detailed questions relating to the design of the modules were discussed. These contributed to the refinements in the white papers, which were updated throughout this period. All stakeholders who reviewed the white papers therefore were able to review the performance benchmark. Particularly, detailed discussions of the following topics took place with the Environmental Advisory Board and USGBC:

- Baseline designs
- Project boundary definitions
- Applicability tests/conditions needed
- Provisions to avoid double counting
- Performance benchmark update processes
- Stratifications
- Performance benchmarks detailed analyses, based on performance curves, relative to percentile equivalents across each segment
- Carbon contribution to incremental capital analyses
- Refinements needed to fine tune the modules (eg, business as usual gains, square foot variances, inclusions/exclusions needed)
- Tests relative to attributable activities undertaken

The stakeholder dialogue was particularly helpful in confirming assumptions for key details and parameters in the modules. Not all discussions have been referenced here but, drawing upon key topics from the final white paper drafts, the main highlights in this category include:

Both modules:

- Refine performance benchmarks every five years – not sooner – to provide project proponents with sensible planning horizons; rather provide updated data on an interim basis to describe performance benchmark trends. Five years is consistent with VCS minimum requirements.
- Utility sign offs and other measures (especially regarding campus reporting of GHG reductions to ACUPCC, STARS etc.) to address double counting/double claiming.
- Project boundaries are appropriately specified to preclude GHG emission reductions resulting from RECs, energy services supplied to neighboring institutions etc.

Campus-wide module:

- The core foundation requires absolute reductions in both scope 1 and scope 2 electricity-based emissions.
- Selection of additionality benchmark as annual percentage improvement in stationary combustion emissions is appropriate. It conforms to VCS requirements, it closely aligns to campuses' ACUPCC reporting structures (which are over historical baselines) and thus encourages leadership capacity building in the sector, and it is consistent with precedent set by other performance methods under VCS.
- Stratify by Carnegie class, consistent with ACUPCC practice.
- Base the level of each additionality benchmark on the average annual percentage reduction by Carnegie class, not just a single percentile (eg, 85^{th}), to most accurately reflect superior performance achievement and minimize false positive/negatives.
- This approach generates performance benchmarks that are credible (around the 85^{th} percentile) relative to UNFCCC parameters and other VCS performance method precedents.
- Financial analysis of the carbon contributions was considered meaningful and providing leverage to deliver superior performance.
- Including a "positive" style test to document the steps taken to achieve the performances, based on leading campuses' ACUPCC Climate Action Reports, is credible and goes beyond other VCS performance method approaches.
- Screening for other potential drivers of performance has been thorough.
- Historical baselines are sound to use and well framed relative to variances for weather etc. Including variances to accommodate for weather changes makes sense if the historical reference period is short; otherwise, these variances are addressed by averaging over a longer historical reference period.
- It would be best to provide avenues in the module to accommodate variances for square footage outside reasonable parameters (declining or increasing more than 5 percent) rather than use an intensity style metric to determine additionality or quantify emission reductions. The latter introduces another orthogonal variable which then needs to be considered for variances relative to false positives and false negatives.
- Baseline adjustments reflecting US average energy efficiency gains should be made, not adjustments reflecting a five percent annual energy efficiency gain. The later would assume that campuses could go climate neutral very rapidly on a business as usual basis.

LEED-certified buildings module:

- Segmentations based on LEED proposed data is appropriate, using LEED overall averages where they feel the sample sets are otherwise too small.
- The average LEED-certified building Energy Star score is credible and the baselines selected make sense since the module then reflects a step-wise increase from national average ES score to average LEED-certified building Energy Star score.

- This approach generates performance benchmarks that are credible (around 86th percentile) relative to UNFCCC parameters and other VCS performance methodology precedents.
- Where EPA Portfolio Manager is not yet sufficiently robust for reporting/benchmarking purposes, it is appropriate to exclude campus laboratories from project consideration when comparisons need to be made to national benchmarks. However internal performance comparisons over time to an individual lab's performance improvements are appropriate. As a result, labs were excluded from EB-B pathway since ES 86 is a national benchmark, while labs are eligible to use EB-A (which compares the lab's EUI performance over time) and NC (where the building's EUI percent improvement over code has been independently assessed in detail through LEED certification). The exclusion of labs from the EB-B route may be reviewed again in year five when the performance parameters need to be updated.
- Including a "positive" style test to document the steps taken to achieve the performances, based on LEED's certification system, is credible and goes beyond other VCS performance method approaches.
- LEED Commercial Interior certifications could be included at a later stage but are too few and limited in energy efficiency scope to include at this stage.
- Baselines are well-defined and measurement approaches outlined in EPA Portfolio Manager are appropriate. Variances for many potential drivers are well-accommodated through Portfolio Manager's reporting system which accounts for such potential variances.
- Although EB-B could use the historical baseline for each building, since LEED does not collect this information for its certification system, it is appropriate to use ES 50 as the baseline.
- A one percent energy efficiency improvement factor is not needed as an adjustment for NC or EB-B to the baseline since EPA Portfolio Manager revises the ES 50 baseline each year to reflect current updated practices. It is only needed for EB-A which uses the project's historical baseline (but not needed for eligibility testing since the metric is EUI-based and thus already anchored on a per square foot basis).

The stakeholders consulted compromise the list of individuals acknowledged above in this methodology. Areas of expertise represented in this stakeholder group were as follows:

- Campus sustainability/energy/climate leadership (CSEC), 32 participants
- Campus financial leadership (CF), 30 participants
- Carbon methodology/project development (C), 23 participants
- Energy efficiency best practices (EE), 17 participants
- Business (B), 40 participants
- NGO (NGO), 6 participants
- Government/policy (G), 10 participants

DOCUMENT HISTORY

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Approved VCS Methodology VM0026

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Sectoral Scope 14

Sustainable Grassland Management

Methodology developed by:

Food and Argriculture Organization of the United Nations

Methodology prepared by:

Institute of Environment and Sustainable Development in Agriculture,
Chinese Academy of Agricultural Sciences

UNIQUE forestry and land use

World Agroforestry Center

Northwest Institute of Plateau Biology, Chinese Academy of Sciences

The views expressed in this publication are those of the authors and do not necessarily reflect the views or policies of the Food and Agriculture Organization of the United Nations.

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This methodology was developed by the following contributors:

- Yue Li and Hongmin Dong, Institute of Environment and Sustainable Development and Agriculture, Chinese Academy of Agricultural Sciences
- Timm Tennigkeit, UNIQUE forestry and land use
- Andreas Wilkes, China & East Asia Node, World Agroforestry Center
- Shiping Wang, Northwest Institute of Plateau Biology, Chinese Academy of Sciences
- Benjamin Henderson and Pierre Gerber, Animal Production and Health Division, Food and Agriculture Organization of the United Nations
- Leslie Lipper, Agricultural Development Economics Division, Food and Agriculture Organization of the United Nations
- Neil Bird, Joanneum Research

1 SOURCES

The methodology was developed based on the requirements in the following documents :

- 2006 IPCC Guidelines for National Greenhouse Gas Inventories
- IPCC 2003 Good Practice Guidelines for Land Use, Land Use Change and Forestry
- IPCC 2000 Good Practice Guidance for Uncertainty Management in National Greenhouse Gas Inventories

This methodology uses the latest versions of the follow modules and tools:

- CDM *General Guidelines for Sampling and Surveys for Small-scale CDM Project Activities*
- CDM *Tool for Calculation of the Number of Sample Plots for Measurements within A/R CDM Project Activities*
- CDM *Tool for Estimation of Carbon Stocks and Change in Carbon Stocks of Trees and Shrubs in A/R CDM Project Activities*
- CDM *Tool for Identification of Degraded or Degrading Lands for Consideration in Implementing CDM A/R Project Activities*
- CDM *Tool for Testing Significance of GHG Emissions in A/R CDM Project Activities*
- VCS *AFOLU Non-Permanence Risk Tool*
- VCS methodology module *VMD0033 Estimation of Emissions from Market Leakage*
- VCS methodology module *VMD0040 Leakage from Displacement of Grazing Activity*
- VCS *VT0001 Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality	Project Method
Crediting Baseline	Project Method

The methodology provides procedures to estimate the GHG emissions reductions and removals from the adoption of sustainable grassland management practices, such as improving the rotation of grazing animals between summer and winter pastures, limiting the timing and number of grazing animals on degraded pastures, and restoration of severely degraded land by replanting with perennial grasses and ensuring appropriate management over the long-term.

The methodology quantifies emissions reductions and removals from increases in soil organic carbon (SOC) stocks and reduction of non-CO_2 GHG emissions. Where biogeochemical models can be demonstrated to be applicable in the project region, they may be used in estimation of soil carbon pool changes. Where such models are not applicable, the methodology provides guidance for estimation of SOC pool changes using direct measurement methods. The methodology uses a project method to determine additionality and the crediting baseline.

3 DEFINITIONS

In addition to the definitions set out in VCS document Program Definitions, the following definitions and acronyms apply to this methodology:

3.1 Defined Terms

Baseline Period
A historical reference period over which the project's baseline emissions are calculated, which is representative of the most plausible baseline scenario and consists of five consecutive years occurring before the project start date

Baseline Year b
The year for which baseline emissions for a parameter are calculated as an average of emissions over the baseline period or as a result of sample surveys

Dry Matter (dm)
Biomass that has been dried to an oven-dry state, as defined by IPCC[1]

Grassland Parcel

A spatially discrete area of grassland that is owned and/or managed by a household or land user (and is identified by a unique geodetic polygon). Each household may have several parcels of land which may be categorized under the same land use stratum

Grazing Agent
An individual or organization responsible for decision-making regarding grazing management

Grazing Season
The period of time when a plot of grassland is available for grazing due to natural climatic and plant growth conditions and/or spatial and temporal management decisions of the grassland user[2]

Land Use Change

[1] IPCC, 2003
[2] Grazing plans typically allocate individual plots to be grazed in different seasons, which may be identified differently in different locations (eg, two season systems, three season systems, four season systems) and some grazing plans may identify shorter periods of time when a specific plot is available for grazing.

Conversion of land from one land use category to another. In this methodology, land use change is conversion of grassland to cropland, forest or wetland

Land Use Stratum (Stratum)
A distinct sub-type of land use. When land use is not homogeneous but instead consists of several sub-types which are known (or thought) to vary with reference to the indicator of interest (eg, with-project carbon stock change), then each sub-type may be treated separately as a land use stratum

Significance
A term used to determine whether an increase or decrease in carbon pool or GHG source can, or cannot, be deemed de minimis (ie, amounts to less than five percent of the total GHG emission reductions generated by the project)

Sustainable Grassland Management (SGM)
Activities on land that meets the definition for grassland under the VCS rules and that reduce net GHG emissions by increasing carbon stocks and/or reducing non-CO_2 GHG emissions

3.2 Acronyms

AEZ	Agroecological Zone
AFOLU	Agriculture, Forestry and Other Land Use
ALM	Agricultural Land Management
dm	dry matter
SGM	Sustainable Grassland Management
SOC	Soil Organic Carbon
VCS	Verified Carbon Standard

4 APPLICABILITY CONDITIONS

This methodology applies to Agricultural Land Management (ALM) project activities that introduce sustainable grassland management practices such as improving the rotation of grazing animals between grassland areas, limiting the number of grazing animals on degraded grassland, and restoring severely degraded grasslands by replanting with grasses and ensuring appropriate management over the long-term into a grassland landscape.

This methodology is applicable under the following conditions:

- The project area is grassland at the start of the project. The project area is land that is degraded at the start of the project and degradation will continue in the baseline scenario on the basis that degradation drivers or pressures are still present in the baseline scenario. The procedures outlined the latest version of the CDM *Tool for Identification* *of Degraded or Degrading Lands for Consideration in Implementing CDM A/R Project Activities* must be used to determine both that the land is degraded at the start of the project and that in the baseline scenario the land will continue to degrade.[3]

- The project area is subject to livestock grazing, burning, and/or nitrogen fertilization in the baseline scenario.
- In the baseline scenario, more than 95 percent of animal dung from grazing animals deposited on grassland is allowed to lie as is, and is not managed, and in the project scenario no more than 5 percent of the animal dung from grazing animals within the project area is managed with alternative manure management systems.
- The project area must not have been cleared of native ecosystems within the 10 year period prior to the project start date.
- The project area is located in a region where precipitation is less than evapotranspiration for most of the year and leaching is unlikely to occur.
- If a biogeochemical model is selected for estimation of change in soil carbon stocks, the following conditions must be met:
  - The model must comply with the requirements for models as set out in the VCS rules.
  - The model must be appropriate for the region within which the project is situated. There must be studies by appropriately qualified experts (eg, scientific journals, university theses, local research studies or work carried out by the project proponent) that demonstrate that the use of the selected biogeochemical model is appropriate for the IPCC climatic regions (see *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4, Chapter 3), or the agroecological zone (AEZ) in which the project is situated (see Section 9.3.2).
- Project activities must not include land use change. Note that seeding perennial grasses or legumes on degraded grassland is not considered a land use change activity.
- Project activities must not lead to an increase in the use of fossil fuels and fuel wood from non-renewable sources for cooking and heating.
- Project activities must not occur on wetlands or peatlands.

5 PROJECT BOUNDARY

The geographic project boundary delineates the location of grasslands where the project implements sustainable grassland management. The projectmay be implemented on more than one discrete areas of land. The following must be specified in the project description:

[3] Such procedures were specified in Section II and III of version 1 of the tool which became inactive 3 Oct 2013

- Each discrete area of land must be identified by a unique geodetic polygon that must be recorded in a KML file.
- Aggregation of grassland parcels with multiple landowners is permitted under the methodology, with aggregated areas treated as a single project area.

Table 1 and Table 2 identify the GHG sources, sinks and reservoirs included or excluded from the project boundary.

Where the increases in greenhouse gas emissions from any project emissions or leakage source, and decreases in carbon stocks in carbon pools, is less than five percent of the total net anthropogenic GHG emission reductions and removals due to the project, such sources and pools may be deemed de minimis and may can be ignored (ie, their value may be accounted as zero). The significance of emissions and removals must be tested using the latest version of the CDM *Tool for Testing Significance of GHG Emissions in A/R CDM Project Activities*.

Table 1: Selected Carbon Pools under Baseline and Project

Carbon Pools	Included	Justification / Explanation
Aboveground woody biomass	Yes	SGM may reduce aboveground woody biomass.
Aboveground non-woody biomass	No	The increase of aboveground non-woody biomass resulting from SGM is transient in nature and can be conservatively excluded.
Belowground biomass	Optional	In calculating the baseline net greenhouse gas removals by sinks and/or actual net greenhouse gas removals by sinks, project proponent can choose not to account for below-ground biomass. This is subject to the provision of transparent and verifiable information that the choice will not increase the expected net anthropogenic greenhouse gas removals by sinks.
Dead wood	No	None of the applicable SGM practices decrease dead wood. Thus it can be conservatively excluded.
Litter	No	None of the applicable SGM practices decrease the amount of litter. Thus it can be conservatively excluded.
Soil organic carbon	Yes	A major carbon pool affected by grassland management practices that is expected to increase after adoption of SGM practices.
Wood products	No	None of the applicable SGM practices increases or decreases wood products. Because carbon changes in aboveground woody biomass is considered, it can be conservatively ignored.

Table 2: GHG Sources Included In or Excluded From the Project Boundary

Source		Gas	Included?	Justification/Explanation
Baseline	Use of fertilizers	CO_2	No	Not applicable.
		CH_4	No	Not applicable.
		N_2O	Yes	Main gas for this source. This includes direct and indirect N_2O emissions from synthetic nitrogen fertilizer use. Indirect N_2O emissions from leaching and runoff a can be excluded from the project boundary, following guidance in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 11* given that this methodology is only applicable in regions where annual precipitation is less than or equal to annual potential evapotranspiration.
		Other	No	Not applicable.
	Use of N-fixing species	CO_2	No	Not applicable.
		CH_4	No	Not applicable.
		N_2O	No	N_2O is the main gas for this source, but in the baseline N_2O emissions from this source are conservatively excluded.
		Other	No	Not applicable.
	Burning of biomass	CO_2	No	CO_2 emissions from biomass burning in grassland are not reported since they are largely balanced by the CO_2 that is reincorporated back into biomass via photosynthetic activity, within weeks to a few years after burning.
		CH_4	Yes	Non-CO_2 emissions from the burning of biomass.
		N_2O	Yes	Non-CO_2 emissions from the burning of biomass.
		Other	No	Not applicable.

	Manure deposition on grassland	CO_2	No	CO_2 emissions from biomass decomposition are not reported because net CO_2 emissions from this source are assumed to be zero – the CO_2 photosynthesized by plants is returned to the atmosphere as respired CO_2.
		CH_4	Yes	Significant emission source.
		N_2O	Yes	Main gas for this source.The baseline N_2O emissions from manure management include direct N_2O emissions from manure and urine deposited on grassland soil during the grazing season and indirect N_2O emissions from manure and urine deposited on grassland soil during the grazing season. Indirect N_2O emissions from leaching and runoff can be excluded from the project boundary, following guidance in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 11* given that this methodology is only applicable in regions where annual precipitation is less than or equal to annual potential evapotranspiration.
		Other	No	Not applicable.
	Farming machine	CO_2	Yes	CO_2 emissions from fossil fuels used in farming machinery is the main gas for this source. Where project emissions from this source are larger than baseline emissions, project proponent may choose to account for this source in the baseline or may choose to conservatively exclude baseline emissions from this source.
		CH_4	No	Not main gas for this source. Excluded for simplification.
		N_2O	No	Not main gas for this source. Excluded for simplification.
		Other	No	Not applicable.
	Animal	CO_2	No	CO_2 emissions from animal respiration are

	respiration / Enteric fermentation			not reported because net CO_2 emissions from this source are assumed to be zero – the CO_2 photosynthesized by plants is returned to the atmosphere as respired CO_2.
		CH_4	Yes	Main gas for this source.
		N_2O	No	No N_2O emission from enteric fermentation.
		Other	No	Not applicable.
Project	Use of fertilizers	CO_2	No	Not applicable.
		CH_4	No	Not applicable.
		N_2O	Yes	Main gas for this source. This includes direct and indirect N_2O emissions from synthetic nitrogen fertilizer use. Indirect N_2O emissions from leaching and runoff a can be excluded from the project boundary, following guidance in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 11*, given that this methodology is only applicable in regions where annual precipitation is less than or equal to annual potential evapotranspiration.
		Other	No	Not applicable.
	Use of N-fixing species	CO_2	No	Not applicable.
		CH_4	No	Not applicable.
		N_2O	Yes	Main gas for this source. Where the area cropped with N-fixing species in the project is more than 50 percent larger than the area cropped with N-fixing species in the baseline, the project N_2O emissions from the use of N-fixing species must be calculated.
		Other	No	Not applicable.
	Burning of biomass	CO_2	No	CO_2 emissions from biomass burning in grassland are not reported since they are largely balanced by the CO_2 that is reincorporated back into biomass via photosynthetic activity, within weeks to a

				few years after burning.
		CH_4	Yes	Non-CO_2 emissions from the burning of biomass.
		N_2O	Yes	Non-CO_2 emissions from the burning of biomass.
		Other	No	Not applicable.
	Manure deposition on grassland	CO_2	No	CO_2 emissions from biomass decomposition are not reported since they are largely balanced by the CO_2 that is reincorporated back into biomass via photosynthetic activity, within weeks to a few years after burning.
		CH_4	Yes	Significant emission source.
		N_2O	Yes	Main gas for this source.The project emissions from manure and urine deposited on grassland soil during the grazing season include direct and indirect N_2O emissions from manure and urine deposited on grassland soil during the grazing season. Indirect N_2O emissions from leaching and runoff a can be excluded from the project boundary, following guidance in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 11*, given that this methodology is only applicable in regions where annual precipitation is less than or equal to annual potential evapotranspiration.
		Other	No	Not applicable.
	Farming machine	CO_2	Yes	CO_2 emissions from fossil fuels used in farming machinery is the main gas for this source. Where project emissions from this source are larger than baseline emissions, project proponent must account for this source of project emissions.
		CH_4	No	Not main gas for this source. Excluded for simplification.
		N_2O	No	Not main gas for this source. Excluded for simplification.

		Other	No	Not applicable.
	Animal respiration / Enteric fermentation	CO_2	No	CO_2 emissions from enteric fermentation are not reported since they are largely balanced by the CO_2 that is reincorporated back into biomass via photosynthetic activity, within weeks to a few years after burning.
		CH_4	Yes	Main gas for this source.
		N_2O	No	No N_2O emissions from enteric fermentation.
		Other	No	Not applicable.

6 BASELINE SCENARIO

This methodology uses a project method to determine the baseline scenario. The following steps must be followed to identify the most plausible baseline scenario.

Step 1. Identification of alternative land use scenarios to the proposed SGM project

Sub-step 1a) Identify and list all credible alternative land use scenarios to the proposed SGM project: The project proponent must identify and list all realistic and credible land use scenarios that could have occurred within the project area in the absence of the SGM project. At a minimum, the identified land use scenarios must include:

1) Continuation of current land uses (ie, the land uses immediately prior to initiation of project activities); and

2) Any previous land use practiced within the project area in the ten years prior to initiation of project activities.

All current land uses c must be deemed realistic and credible. The project proponent must refer to the VCS *Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities* for guidance on identification of realistic and credible alternative land uses. The project proponent must justify that each of the identified alternative land uses is realistic and credible on the basis of verifiable information sources, such as documented management records of land users, agricultural statistics reports, published studies of grazing behavior in the project region, results of Participatory Rural Appraisals and other documented stakeholder discussions, and/or surveys conducted by or on behalf of the project proponent prior to the initiation of project activities.

Sub-step 1b) Check the consistency of credible alternative land use scenarios with enforced mandatory applicable laws and regulations: The project proponent must check whether all alternative land use scenarios identified in sub-step 1a) are either:

1) In compliance with all mandatory applicable legal and regulatory requirements, or

2) Where an alternative does not comply with all mandatory applicable legal and regulatory requirements, it must be shown that on the basis of current practice in the region to which the mandatory law or regulation applies that those laws or regulations are not systematically enforced or that non-compliance is widespread.

Where an alternative land use scenario identified does not meet either of these two criteria, the alternative land use scenario must be removed from the list. The resulting revised list is a list of credible alternative land use scenarios that are consistent with enforced mandatory applicable laws and regulations.

Step 2: Select the most plausible baseline scenario.

Sub-step 2a) Barrier analysis: Taking the list of credible alternative land use scenarios resulting from sub-step 1b, a barrier analysis must be conducted to identify realistic and credible barriers that prevent implementation of these land use scenarios following the procedures described in Step 3 of the VCS *Tool for the Demonstration and Assessment of Additionality in VCS AFOLU Project Activities.* The project proponent must indicate which of the alternative land use scenarios would face which identified barrier, and provide verifiable information to support the presence of each particular barrier in relation to each alternative land use scenario.

Sub-step 2b) Eliminate alternative land use scenarios that face a barrier to implementation: All land use scenarios that face a barrier to implementation must be removed from the list.

Sub-step 2c) Select most plausible baseline scenario (if allowed by barrier analysis): Where there is only one alternative land use remaining in the list, this must be selected as the most plausible baseline scenario.

Where there is more than one alternative land use remaining in the list, and one of these alternatives includes continuation of current land use (ie, land use immediately prior to commencement of the project), continuation of current land use must be chosen as the most plausible baseline scenario where the following conditions are met:

1) The grazing agent(s) has not changed in the five years prior to initiation of project activities;
2) The current land uses have not changed in the five years prior to initiation of project activities; and
3) There have been no changes in mandatory applicable legal or regulatory requirements during this five year period and no such changes are currently under legal review by the relevant authorities.

Where there is more than one alternative land use remaining in the list and the most plausible land use has still not been chosen, then proceed to Step 2d.

Step 2d) Assess the profitability of alternative land use scenarios: Taking the list resulting from Step 2b of alternative land use scenarios that face no barriers to implementation, document the costs and revenues associated with each alternative land use and estimate the profitability of each alternative land use. The profitability of alternative land uses must be assessed in terms of the net present value of net incomes over the project crediting period. The key economic parameters and assumptions used in the analysis must be justified in a transparent manner.

Step 2e) Select the most plausible baseline scenario: The most profitable alternative land use among the land uses assessed in Step 2d must be selected as the most plausible baseline scenario.

Where, the most plausible baseline scenario selected conforms to the applicability conditions that pertain to the baseline scenario as specified in Section 4 of this methodology the project will be eligible to apply this methodology.

7 ADDITIONALITY

The project proponent must demonstrate the additionality of the project using the most recent version of the VCS *Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities*. When applying Steps 2, 3 and 4 of that tool, the most plausible baseline scenario identified through application of procedures in Section 6 of this methodology must be assessed together with the project scenario.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

8.1.1 Baseline N_2O emissions due to fertilizer use

Baseline N_2O emissions due to fertilizer use equals baseline direct N_2O emission plus indirect N_2O emission, as described using the following:.

$$BE_{N_2O_{SN},b} = GWP_{N,O} \times (BE_{D,N_2O_{SN},b} + BE_{ID,N_2O_{SN},b}) \quad (1)$$

Where:

$BE_{N_2O_{SN}\,b}$ = Baseline N_2O emissions due to fertilizer use in baseline year b (t CO_2e)

$BE_{D,N_2O_{SN}\,b}$ = Baseline direct N_2O emissions from synthetic nitrogen fertilizer use in baseline year b (t N_2O)

$BE_{ID,N_2O_{SN}\,b}$ = Baseline indirect N_2O emissions from synthetic nitrogen fertilizer use in baseline year b, (t N_2O)

GWP_{N_2O} = Global-warming potential for N_2O (t CO_2e/t N_2O)

1) Baseline direct N_2O emissions from synthetic nitrogen fertilizer use:

Baseline direct N_2O emissions from synthetic fertilizer use in year *b*, $BE_{D,N_2O_{SN},b}$, must be calculated following Chapter 11, Volume 4 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, as described using the following:

$$BE_{D,N_2O_{SN},b} = F_{SN,b} \times EF_{Nfert} \times 44/28 \quad (2)$$

Where:

$BE_{D,N_2O_{SN}\,b}$ = Baseline direct N_2O emissions from synthetic nitrogen fertilizer use in baseline year b (t N_2O)

$F_{SN,b}$	=	Annual amount of synthetic fertilizer N applied to grassland soils in baseline year *b*, adjusted for volatilization as NH_3 and NO_x (t N)
EF_{Nfert}	=	N_2O emission factor for synthetic N fertilizer use (kg N_2O-N/kg N applied)
44/28	=	Conversion of N_2O-N to N_2O

$$F_{SN,b} = \sum_{i=1}^{I} M_{SNi,b} \times NC_{SNi,b} \times (1 - Frac_{GAS,F}) \quad (3)$$

Where:

$F_{SN,b}$	=	Annual amount of synthetic fertilizer N applied to grassland soils in baseline yearb, adjusted for volatilization as NH3 and NOx (t N)
$M_{SNi,b}$	=	Mass of synthetic N fertilizer type *i* applied in baseline year *b* (t fertilizer)
$NC_{SNi,b}$	=	Nitrogen content of synthetic N fertilizer type *i* applied in baseline year *b* (g N/g fertilizer)
$Frac_{GAS,F}$	=	Fraction of synthetic N fertilizer that volatilizes as NH_3 and NO_x (kg N volatilized/kg N applied)
I	=	Index of synthetic N fertilizer types

2) Baseline indirect N_2O emissions from synthetic N fertilizer use:

The N_2O emissions from the atmospheric deposition of N volatilized as NH_3 and NO_x after fertilizer is applied to grassland soils in baseline year b, is calculated using the below equation. Indirect N_2O emissions from leaching and runoff are excluded from the project boundary as described in Section 5:

$$BE_{ID,N_2O_{SN},b} = \sum_{i=1}^{I} (F_{SNi,b} \times Frac_{GAS,F}) \times EF_{4,SN} \times 44/28 \quad (4)$$

Where:

$BE_{ID,N_2O_{SN}\,b}$	=	Baseline indirect N2O emissions from synthetic nitrogen fertilizer use in baseline year b, (t N2O)
$F_{SNi,b}$	=	Annual amount of synthetic N fertilizer type *i* applied to grassland soils in baseline year b, adjusted for volatilization as NH_3 and NOx (t N)
$Frac_{GAS,F}$	=	Fraction of synthetic N fertilizer that volatilizes as NH_3 and NO_x (kg N volatilized/kg N applied)
$EF_{4,SN}$	=	N_2O emission factor for atmospheric deposition of synthetic N on soils and water surfaces (kg N_2O-N/(kg NH_3-N + NO_x-N volatilized)).

8.1.2 Baseline emissions due to the use of N-fixing species

N_2O emissions due to the use of N-fixing species in the baseline are excluded from the project boundary as described in Section 5.

8.1.3 Baseline emissions due to burning of biomass

The baseline emissions due to burning of biomass, $BE_{BB,b}$, include CH_4 emissions from biomass burning plus N_2O emissions from biomass burning in baseline year *b*, as described using the following:

$$BE_{BB,b} = BE_{CH_{4BB},b} + BE_{N_2O_{BB},b} \quad (5)$$

Where:

$BE_{BB,b}$ = Baseline GHG emissions from biomass burning in baseline year *b* (t CO_2e)

$BE_{CH_{4BB},b}$ = Baseline CH_4 emissions from biomass burning in baseline year *b* (t CO_2e)

$BE_{N_2O_{BB},b}$ = Baseline N_2O emissions from biomass burning in baseline year *b* (t CO_2e)

1) CH_4 emissions from biomass burning:

CH_4 emissions from biomass burning in baseline year *b* must be calculated using the following:

$$BE_{CH_{4BB},b} = \frac{A_{B,b} \times M_{B,b} \times C_f \times EF_{CH_4} \times GWP_{CH_4}}{1000} \quad (6)$$

Where:

$BE_{CH_{4BB},b}$ = Baseline CH_4 emissions from biomass burning in baseline year b (t CO_2e)

$A_{B,b}$ = Area burned in baseline year *b* (ha)

$M_{B,b}$ = Aboveground biomass burned in baseline year *b* (t biomass/ha)

C_f = Combustion factor (t dry matter burnt/t biomass)

EF_{CH_4} = CH_4 emission factor for biomass burning (g CH_4/kg dry matter burnt)

GWP_{CH_4} = Global-warming potential for CH_4 (t CO_2e/t CH_4)

2) N_2O emissions from biomass burning:

N_2O emissions from biomass burning in baseline year *b* must be calculated using the following:

$$BE_{N_2O_{BB},b} = \frac{A_{B,b} \times M_{B,b} \times C_f \times EF_{N_2O} \times GWP_{N_2O}}{1000} \quad (7)$$

Where:

$BE_{N_2O_{BB},b}$ = Baseline N_2O emissions from biomass burning in baseline year b (t CO_2e)

$A_{B,b}$ = Area burned in baseline year *b* (ha)

$M_{B,b}$	=	Aboveground biomass burned in baseline year *b* (t biomass/ha)
C_f	=	Combustion factor (t dry matter burnt/t biomass)
EF_{N_2O}	=	N_2O emission factor (g N_2O/kg dry matter burnt)
GWP_{N_2O}	=	Global-warming potential for N_2O (t CO_2e/t N_2O)

8.1.4 Baseline CH_4 emissions due to enteric fermentation

Baseline CH_4 emissions from enteric fermentation must be calculated based on the approach in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, with the addition of a parameter to reflect the proportion of the year that livestock are present inside the project area, as described using the following:

$$BE_{CH_{4EF},b} = \frac{GWP_{CH4} \times \sum_{l=1}^{L} P_{l,b} \times EF_l \times Days_{l,b}}{1000 \times 365} \quad (8)$$

Where:

$BE_{CH_{4EF},b}$	=	Baseline CH_4 emissions from enteric fermentation in baseline year *b* (t CO_2e)
GWP_{CH_4}	=	Global-warming potential for CH_4 (t CO_2e/t CH_4)
$P_{l,B}$	=	Population of grazing livestock type *l*, in baseline year *b* (head)
l	=	Index of livestock type
EF_l	=	Enteric CH_4 emission factor per head of livestock type *l* per year (kg CH_4/(head*year))
$Days_{l,b}$	=	Grazing days inside the project area for each livestock type *l* in baseline year *b* (days)

8.1.5 Baseline N_2O and CH_4 emissions due to manure management

Baseline emissions from manure management include N_2O and CH_4 emissions from manure and urine deposited on grassland soil during the grazing season.

$$BE_{GHG_{MD},b} = BE_{N_2O_{MD},b} + BE_{CH_{4MD},b} \quad (9)$$

Where:

$BE_{GHG_{MD},b}$	=	Baseline GHG emissions from manure management in baseline year *b* (t CO_2e)
$BE_{N_2O_{MD},b}$	=	Baseline N_2O emissions from manure and urine deposited on grassland soil in baseline year *b* (t CO_2e)
$BE_{CH_{4MD},b}$	=	Baseline CH_4 emissions from manure and urine deposited on grassland soil in baseline year *b* (t CO_2e)

1) Baseline N_2O emissions from manure management

Baseline N_2O emissions from manure and urine deposited on grassland soil in baseline year b are the sum of direct and indirect N_2O emissions from manure and urine deposited on grassland soil during the grazing season and is calculated as described using the following:

$$BE_{N_2O_{MD},b} = GWP_{N_2O} \times (BE_{D,N_2O_{MD},b} + BE_{ID,N_2O_{MD},b}) \quad (10)$$

Where:

$BE_{N_2O_{MD},b}$	=	Baseline N_2O emissions from manure and urine deposited on grassland soil in baseline year b (t CO_2e)
GWP_{N_2O}	=	Global-warming potential for N_2O (t CO_2e / t N_2O)
$BE_{D,N_2O_{MD},b}$	=	Direct N_2O emissions from manure and urine deposited on grassland soil during the grazing season in baseline year *b* (t N_2O)
$BE_{ID,N_2O_{MD},b}$	=	Indirect N_2O emissions from manure and urine deposited on grassland soil during the grazing season in baseline year *b* (t N_2O)

2) Baseline direct N_2O emissions from manure and urine deposited on grassland soil:

Baseline direct N_2O emissions from manure and urine deposited on grassland soil must be calculated using the methodology recommended in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, as described in the following equations. Equation 11 calculates direct N_2O emissions from livestock types classified as cattle (dairy, non-dairy and buffalo), poultry and pigs. Equation 12 calculates direct N_2O emissions .from livestock types classified as sheep and other animals. Where both kinds of livestock are present the following equations must be summed.

$$BE_{D,N_2O_{MD},b} = \sum_{l1=1}^{L1} F_{MD,l1,b} \times EF_{3,PRP,CPP} \times 44/28 \quad (11)$$

and/or

$$BE_{D,N_2O_{MD},b} = \sum_{l2=1}^{L2} F_{MD,l2,b} \times EF_{3,PRP,SO} \times 44/28 \quad (12)$$

Where:

$BE_{D,N_2O_{MD},b}$	=	Direct N_2O emissions from manure and urine deposited on grassland soil during the grazing season in baseline year b (t N_2O)
$F_{MD,l1,b}$	=	Annual amount of nitrogen in cattle, poultry and pigs manure and urine deposited on grassland soil during the grazing season in baseline year *b*, adjusted for volatilization as NH_3 and NO_x (t N)
$F_{MD,l2,b}$	=	Annual amount of nitrogen in sheep and other animals manure and urine deposited on grassland soil during the grazing season in baseline year *b*, adjusted for volatilization as NH_3 and NO_x (t N)
$EF_{3,PRP,CPP}$	=	N_2O emission factor for cattle, poultry and pigs manure and urine deposited on grassland soil during the grazing season (kg N_2O-N/kg N input)

$EF_{3,PRP,SO}$	=	N_2O emission factor for sheep and other animals manure and urine deposited on grassland soil during the grazing season (kg N_2O-N/kg N input)
L_1	=	Index of livestock cattle, poultry and pigs
L_2	=	Index of livestock sheep and other animals

$F_{MD,l1,b}$ and $F_{MD,l2,b}$ must be calculated using equation for each livestock type *l*.

$$F_{MD,l,b} = \frac{P_{l,b} \times W_{l,b} \times Nex_l \times H_{l,b} \times Days_{l,b} \times (1 - Frac_{GAS,MD})}{1000_a \times 24 \times 1000_b} \quad (13)$$

Where:

$F_{MD,l,b}$	=	Annual amount of manure and urine deposited on grassland soil from livestock type *l* during the grazing season in baseline year b, adjusted for volatilization as NH_3 and NO_x (t N)
$P_{l,b}$	=	Population of livestock type *l* in baseline year *b* (head)
$W_{l,b}$	=	Average weight of livestock type *l* in baseline year *b* (kg livestock mass/head)
Nex_l	=	Nitrogen excretion of livestock type *l* (kg N deposited/(t livestock mass*day))
1000_a	=	Conversion factor for t livestock mass to kg livestock mass
$H_{l,b}$	=	Average grazing hours per day for livestock type *l* in baseline year *b* (hour)
24	=	Conversion factor for days to hours
$Days_{l,b}$	=	Grazing days for livestock type*l*inside the project area in baseline year *b* (days)
1000_b	=	Conversion factor for tonnes N to kg t N
$Frac_{GAS,MD}$	=	Fraction of volatilization from manure and urine deposited by grazing animals as NH_3 and NO_x (kg N volatilized/kg of N deposited)
L	=	Index of grazing livestock types

3) Baseline indirect N_2O emissions from urine and manure N deposited on grassland soils:

The indirect N_2O emissions from the atmospheric deposition of N volatilized as NH_3 and NO_x after urine and manure N is deposited on grassland soils in baseline year *b,* are calculated using the following equation. Indirect N_2O emissions from urine and manure N deposited on grassland soils excludes N_2O emissions from leaching and runoff in regions.

$$BE_{IDV,N_2O_{MD},b} = \sum_{l=1}^{L} F_{MD,l,b} \times Frac_{GAS,MD} \times EF_{4,MD} \times 44/28 \quad (14)$$

Where:

$BE_{ID,N_2O_{MD},b}$	=	Indirect N_2O emissions from manure and urine deposited on grassland soil during the grazing season in baseline year b (t N_2O)

$F_{MD,l,b}$	=	Annual amount of manure and urine deposited on grassland soil from livestock type *l* during the grazing season in baseline year b, adjusted for volatilization as NH_3 and NO_x (t N)
$Frac_{GAS,MD}$	=	Fraction of volatilization from manure and urine deposited by grazing animals as NH_3 and NO_x (kg N volatilized/kg of N deposited)
$EF_{4,MD}$	=	N_2O emission factor for atmospheric deposition of urine and manure N on soils and water surfaces, (kg N_2O-N/(kg NH_3-N + NO_x-N volatilized))
L	=	Index of grazing livestock types

4) **CH_4 emissions from manure management**:

The Tier 1 approach recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* must be used to calculate CH_4 emissions from manure management, as described using the following:

$$BE_{CH_{4MD},b} = \frac{GWP_{CH4} \times \sum_{l=1}^{L} EF_{lM} \times P_{l,b} \times H_{l,b} \times Days_{l,b}}{24 \times 365 \times 1000} \quad (15)$$

Where:

$BE_{CH_{4MD},b}$	=	Baseline CH_4 emissions from manure and urine deposited on grassland soil in baseline year b (t CO_2e)
GWP_{CH_4}	=	Global warming potential for CH_4 (t CO_2e / t CH_4)
EF_{lM}	=	CH_4 emission factor from manure of livestock type *l* (kg CH_4/(head*year)
$P_{l,b}$	=	Population of grazing livestock type *l*, in baseline year *b*, head
$H_{l,b}$	=	Average grazing hours per day for livestock type *l* in baseline year *b* (hour)
$Days_{l,b}$	=	Grazing days for livestock type *l* inside the project area in baseline year *b* (days)
24	=	Conversion factor for days to hours
365	=	Conversion factor for years to days
1000	=	Conversion factor for t CH4 to kg CH4

8.1.6 Baseline CO_2 emissions due to the use of fossil fuels for grassland management

If project emissions from this source are larger than baseline emissions, the project proponent may choose to account for this source in the baseline or may choose to conservatively ignore baseline emissions from this source. The following is applied to calculate CO_2 emissions from consumption of fossil fuels for SGM in baseline year *b*.

$$BE_{FC,b} = \frac{\sum_{p=1}^{P} \sum_{j=1}^{J} \sum_{k=1}^{K} FC_{p,j,k,b} \times EF_{CO_2,k} \times NCV_k}{1000} \quad (16)$$

Where:

$BE_{FC,b}$	=	Baseline CO_2 emissions from farming machine fossil fuel consumption in baseline year *b* (t CO_2)
$FC_{p,j,k,b}$	=	Fuel consumption by fuel type *k*, by machine type *j* , on parcel grassland *p*, in baseline year *b* (kg fuel/year)
$EF_{CO_2,k}$	=	CO_2 emission factor by fuel type *k* (t CO_2/GJ)
NCV_k	=	Thermal value of fuel type *k* (GJ/t fuel)
1000	=	Conversion factor for tonnes fuel to kg fuel
K	=	Index of fuel type
J	=	Index of machine type
P	=	Index of grassland parcel

8.1.7 Baseline emission removals from existing woody perennials

Where the project proponent includes above and below ground woody biomass pools as a selected carbon pool, baseline removals from existing woody perennials ($BRWP_b$) are calculated using the latest version of the CDM A/R tool for *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*. Where the project proponent chooses not to include above and below ground woody biomass pools, baseline removals, $BRWP_b$, are assumed to be zero.

The carbon gain-loss approach must be applied to estimation of baseline removals from existing woody perennials.

Baseline removals by existing woody perennials in baseline year *b* ($BRWP_b$) must be calculated using the following:

$$BRWP_b = \sum_{j=1}^{J} \Delta C_{BG,j} - \Delta C_{BL,j} \quad (17)$$

Where:

$BWRP_b$	=	Baseline removals from existing woody perennials in baseline year *b* (t CO_2)
$\Delta C_{BG,j}$	=	Average annual increase in carbon stocks of existing woody biomass for species *j*, under the baseline scenario (t CO_2)
$\Delta C_{BL,j}$	=	Average annual loss of carbon stocks of existing woody biomass for species *j*, under the baseline scenario (t CO_2)
J	=	Index of species

As noted under the assumptions used in developing this methodological tool, no explicit accounting of the term representing stock losses, $\Delta C_{BL,j}$, is included in this tool. That is, $\Delta C_{BG,j}$ is assumed to be a measure of net growth increment and thus to implicitly accounts for $\Delta C_{BL,j}$.

The average annual increase in carbon stocks in existing live woody biomass for each species must be calculated using the following:

$$\Delta C_{BG,j} = \sum_{s=1}^{S} A_{B,j,s} \times G_{B,j,s} \times CF_j \times \frac{44}{12} \quad (18)$$

Where:

$\Delta C_{BG,j}$	=	Average annual increase in carbon stocks of existing woody biomass for species *j*, under the baseline scenario (t CO_2)
$A_{B,j,s}$	=	Area of species *j* in stratum s under the baseline scenario (ha)
$G_{B,j,s}$	=	Average annual increase in existing woody biomass of species *j* in stratum *s*, under the baseline scenario (t dm/(ha)
CF_j	=	Carbon fraction for species *j* (t C/t dm)
S	=	Index of stratum
44/12	=	Ratio of molecular weights of CO_2 and C

The average annual increase in existing live woody biomass stocks for each species in a vegetation class in a stratum must be calculated from:

$$G_{B,j,s} = G_{AB,B,j,s}(1 + R_j) \quad (19)$$

Where:

$G_{B,j,s}$	=	Average annual increase in existing woody biomass of species *j* in stratum *s*, under the baseline scenario (t dm/ha)
$G_{AB,B,j,s}$	=	Average annual increase in existing above-ground woody biomass of species *j* in stratum *s* (t dm aboveground biomass/ha)
R_j	=	Root to shoot ratio of species *j* (t dm belowground biomass/t dm aboveground biomass)

Since below ground biomass is an optional carbon pool (Table 1), the term $(1 + R_j)$ may be removed from the above equation if this carbon pool is not included in the project boundary.

8.1.8 Baseline emission removals due to changes in soil organic carbon

Since the applicability conditions limit the project to land that is degraded and is continuing to degrade, it can be conservatively assumed that the changes in SOC in the baseline scenario is zero. Therefore:

$$BRS = 0 \quad (20)$$

Where:

BRS	=	Baseline removals due to changes in SOC under the baseline scenario (t CO_2e)

8.1.9 Baseline emissions and removals

The emissions and removals in baseline year *b* are given by:

$$BE_b = BE_{N_2O_{SN},b} + BE_{BB,b} + BE_{CH_{4EF},b} + BE_{GHG_{MD},b} + BE_{FC,b} - BRWP_b \quad (21)$$

Where:

BE_b	=	Baseline emissions and removals in year *b* (t CO_2e)
$BE_{N_2O_{SN}\,b}$	=	Baseline N_2O emissions due to fertilizer use in baseline year b (t CO_2e)
$BE_{BB,b}$	=	Baseline GHG emissions from biomass burning in baseline year *b* (t CO_2e)
$BE_{CH_{4EF},b}$	=	Baseline CH_4 emissions from enteric fermentation in baseline year *b* (t CO_2e)
$BE_{GHG_{MD},b}$	=	Baseline GHG emissions from manure management in baseline year *b* (t CO_2e)
$BE_{FC,b}$	=	Baseline CO_2 emissions from farming machine fossil fuel consumption in baseline year *b*, (t CO_2)
$BWRP_b$	=	Baseline removals from existing woody perennials in baseline year *b* (t CO_2)

8.2 Project Emissions

8.2.1 Project N_2O emissions due to fertilizer use

Project N_2O emissions due to fertilizer use equals the sum of project direct and indirect N_2O emissions, as described using the following:

$$PE_{N_2O_{SN},t} = GWP_{N_2O} \times (PE_{D,N_2O_{SN},t} + PE_{ID,N_2O_{SN},t}) \quad (22)$$

Where:

$PE_{N_2O_{SN},t}$	=	Project N_2O emissions due to fertilizer use in year *t* (t CO_2e)
$PE_{D,N_2O_{SN},t}$	=	Project direct N_2O emissions from synthetic nitrogen fertilizer use in year *t* (t N_2O)
$PE_{ID,N_2O_{SN},t}$	=	Project indirect N_2O emissions from synthetic nitrogen fertilizer use in year *t* (t N_2O)
GWP_{N_2O}	=	Global-warming potential of N_2O

1) Project direct N_2O emissions from synthetic nitrogen fertilizer use:

Project direct N_2O emissions from synthetic fertilizer use is calculated using IPCC methodology recommended in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, as described using the following:

$$PE_{D,N_2O_{SN},t} = F_{SN,t} \times EF_{Nfert} \times 44/28 \quad (23)$$

Where:

$PE_{D,N_2O_{SN},t}$	=	Project direct N_2O emissions from synthetic nitrogen fertilizer use in year *t* (t N_2O)
$F_{SN,t}$	=	Annual amount of synthetic fertilizer N applied to grassland soils in year *t*, adjusted for volatilization as NH_3 and NO_x (t N)
EF_{Nfert}	=	N_2O emission factor for synthetic N fertilizer use (kg N_2O-N/kg N applied)
44/28	=	Conversion of N_2O-N to N_2O

$$F_{SN,t} = \sum_{i=1}^{I} M_{SNi,t} \times NC_{SNi,p} \times (1 - Frac_{GAS,F}) \qquad (24)$$

Where:

$F_{SNi,t}$	=	Annual amount of synthetic fertilizer N applied to grassland soils in year t, adjusted for volatilization as NH_3 and NO_x (t N)
$M_{SNi,t}$	=	Mass of synthetic N fertilizer type *i* applied in year *t* (t fertilizer)
$NC_{SNi,p}$	=	Nitrogen content of synthetic N fertilizer type *i* applied (g-N/g fertilizer)
$Frac_{GAS,F}$	=	Fraction of synthetic N fertilizer that volatilizes as NH_3 and NO_x (kg N volatilized/kg of N applied)
I	=	Index of synthetic N fertilizer types

2) Project indirect N_2O emissions from the synthetic N fertilizer use:

The N_2O emissions from the atmospheric deposition of N volatilized as NH_3 and NO_x after fertilizer is applied to grassland soils under the project scenario in year t, is calculated using the below equation. Indirect N_2O emissions from leaching and runoff are excluded from the project boundary as described in Section 5.

$$PE_{ID,N_2O_{SN},t} = \sum_{i=1}^{I} (F_{SNi,t} \times Frac_{GAS,F}) \times EF_{4,SN} \times 44/28 \qquad (25)$$

Where:

$PE_{ID,N_2O_{SN},t}$	=	Project indirect N_2O emissions from synthetic nitrogen fertilizer use in year t (t N_2O)
$F_{SNi,t}$	=	Annual amount of synthetic fertilizer N applied to grassland soils in year t, adjusted for volatilization as NH3 and NOx (t N)
$Frac_{GAS,F}$	=	Fraction of synthetic N fertilizer that volatilizes as NH_3 and NO_x (kg N volatilized/kg of N applied)
$EF_{4,SN}$	=	N_2O emission factor for atmospheric deposition of synthetic N on soils and water surfaces (kg N_2O-N/(kg NH_3-N + NO_x-N volatilized)$^{-1}$)
I	=	Index of synthetic N fertilizer types

8.2.2 Project emissions due to the use of N-fixing species

Project emissions from N-fixing species must only be accounted for. if the area cropped with N-fixing species in the project is more than 50 percent larger than the area cropped with N-fixing species in the baseline.

The project emissions from the use of N-fixing species, $PE_{N_2O_{NF},t}$, must be calculated using the following equations:

$$PE_{N_2O_{NF},t} = F_{CR,t} \times EF_{Nfix} \times 44/28 \times GWP_{N_2O} \quad (26)$$

Where:

$PE_{N_2O_{NF},t}$	=	Project N_2O emissions as a result of N-fixing species within the project area in year *t* (t CO_2e)
$F_{CR,t}$	=	Amount of N in N-fixing species (above and below ground) and from forage/pasture renewal, returned to soils under project in year *t* (t N)
EF_{Nfix}	=	Emission factor for N_2O emissions from N inputs of N-fixing species to grassland soil (kg N_2O-N/kg N input)
GWP_{N_2O}	=	Global-warming potential for N_2O (t CO_2/t N_2O)

$$F_{CR,t} = \sum_{g=1}^{G} Area_{g,t} \times Crop_{g,t} \times N_{content,g} \quad (27)$$

Where:

$F_{CR,t}$	=	Amount of N in N-fixing species (above and below ground) and from forage/pasture renewal, returned to soils under project in year t (t N)
$Area_{g,t}$	=	Annual area of N-fixing species *g* in year *t* (ha)
$Crop_{g,t}$	=	Annual dry matter, including aboveground and below ground, returned to grassland soils for N-fixing species *g* under project in year *t* (t dm/ha)
$N_{content,g}$	=	Fraction of N in dry matter for N-fixing species *g* (t N/t dm)
G	=	Index of N-fixing species

8.2.3 Project emissions due to burning of biomass

The project GHG emissions equals CH_4 emissions from biomass burning plus N_2O emissions from biomass burning under the project, as described using the following:

$$PE_{GHG_{BB,t}} = PE_{CH_{4BB},t} + PE_{N_2O_{BB},t} \quad (28)$$

Where:

$PE_{GHG_{BB,t}}$	=	Project GHG emissions from biomass burning in year *t* (t CO_2e)
$PE_{CH_{4BB},t}$	=	Project CH_4 emissions from biomass burning in year *t* (t CO_2e)
$PE_{N_2O_{BB},t}$	=	Project N_2O emissions from biomass burning in year *t* (t CO_2e)

1) CH_4 emissions from biomass burning under project:

CH_4 emissions from biomass burning must be calculated using the following:

$$PE_{CH_{4BB},t} = \frac{A_{B,t} \times M_{B,t} \times C_f \times EF_{CH_4} \times GWP_{CH_4}}{1{,}000} \quad (29)$$

Where:

$PE_{CH_{4BB},t}$	=	Project CH_4 emissions from biomass burning in year *t* (t CO_2e)
$A_{B,t}$	=	Area burned under project in year *t* (ha)
$M_{B,t}$	=	Aboveground biomass burned, excluding litter and dead wood under project in year *t* (t biomass/ha)
C_f	=	Combustion factor (t dry matter burnt/t biomass)
EF_{CH_4}	=	CH_4 emission factor for biomass burning (g CH_4/kg dry matter burnt)
GWP_{CH_4}	=	Global-warming potential for CH_4 (t CO_2e/t CH_4)

2) N_2O emissions from biomass burning under project:

N_2O emissions from biomass burning must be calculated using the following:

$$PE_{N_2O_{BB},t} = \frac{A_{B,t} \times M_{B,t} \times C_f \times EF_{N_2O} \times GWP_{N_2O}}{1{,}000} \quad (30)$$

Where:

$PE_{N_2O_{BB},t}$	=	Project N_2O emissions from biomass burning in year *t* (t CO_2e)
$A_{B,t}$	=	Area burned under project in year *t* (ha)
$M_{B,t}$	=	Aboveground biomass burned, excluding litter and dead wood under project in year *t* (t biomass/ha)
C_f	=	Combustion factor (t dry matter burnt/t biomass)
EF_{N_2O}	=	N_2O emission factor (g N_2O/kg dry matter burnt)
GWP_{N_2O}	=	Global-warming potential for N_2O (t CO_2e/t N_2O)

8.2.4 Project CH_4 emissions due to enteric fermentation

Project CH_4 emissions from enteric fermentation are calculated based on an IPCC methodology recommended in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, with the addition of a parameter to reflect the proportion of the year that livestock are present inside the project area, as described using the following:

$$PE_{CH_{4EF},t} = \frac{GWP_{CH_4} \times \sum_{l=1}^{L} P_{l,t} \times EF_l \times Days_{l,t}}{1000 \times 365} \quad (31)$$

Where:

$PE_{CH_{4EF},t}$	=	Project CH_4 emissions from enteric fermentation in year *t* (t CO_2e)
GWP_{CH_4}	=	Global-warming potential for CH_4 (t CO_2e/t CH_4)
$P_{l,t}$	=	Population of grazing livestock type *l* in year *t* under project (head)
L	=	Index of livestock type
EF_l	=	Enteric CH_4 emission factor per head of livestock type *l* per year (kg CH_4 head*year)
$Days_{l,t}$	=	Grazing days inside the project area for each livestock type *l* in the project year *t* (days)
1000	=	Conversion factor for t CH_4 to kg t CH_4
365	=	Conversion factor for years to days

8.2.5 Project N_2O and CH_4 emissions due to manure management

The project emissions from manure management include N_2O and CH_4 emissions from manure and urine deposited on grassland soil during the grazing season.

$$PE_{GHG_{MD},t} = PE_{N_2O_{MD},t} + PE_{CH_{4MD},t} \quad (32)$$

Where:

$PE_{GHG_{MD},t}$	=	Project GHG emissions from manure management in year *t* (t CO_2e)
$PE_{N_2O_{MD},t}$	=	Project N_2O emissions from manure and urine deposited on grassland soil in year *t* (t CO_2e)
$PE_{CH_{4MD},t}$	=	Project CH_4 emissions from manure and urine deposited on grassland soil in year *t* (t CO_2e)

1) Project N_2O emissions from manure management

The project emissions from manure and urine deposited on grassland soil during the grazing season include direct and indirect N_2O emissions from manure and urine deposited on grassland soil during the grazing season. Project N_2O emissions from manure and urine deposited on grassland soil are calculated as described in the following:

$$PE_{N_2O_{MD},t} = GWP_{N_2O} \times (PE_{D,N_2O_{MD},t} + PE_{ID,N_2O_{MD},t}) \quad (33)$$

Where:

$PE_{N_2O_{MD},t}$	=	Project N_2O emissions from manure and urine deposited on grassland soil in year *t* (t CO_2e)
GWP_{N_2O}	=	Global warming potential for N_2O (t CO_2e/t N_2O)
$PE_{D,N_2O_{MD},t}$	=	Project direct N_2O emissions from manure and urine deposited on grassland soil during the grazing season in year *t* (t N_2O)

$PE_{ID,N_2O_{MD},t}$	=	Project indirect N_2O emissions from manure and urine deposited on grassland soil during the grazing season in year *t* (t N_2O)

2) Project direct N_2O emissions from manure and urine deposited on grassland soil

Project direct N_2O emissions from manure and urine deposited on grassland soil are calculated using IPCC methodology recommended by *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, as described using the following Equations 34 and 45. Equation 34 calculates direct N_2O emissions from livestock types classified as cattle (dairy, non-dairy and buffalo), poultry and pigs and Equation 35 calculates direct N_2O emissions from livestock types classified as sheep and other animals. Note that where both kinds of livestock are present the following equations must be summed.

$$PE_{D,N_2O_{MD},t} = \sum_{l1=1}^{L1} F_{MD,l1,t} \times EF_{3,PRP,CPP} \times 44/28 \quad (34)$$

and/or

$$PE_{D,N_2O_{MD},t} = \sum_{l2=1}^{L2} F_{MD,l2,t} \times EF_{3,PRP,SO} \times 44/28 \quad (35)$$

Where:

$PE_{D,N_2O_{MD},t}$	=	Project direct N_2O emissions from manure and urine deposited on grassland soil during the grazing season in year t (t N_2O)
$F_{MD,l1,t}$	=	Annual amount of nitrogen in cattle, poultry and pigs manure and urine deposited on grassland soil during the grazing season in year *t*, adjusted for volatilization as NH_3 and NO_x (t N)
$F_{MD,l2,t}$	=	Annual amount of nitrogen in sheep and other animals manure and urine deposited on grassland soil during the grazing season in year *t*, adjusted for volatilization as NH_3 and NO_x (t N)
$EF_{3,PRP,CPP}$	=	N_2O emission factor for cattle, poultry and pigs manure and urine deposited on grassland soil during the grazing season (kg N_2O-N/kg N input)
$EF_{3,PRP,SO}$	=	N_2O emission factor for sheep and other animals manure and urine deposited on grassland soil during the grazing season (kg N_2O-N/kg N input)
L_1	=	Index of livestock cattle, poultry and pigs
L_2	=	Index of livestock sheep and other animals

$F_{MD,l1,t}$ and $F_{MD,l2,t}$ must be calculated using the following equation for livestock type *l*.

$$F_{MD,l,t} = \frac{P_{l,t} \times W_{l,p} \times Nex_l \times H_{l,t} \times Days_{l,t} \times (1 - Frac_{GAS,MD})}{1000_a \times 24 \times 1000_b} \quad (36)$$

Where:

$F_{MD,l,t}$	=	Annual amount of manure and urine deposited on grassland soil from livestock type l during the grazing season in year *t*, adjusted for volatilization

as NH_3 and NO_x (t N)

$P_{l,t}$	=	Population of grazing livestock type*l*in year *t* (head)
$W_{l,p}$	=	Average weight of livestock/under project (kg livestock mass/head)
Nex_l	=	Nitrogen excretion of livestock typ *l* (kg N deposited /(t livestock mass*day))
1000_a	=	Conversion factor for t livestock mass to kg livestock mass
$H_{l,t}$	=	Average grazing hours per day during grazing season in year *t* (hours)
24	=	Conversion factor for days to hours
$Days_{l,t}$	=	Grazing days for livestock type *l* inside the project area in year t (days)
1000_b	=	Conversion factor for t N to kg N
$Frac_{GAS,MD}$	=	Fraction of volatilization from manure and urine deposited by grazing animals as NH_3 and NO_x (kg N volatilized/kg of N deposited)
L	=	Index of grazing livestock types

3) Project indirect N_2O emissions from urine and manure N deposited on grassland soils

Indirect N_2O emissions from rine and manure N deposited on grassland soils excludes N_2O emissions from leaching and runoff in regions as set out in Section 5.

Indirect N_2O emissions from the atmospheric deposition of N volatilized as NH_3 and NO_x after urine and manure N is deposited on grassland soils under the project in year t, are calculated using the following:

$$PE_{ID,N_2O_{MD},t} = \sum_{l=1}^{L} F_{MD,l,t} \times Frac_{GAS,MD} \times EF_{4,MD} \times 44/28 \qquad (37)$$

Where:

$PE_{ID,N_2O_{MD},t}$	=	Project indirect N_2O emissions from manure and urine deposited on grassland soil during the grazing season in year t (t N_2O)
$F_{MD,l,t}$	=	Annual amount of manure and urine deposited on grassland soil from livestock type l during the grazing season in year *t*, adjusted for volatilization as NH_3 and NO_x (t N)
$Frac_{GAS,MD}$	=	Fraction of volatilization from manure and urine deposited by grazing animals as NH_3 and NO_x (kg N volatilized/kg of N deposited)
$EF_{4,MD}$	=	N_2O emission factor for atmospheric deposition of urine and manure N on soils and water surfaces, (kg N_2O-N/(kg NH_3-N + NO_x-N volatilized))

4) CH_4 emissions from manure management

Project CH_4 emissions from manure management must be calculated using the Tier 1 approach, recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, as described using the following:

$$PE_{CH_{4MD},t} = \frac{GWP_{CH4} \times \sum_{l=1}^{L} EF_{lM} \times P_{l,t} \times H_{l,t} \times Days_{l,t}}{1000 \times 365 \times 24} \quad (38)$$

Where:

$PE_{CH_{4MD},t}$	=	Project CH_4 emissions from manure and urine deposited on grassland soil in year t (t CO_2e)
$P_{l,t}$	=	Population of livestock type *l* in year *t* (head)
EF_{lM}	=	CH_4 emission factor from manure of of livestock type *l* (kg CH_4/(head*year))
$H_{l,t}$	=	Average grazing hours per day during grazing season in year *t* (hours)
$Days_{l,t}$	=	Grazing days for livestock type *l* inside the project area in year t (days)
1000	=	Conversion factor for t CH_4 to kg CH_4
365	=	Conversion factor for years to days
24	=	Conversion factor for days to hours

8.2.6 Project CO_2 emissions due to the use of fossil fuels

If project emissions from this source are larger than baseline emissions, the project proponent must account for this source of project emissions. The following equation is applied to calculate CO_2 emissions from consumption of fossil fuels for management practices implemented as part of the project.

$$PE_{FC,t} = \frac{\sum_{p=1}^{P}\sum_{j=1}^{J}\sum_{k=1}^{K} FC_{p,j,k,t} \times EF_{CO2,k} \times NCV_k}{1000} \quad (39)$$

Where:

$PE_{FC,t}$	=	Project CO_2 emissions from farming machine fossil fuel consumption in year *t* (t CO_2)
$FC_{p,j,k,t}$	=	Fuel consumption by fuel type *k*, by machine type *j*, on grassland parcel *p*, in year *t* (kg fuel/year)
$EF_{CO_2,k}$	=	CO_2 emission factor by fuel type *k* (t CO_2/GJ).
NCV_k	=	Thermal value of fuel type *k* (GJ/t fuel)
1000	=	Conversion factor for tonnes fuel to kg fuel
K	=	Index of fuel type
J	=	Index of machine type
P	=	Index of grassland parcel

8.2.7 Project removals from woody perennials

Where the project proponent chooses to include the aboveground woody biomass pool, project removals from woody perennials ($PRWP_t$) is calculated using CDM A/R tool for *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*. Where the project proponent chooses not to include the aboveground woody biomass pool, with-project removals, $PRWP_t$, are assumed to be zero.

The carbon gain-loss approach must be applied to estimation of the project removals from woody perennials. Project removals from woody perennials must be calculated using the following:

$$PRWP_t = \sum_{j=1}^{J} \Delta C_{PG,j,t} - \Delta C_{PL,j,t} \qquad (40)$$

Where:

$PRWP_t$	=	Project average net change in carbon stocks of existing woody biomass in year *t* (t CO_2)
$\Delta C_{PG,j,t}$	=	Project average increase in carbon stocks of existing woody biomass for species *j*, in year *t* (t CO_2)
$\Delta C_{PL,j,t}$	=	Project average loss in carbon stocks of existing woody biomass for species *j*, in year *t* (t CO_2)
J	=	Index of species

As noted under the assumptions used in developing this methodology, no explicit accounting of the term representing stock losses, $\Delta C_{PL,j,t}$, is included in this methodology. That is, $\Delta C_{PG,j,t}$ is assumed to be a measure of net growth increment and thus to implicitly account for $\Delta C_{PL,j,t}$.

The average increase in carbon stocks in existing live woody biomass for each species must be calculated using the following:

$$\Delta C_{PG,j,t} = \sum_{s=1}^{S} A_{P,j,s,t} \times G_{P,j,s,t} \times CF_j \times 44/12 \qquad (41)$$

Where:

$\Delta C_{PG,j,t}$	=	Project average increase in carbon stocks of existing woody biomass for species *j*, for year *t* (t CO_2)
$A_{P,j,s,t}$	=	Area of species *j* in stratum *s* under project in year *t* (ha)
$G_{P,j,s,t}$	=	Project average increase in existing woody biomass for species *j* in grassland management stratum *s* in year *t* (t dm/ha)
CF_j	=	Carbon fraction for species *j* (t C/t dm)
S	=	Index of stratum
44/12	=	Ratio of molecular weights of CO_2 and C

The average annual increase in existing live woody biomass stocks for each species in a vegetation class in a stratum must be calculated using the following:

$$G_{P,j,s,t} = G_{AB,P,j,s,t}(1+R_j) \qquad (42)$$

Where:

$G_{P,j,s,t}$	=	Project average increase in existing woody biomass for species *j* in grassland management stratum *s* in year *t* (t dm/ha)
$G_{AB,P,j,s,t}$	=	Project average increase in existing above-ground woody biomass for species *j* in grassland management stratum *s*, in year *t* (t dm/ha)
R_j	=	Root to shoot ratio of species *j* (t dm belowground biomass/t dm aboveground biomass)

Since below ground biomass is an optional carbon pool (see Table 1), the term (1 + R_j) may be removed from the above, Equation 42, if this carbon pool is not included in the project boundary.

8.2.8 Project removals due to changes in soil organic carbon

Soil carbon is a major pool affected by changes in grassland management practices. In this methodology, proponents may either make direct measurements of SOC, or use a modeling approach. If there are peer-reviewed studies (eg, scientific journals, university theses, or work carried out by the project proponent) that demonstrates that the use of the selected model is valid for the project region, the model can be applied for estimating of carbon stock changes (Option 1 below). Otherwise, direct measurement of carbon stocks will be carried out (Option 2 below).

Option 1: Estimate of project removals due to changes in SOC using a validated model

Using a biogeochemical model that has been accepted in peer-reviewed scientific publications and validated for the project region (eg, CENTURY soil organic matter model[4]) estimate SOC stocks at equilibrium ($SOC_{m_G,s,Equil}$) and the time to reach the equilibrium ($D_{m_G,s}$) under each of the identified management practices of stratum s. The details of each management practice that are recorded will depend on the choice of the soil model selected and the type of activity being promoted.

If $D_{m_G,s}$ is longer than the length of the project crediting period, it means that the SOC will not reach equilibrium during the project implementation. The annual changes of SOC stock ($\Delta SOC_{m_G,s}$) and project removals due to changes in SOC (PR_t) in year t must be calculated using the following:

$$\Delta SOC_{m_G,s} = \frac{SOC_{m_G,s,Equil} - SOC_{s,Baseline}}{D_{m_G,s}} \qquad (43)$$

4 Parton et. al., 1987

Where:

$\Delta SOC_{m_G,s}$	=	Annual changes of SOC stock under management practice m_G in stratum *s* (t C/(ha * year)
$SOC_{m_G,s,Equil}$	=	Estimated SOC stocks in the top 30 cm of soil layer (or greater depth if required) at equilibrium, under management practice m_G in stratum *s* (t C/ha)
$SOC_{s,Baseline}$	=	Baseline SOC stock in the top 30 cm of soil layer (or greater depth if required) in stratum *s* (t C/ha)
$D_{m_G,s}$	=	The time to reach equilibrium under management practice m_G in stratum *s* (years)

The annual project removals due to changes in SOC in year *t* must be calculated using area-weighted average values of model input parameters for each management practice identified.

$$PR_t = \sum_{m_G} \sum_{s} PA_{m_G,s,t} \bullet \Delta SOC_{m_G,s} \times \frac{44}{12} \qquad (44)$$

Where:

PR_t	=	Project removals due to changes in SOC in year *t* (t CO_2e)
$PA_{m_G,s,t}$	=	Project areas with management practice m_G in stratum s in year *t* (ha)
$\Delta SOC_{m_G,s}$	=	Average annual changes of SOC stock under management practice m_G in stratum s (t C/(ha*year))
S	=	Index of stratum
m_G	=	Index for grassland management types

If $D_{m_G,s}$ is shorter than the length of the project crediting period, it means that the SOC will reach equilibrium during project implementation. The annual change in SOC occurring between the project start date and the time where SOC stocks reach equilibrium, $\Delta SOC_{m_G,s}$ can be calculated using Equation 43 and 44. For the period from the SOC stock reached equilibrium to the end of the project crediting period, $\Delta SOC_{m_G,s}$ and PR_t must be set to zero.

The applicability of the selected model and parameters recorded for the various activities, soil and climate types are dependent on the actual project. Since these are project specific and not methodology specific, they should be discussed in detail in the project document. However, data used to parameterize the selected model must be based on measurements of soil properties including bulk density and organic carbon concentrations to the full depth of affected soil layers, or a minimum depth of 30 cm where the full depth of affected soil layers is not known in advance.The required procedures for the sampling and measurement of these soil properties are outlined in Option 2 immediately below.

Option 2: Estimate of project removals due to changes in SOC using a measurement approach

For measuring soil organic carbon stock changes, soil sampling must follow a scientifically established method (eg, methods described in Carter and Gregoroch, 2006), or a nationally-approved standard (eg, the soil sampling protocol used to certify the changes of organic carbon stock in mineral soil of the European Union[5]). The frequency of SOC monitoring must be at least once every five years. Handling, storage, processing, measurement, and quality control of soil samples must follow scientifically established procedures such as the procedures described in Carter and Gregoroch, 2006, OECD, 1998, or nationally approved standards. Procedures should ensure that the presence of carbonates is adequately accounted for. Soil properties including bulk density and organic carbon concentration must be measured to the full depth of affected soil layers, or a minimum depth of 30 cm where the full depth of affected soil layers is not known in advance.

The below Equation 45 is used to calculate the SOC stock in stratum s, sampling site *i*, under project in year *t*. Sampling procedures should be designed such that the statistical significance of soil carbon stock changes between the baseline carbon stock and the carbon stock in time *t* can be determined with a 95 percent confidence interval. The *General Guidelines for Sampling and Surveys for Small-Scale CDM Project Activities* should be followed to determine the sampling procedure and sample size.

$$P_{SOC_{m_G,s,i,t}} = SOC_{m_G,s,i,t} \times BD_{m_G,s,i,t} \times Depth \times (1 - FC_{m_G,s,i,t}) \times 0.1 \quad (45)$$

Where:

$P_{SOC_{m_G,s,i,t}}$	=	SOC stock in the top 30 cm (or greater depth if required) of soil for management practice m_G, stratum *s*, sampling site *i* under project in year *t* (t C/ha)
$SOC_{m_G,s,i,t}$	=	SOC content in the top 30 cm of soil (or greater depth if required) for management practice m_G, stratum s, sampling site *i*, under project in year *t* (g C/kg soil)
$BD_{m_G,s,i,t}$	=	Soil bulk density in the top 30 cm of soil (or greater depth if required) for management practice m_G, stratum *s*, sampling site *i*, under project in year *t* (g soil/cm^3)
$Depth$	=	Top soil depth, for calculating grassland SOC stock in the top 30 cm of soil (or greater depth if required) (cm)
$FC_{m_G,s,i,t}$	=	Percentage of rocks larger than 2mm, roots, and other dead residues with a diameter in the top 30 cm of soil (or greater depth if required), for management practice m_G, stratum *s*, sampling site *i* under project in year *t* (percent)
0.1	=	Conversion factor for SOC to t C/ha
m_G	=	Index of management practice

[5] Stolbovoy et al., 2007

s	=	Index of stratum
i	=	Index of sampling site

Among the laboratory methods available to determination of TC and OC in soils, the total combustion method described in Nelson and Sommers (1996) is the most widely accepted and is therefore recommended for this purpose.

Calculate average carbon stock of all monitored sites in management practice m_G, stratum s, under project using the following:

$$P_{SOC_{m_G,s,t}} = \frac{\sum_{i=1}^{I} P_{SOC_{m_G,s,i,t}}}{I} \quad (46)$$

Where:

$P_{SOC_{m_G,s,t}}$	=	Average carbon stock in stratum *s* under project (t C/ha)
$P_{SOC_{m_G,s,i,t}}$	=	SOC stock in the top 30 cm (or greater depth if required) of soil for management practice m_G, stratum *s*, sampling site *i* under project in year *t* (t C/ha)
I	=	Monitored sites in stratum *s*, under project

The following is used to calculate the difference between the carbon stock for management practice m_G under project in year *t,* and the carbon stock under the baseline scenario, for all strata.

$$P_{m_G,t} = \sum_{s=1}^{S} (P_{SOC_{m_G,s,t}} - SOC_{s,Baseline}) \times PA_{m_G,s,t}) \quad (47)$$

Where:

$P_{m_G,t}$	=	Difference in the carbon stock between the project in year *t* and the baseline scenario (t C)
$PA_{m_G,s,t}$	=	Project areas with management practice m_G in stratum *s* in year *t* (ha)
$P_{SOC_{m_G,s,t}}$	=	Average carbon stock in stratum *s* under project in year *t* (t C / ha)
$SOC_{s,Baseline}$	=	Baseline SOC stock of stratum *s*, in the top 30 cm soil layer (or greater depth if required) (t C / ha)
S	=	Strata under project
s	=	Index of stratum

The following is applied to calculate average carbon stock of all management practice, under project in year *t*.

$$P_t = \sum_{m_G=1}^{M} P_{mG,t} \quad (48)$$

Where:

P_t	=	Carbon stock under project in year t (t C)
$P_{m_G,t}$	=	Difference in the carbon stock between the project in year *t* and the baseline scenario (t C)
M	=	Number of management practice

For the first monitoring of SOC stock, the annual project removals due to changes in SOC stock in year t must be calculated using the following:

.

$$PR_t = \frac{(P_t)}{n} \bullet \frac{44}{12} \quad (49)$$

Where:

PR_t	=	Project removals due to changes in SOC in year *t* (t CO_2e)
P_t	=	Carbon stock under project in year t (t C)
n	=	Number of years from the project start date to year t (years)

For the second and subsequent monitoring of SOC stock, the annual project removals due to changes in SOC stock in year t must be calculated using the following:

$$PR_t = \frac{(P_t - P_{t-f})}{f} \bullet \frac{44}{12} \quad (50)$$

Where:

PR_t	=	Project removals due to changes in SOC in year *t* (t CO_2e)
P_t	=	Carbon stock under project in year *t* (t C)
P_{t-f}	=	Carbon stock under project in year *t-f* (t C)
f	=	SOC monitoring frequency (years)

8.2.9 Uncertainty analysis

The methodology requires that all parameters used to estimate emissions and removals are conservative. Where conservative estimates are used that are based on verifiable literature sources or expert judgment, for the purposes of calculating uncertainty, it is not required to estimate a confidence interval for the parameter and uncertainty may be considered to be zero. Guidance on conservativeness of default parameters is given in the CDM EB *Guidelines on*

Conservative Choice and Application of Default Data in Estimation of the Net Anthropogenic GHG Removals by Sinks. Where parameter values are derived from sample surveys undertaken within the project area, and the sample size is large (ie, >30), a conservative estimate of baseline carbon sequestration by carbon pools or project emissions by GHG sources is given by adopting a value that represents the upper bound of the 95 percent confidence interval (ie, sample mean + 1.96 × standard error), while a conservative estimate of baseline emissions by GHG sources or carbon sequestration by carbon pools in the project scenario is given by adopting a value that represents the lower bound of the 95 percent confidence interval (ie, sample mean - 1.96 × standard error).[6]

Where Option 1 (use of a validated SOC model) is adopted to estimate changes in soil carbon stocks, quantification of uncertainty is required, and deductions for uncertainty must be applied following the procedures set out in this section. In addition to ex post deductions for uncertainty, the project proponent should also plan to diminish uncertainty in the process of planning data collection. The project proponent should refer to CDM EB approved *General Guidelines For Sampling And Surveys For Small-Scale CDM Project Activities* with a view to reducing uncertainty of model input parameters. The generation of model parameters follows the standard procedures on surveys and quality assurance in the collection and organization of data.

The project proponent must estimate the uncertainty of agricultural input parameters to the soil organic model selected. The project area should be stratified, and the sampling effort should represent the relevant strata in the sample frame. Where there is no specific survey guidance from national institutions, the project proponent must use a precision of 15 percent at the 95 percent confidence level as the criteria for reliability of sampling efforts. This reliability specification must be applied to determine the sampling requirements for assessing parameter values. The sampling intensity could be increased to ensure that the model parameters estimated from SGM lead to the achievement of a precision of ±15 at the 95 percent confidence level for the estimate of greenhouse gas emission reductions from the project. The project proponent should calculate the soil model response using the model input parameters with the upper and lower confidence levels. The range of model responses demonstrates the uncertainty of the soil modeling.

Step 1: Calculate the values for all input parameters at the upper and lower confidence limit.

Calculate the mean, X_p and standard deviation, ∂_p for all parameters measured in SGM, then the standard error in the mean is given by:

[6] This approach assumes a large sample size and a normal distribution. Where sample size is small, and/or where the assumption of a normal distribution is not appropriate, alternative methods to derive a conservative estimate may be adopted following the guidance provided in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories,* Vol. 1, Chapter 3.

$$SE_p = \frac{\partial_p}{\sqrt{n_p}} \quad (51)$$

Where:

SE_p	=	Standard error in the mean of parameter, *p* in year *t*
∂_p	=	Standard deviation of the parameter p in year *t*
n_p	=	Number of samples used to calculate the mean and standard deviation of parameter *p*

Assuming that values of the parameter are normally distributed about the mean, the minimum and maximum values for the parameters are given in the following:

$$P_{\min} = \overline{X_p} - 1.96 * SE_p$$
$$P_{\max} = \overline{X}_p + 1.96 * SE_p \quad (52)$$

Where:

$P_{\min}$	=	Minimum value of the parameter at the 95 percent confidence interval
$P_{\max}$	=	Maximum value of the parameter at the 95 percent confidence interval
SE_p	=	Standard error in the mean of parameter, *p* in year *t*
1.96	=	Value of the cumulative normal distribution at 95 percent confidence interval

Step 2: Calculate the project removals due to changes in soil organic carbon with the minimum and maximum values of the input parameters

The project removals due to changes in soil organic carbon using the minimum and maximum values of the parameters is given bin the following:

$$PR_{\min,t} = Model(P_{\min}, Temperature_{\max}, \Pr ecipitation_{\max}, ClayContent_{\min})$$
$$PR_{\max,t} = Model(P_{\max}, Temperature_{\min}, \Pr ecipitation_{\min}, ClayContent_{\max}) \quad (53)$$

Where:

$PR_{\min,t}$	=	Minimum value of project removals due to changes in soil organic carbon at the 95 percent confidence interval in year *t*
$PR_{\max,t}$	=	Maximum value of project removals due to changes in soil organic carbon at the 95 percent confidence interval in year *t*

Step 3: Calculate the uncertainty in the model output

The uncertainty in the output model must be calculated as described in the following:

$$UNC_t = \frac{\left|PR_{\max,t} - PR_{\min,t}\right|}{2 * PR_t} \quad (54)$$

Step 4: Adjust the estimate of soil sequestration based on the uncertainty in the model output

If the uncertainty of soil models is less than or equal to 15 percent of the mean value then the project proponent may use the estimated value without any deduction for conservativeness or increase in sampling.

If the uncertainty of soil models is greater than 15 percent but less than or equal to 30 percent of the mean value, then the project proponent may use the estimated value subject to a deduction calculated as described in the following:

$$PR_{Deduction,t} = PR_t * (UNC_t - 15\%) \quad (55)$$

And the following term will be used for calculation of net GHG emission reductions in Equation 60 in place of PR_t:

$$PR_{Adj,t} = PR_t - PR_{Deduction,t} \quad (56)$$

Where:

PR_t	=	Estimate of project removals due to changes in soil organic carbon in year *t* (t CO_2e)
PR_{Unc}	=	Estimate of uncertainty in the mean of changes in soil organic carbon in year *t* (t CO_2e)
$PR_{Deduction,t}$	=	Calculated deduction to the estimate of the change in soil organic removals year *t* (t CO_2e)
$PR_{Adj,t}$	=	Adjusted estimate of project removals due to changes in soil organic carbon in year *t* (t CO_2e)

In this way, when the uncertainty is 15 percent or less than 15 percent there is no deduction and when the uncertainty is between 15 and 30 percent a deduction as calculated in Step 4 above will apply.

If the uncertainty of soil models is greater than 30 percent of the mean value then the project proponent should increase the sample size of the input parameters until the soil model uncertainty is better than ± 30 percent.

8.2.10 Project net GHG emissions by sources and removals by sinks

The net GHG emissions and removals by sinks in project year *t* are given by:

$$PE_t = PE_{N_2O_{SN},t} + PE_{N_2O_{NF},t} + PE_{GHG_{BB},t} + PE_{CH_{4EF},t} + PE_{GHG_{MD},t} + PE_{FC,t} - PRWP_t - PR_t \quad (57)$$

Where:

PE_t	=	Project net GHG emissions by sources and removals by sinks in year *t* (t CO_2e)
$PE_{N_2O_{SN},t}$	=	Project N_2O emissions due to fertilizer use in year t (t CO_2e)
$PE_{N_2O_{NF},t}$	=	Project N_2O emissions as a result of N-fixing species within the project area in year *t* (t CO_2e)
$PE_{GHG_{BB,t}}$	=	Project GHG emissions from biomass burning in year *t* (t CO_2e)
$PE_{CH_{4EF},t}$	=	Project CH_4 emissions from enteric fermentation in year *t* (t CO_2e)
$PE_{GHG_{MD},t}$	=	Project GHG emissions from manure management in year *t* (t CO_2e)
$PE_{FC,t}$	=	Project CO_2 emissions from farming machine fossil fuel consumption in year *t* (t CO_2)
$PRWP_t$	=	Project average net change in carbon stocks of existing woody biomass in year *t* (t CO_2)
PR_t	=	Project removals due to changes in SOC in year *t* (t CO_2e)

8.3 Leakage Emissions

Under this methodology, project activities must not involve increase in use of fossil fuels or fuel wood and must not include significanlty different manure management practices. Therefore the only potential sources of leakage in this methodology are the following:

1) Market leakage due to reduction in the production of livestock products within the project boundary;
2) Displacement of grazing beyond the project boundary.

Market leakage must be assessed and quantified using VCS Module *VMD0033 Estimation of Emissions from Market Leakage*. The result of applying the module is estimation of the parameter $LE_{M,t}$. Leakage from displacement of grazing activities to outside the project boundary must be assessed and quantified using VCS module *VMD0040 Leakage from Displacement of Grazing Activities*. The result of applying that module is estimation of the parameter $LE_{GD,t}$. Leakage emissions must be calculated as:

$$LE_t = LE_{M,t} + LE_{GD,t} \quad (58)$$

Where:

LE_t	=	Leakage emissions in year *t* (t CO_2e)
$LE_{M,t}$	=	Leakage emissions due to market leakage in year *t* (t CO_2e)
$LE_{GD,t}$	=	Leakage emissions due to grazing displacement in year *t* (t CO_2e)

8.4 Summary of GHG Emission Reduction and/or Removals

The amount of emission reductions achieved by the project in project year *t* must be calculated using the following Equation 59. Where relevant, emission reductions must be adjusted for uncertainty, as described in Section 8.2.9.

$$ER_t = BE_b - PE_t - LE_t \tag{59}$$

Where:

ER_t	=	Emission reductions in year *t* (t CO_2e)
BE_b	=	Baseline emissions and removals in year *b* (t CO_2e)
PE_t	=	Project emissions and removals in year *t* (t CO_2e)
LE_t	=	Leakage emissions in year *t* (t CO_2e)

The amount of emission reductions that can be issued as credits during the monitoring period must be calculated using the Eqauation 60. The emissions reductions generated during the monitoring period should be summed from the first year of the monitoring period, t_f, to the final year of the monitoring period, t_m.

AFOLU buffer credits must be deposited into the AFOLU pooled buffer account when the project requests issuance of VCUs, in accordance with the procedures in the VCS document *Registration and Issuance Process*. AFOLU buffer credits must be deducted from the total emission reducitons achieved to determine the total number of emission reductions elibile to be issued as VCUs, as calculated in the following:

$$VCU_t = ER_t - BC_t \tag{60}$$

Where:

VCU_t	=	Emission reductions eligible to be issued as VCUs in year *t* (t CO_2e)
ER_t	=	Emission reductions in year *t* (t CO_2e)
BC_{tm}	=	AFOLU buffer credits in year *tm* (t CO_2e)

The amount of AFOLU buffer credits that must be depositied into the AFOLU pooled buffer account must be calculated by multiplying the non-permanence risk rating by the change in carbon stocks in a given monitoring period. The non-permanence risk rating must be determined using the VCS *AFOLU Non-Permanence Risk Tool*. The amount of AFOLU buffer credits required for the monitoring period can be determined for the first monitoring period using Equation 61 or subsequent monitoring periods using Equation 62.

$$BC_t = RR_t * (PRWP_t + PR_t - BRWP_b) \tag{61}$$

or

$$BC_t = RR_t * (PRWP_t + PR_t - PRWP_{tp} - PR_{tp}) \quad (62)$$

Where:

BC_{tm}	=	AFOLU buffer credits in year *tm* (t CO_2e)
RR_t	=	Non-permanence risk rating in year *t* (percent)
$PRWP_t$	=	Project average net change in carbon stocks of existing woody biomass for species *j*, in year *t* (t CO_2)
PR_t	=	Project removals due to changes in SOC in year *t* (t CO_2e)
$BWRP_b$	=	Baseline removals from existing woody perennials in baseline year *b* (t CO_2)
$PRWP_{tp}$	=	Project average net change in carbon stocks of existing woody biomass at the end of the previous monitoring period *tp* (t CO_2)
PR_{tp}	=	Project removals due to changes in SOC at the end of the previous monitoring period *tp* (t CO_2e)

9 MONITORING

The purpose of the monitoring plan is to define a series of monitoring tasks to be conducted in order to ensure that the GHG emissions reductions claimed by the proposed project are real, additional and measurable. Subject to the specific requirements and guidance below, procedures specified in monitoring plans should meet the requirements of the most recent version of the *VCS Standard* and other VCS rules, and be consistent with guidance in internationally accepted guidance documents such as Volume 4 (Agriculture, Forestry and Other Land Use (AFOLU)) of the *2006 IPCC Guidelines on National Greenhouse Gas Inventories*.

Where sampling is conducted, procedures must attain a precision of 15 percent at the 95 percent confidence level.

Monitoring plans must include procedures for managing data quality that are consistent with internationally accepted guidance documents such as IPCC (2003) Chapter 5, or IPCC (2000) Chapter 8.

9.1 Data and Parameters Available at Validation

Data/Parameter	GWP_{N_2O}
Data unit	t CO_2e/t N_2O
Description	Global-warming potential for N_2O
Equations	1, 7, 10, 21, 26, 30 and 33

Source of data	GWP_{N_2O} must be obtained from the IPCC Second Assessment Report
Value applied	310
Justification of the choice of data or description of measurement methods and procedures applied	
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comments	

Data / Parameter	EF_{Nfert}
Data unit	kg N_2O-N/kg N applied
Description	N_2O emission factor for synthetic N fertilizer use
Equations	2 and 23
Source of data	Peer-reviewed scientific studies or default values from *IPCC Guidelines for National Greenhouse Gas Inventories*
Value applied	Project-specific value or IPCC default value
Justification of the choice of data or description of measurement methods and procedures applied	Where detailed emission factors from peer-reviewed scientific studies, specific to the project area or country, taking into account specific environmental, climatic and soil management conditions, are available, such data must be applied. Where detailed emission factors are unavailable, the default Tier 1 N_2O emission factor recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Table 11.1, Chapter 11, Volume 4) or the most recent version of IPCC good practice guidance for AFOLU, must be followedAFOLU, must be followed.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comments	

Data Unit / Parameter	EF_{Nfix}
Data unit	kg N_2O-N/kg N input
Description	N_2O emission factor for N from N-fixing species

Equations	26
Source of data	Peer-reviewed scientific studies or default values from I*PCC Guidelines for National Greenhouse Gas Inventorie*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where detailed emission factors from peer-reviewed scientific studies, specific to the project area or country, taking into account specific environmental, climatic and soil management conditions, are available, such data must be applied. Where detailed emission factors are unavailable, the default Tier 1 N2O emission factor recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Table 11.1, Chapter 11, Volume 4) or the most recent version of IPCC good practice guidance for AFOLU, must be followed.
Purpose of data	Calculation of project emissions
Comment	

Data Unit / Parameter	EF_{Nfix}
Data unit	kg N_2O-N/kg N input
Description	N_2O emission factor for N from N-fixing species
Equations	26
Source of data	Peer-reviewed scientific studies or default values from I*PCC Guidelines for National Greenhouse Gas Inventorie*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where detailed emission factors from peer-reviewed scientific studies, specific to the project area or country, taking into account specific environmental, climatic and soil management conditions, are available, such data must be applied. Where detailed emission factors are unavailable, the default Tier 1 N2O emission factor recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Table 11.1, Chapter 11, Volume 4) or the most recent version of IPCC good practice guidance for AFOLU, must be followed.
Purpose of data	Calculation of project emissions
Comment	

Data Unit / Parameter	$M_{SNi,b}$
Data unit	t fertilizer
Description	Mass of synthetic N fertilizer type i applied in baseline year *b*

Equations	3
Source of data	Documented management records or sample surveys
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	The mass of synthetic N fertilizer must be based on documented management records of all synthetic N fertilizer types applied during the baseline period. Documented management records may include fertilizer application records or fertilizer purchase records. For new management entities or where such records are unavailable, a conservative estimate of the mass of synthetic N fertilizer applied per ha must be provided based on a sample survey conducted in the project area provide a conservative estimate of baseline N fertilizer application over the baseline period. Where data from sample surveys are used, a conservative estimate must be made following the guidance in Section 8.2.9. The total mass of synthetic N fertilizer applied must be estimated by multiplying the mass of synthetic N fertilizer applied per ha by the total grassland area involved in the project.
Purpose of data	Calculation of baseline emissions
Comment	

Data Unit / Parameter	$NC_{SNi,b}$
Data unit	g N/g fertilizer
Description	Nitrogen content of synthetic N fertilizer type i applied in baseline year *b*
Equations	3
Source of data	Manufacturer product label or other manufacturer data
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	The nitrogen content must be recorded for each synthetic N fertilizer type i that has been applied in the baseline scenario. The value must be obtained from the product description stated by the manufacturer on the product label.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	$Frac_{GAS,F}$

Data unit	kg N volatilized/kg N applied
Description	Fraction of synthetic N fertilizer that volatilizes as NH_3 and NO_x
Equations	3, 4, 24 and 25
Source of data	Peer reviewed scientific studies or default values from *IPCC Guidelines for National Greenhouse Gas Inventories*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where detailed data from peer-reviewed scientific studies, specific to the project area or country are available, such data must be applied. Where detailed data are unavailable, the default value recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Table 11.3, Chapter 11, Volume 4) or the most recent version of IPCC good practice guidance for AFOLU, must be followed.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	$EF_{4,SN}$
Data unit	kg N2O-N/(kg NH_3-N + NOx-N volatilized)
Description	N_2O emission factor for atmospheric deposition of synthetic N on soils and water surfaces
Equations	4 and 25
Source of data	Peer reviewed scientific studies or default values from *IPCC Guidelines for National Greenhouse Gas Inventories*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where detailed data from peer-reviewed scientific studies, specific to the project area or country are available, such data must be applied. Where detailed data are unavailable, the default value recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Table 11.3, Chapter 11, Volume 4) or the most recent version of IPCC good practice guidance for AFOLU, must be followed.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	$EF_{4,MD}$
Data unit	kg N_2O-N/(kg NH_3-N + NOx-N volatilized)
Description	N_2O emission factor for atmospheric deposition of urine and manure N on soils and water surfaces
Equations	14 and 37
Source of data	Peer reviewed scientific studies or default values from *IPCC Guidelines for National Greenhouse Gas Inventories*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where detailed data from peer-reviewed scientific studies, specific to the project area or country are available, such data must be applied. Where detailed data are unavailable, the default value recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Table 11.3, Chapter 11, Volume 4) or the most recent version of IPCC good practice guidance for AFOLU, must be followed.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	$A_{B,b}$
Data unit	Ha
Description	Area burned in baseline year *b*
Equations	6 and 7
Source of data	Documented management records or sample surveys
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Area burned in each year during the baseline period must be based on documented fire management records averaged over the five year period prior to the project start date. For new management entities or where such records are unavailable, a conservative estimate of the area burned during the baseline period must be provided based on a sample survey conducted in the project area. The sample survey must provide a conservative estimate of the area burned in each year during the baseline period. Where sample survey data are used, a conservative estimate of the area burned must be made following the guidance in Section 8.2.9. The annual area burned must be equal to the percentage area burned times the total grassland area involved in the

	project.
Purpose of data	Calculation of baseline emissions
Comment	

Data Unit / Parameter	$M_{B,b}$
Data unit	t biomass dm/ha
Description	Aboveground biomass in terms of dry matter burned in baseline year *b*
Equations	6 and 7
Source of data	Documented management records or sample surveys
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Aboveground biomass burned under baseline must be based on documented fire management records averaged over the baseline period. For new management entities or where such records are unavailable, aboveground biomass burned under the baseline scenario must be conservatively estimated based on sample surveys conducted before the project start date. Where sample survey data are used, the mean aboveground biomass burned under the baseline scenario must be converted to a conservative estimate following the guidance on conservative parameter estimates presented in Section 8.2.9.
Purpose of data	Calculation of baseline emissions
Comment	

Data Unit / Parameter	C_f
Data unit	t dry matter burnt/t biomass
Description	Combustion factor
Equations	6, 7, 29 and 30
Source of data	Peer reviewed scientific studies or default values from *IPCC Guidelines for National Greenhouse Gas Inventories*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where detailed data from peer-reviewed scientific studies, specific to the project area or country are available, such data must be applied. Where detailed data are unavailable, the default value recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Table 2.6, Chapter 2, Volume 4)

	or the most recent version of IPCC good practice guidance for AFOLU, must be followed.peer-reviewed.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	EF_{CH_4}
Data unit	g CH_4/kg dry matter burnt
Description	CH_4 emission factor for biomass burning
Equations	6 and 29
Source of data	Peer reviewed scientific studies or default values from *IPCC Guidelines for National Greenhouse Gas Inventories*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where detailed data from peer-reviewed scientific studies, specific to the project area or country are available, such data must be applied. Where detailed data are unavailable, the default value recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Table 2.6, Chapter 2, Volume 4) or the most recent version of IPCC good practice guidance for AFOLU, must be followed.peer-reviewed.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	GWP_{CH_4}
Data unit	t CO_2e/t CH_4
Description	Global-warming potential for CH_4
Equations	6, 8, 15, 29 and 31
Source of data	GWP_{CH_4} must be obtained from the IPCC Second Assessment Report
Value applied	21
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data	Calculation of baseline emissions

	Calculation of project emissions
Comment	

Data Unit / Parameter	$P_{l,b}$
Data unit	Head
Description	Population of grazing livestock type l, in baseline year *b*
Equations	8, 13 and 15
Source of data	Documented management records or sample surveys
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Population of grazing livestock must be based on documented management records, averaged over the baseline period. For new management entities or where such records are unavailable, a conservative estimate of the animal population must be provided based on a sample survey of the animal population grazing in the project area year prior to the project start dateduring the baseline period. The design of the sample survey must consider the annual livestock population during the baseline period, which may not be the same as the population present at the time of the survey. Where data from sample surveys are used, a conservative estimate of the baseline livestock population must be made following the guidance on using conservative parameter estimates derived from sample surveys, presented in Section 8.2.9.
Purpose of data	Calculation of baseline emissions
Comment	

Data Unit / Parameter	EF_l
Data unit	kg CH_4/(head * year)
Description	Enteric CH_4 emission factor per head of livestock type l per year
Equations	8 and 31
Source of data	Peer reviewed scientific studies or default values from *IPCC Guidelines for National Greenhouse Gas Inventories*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where detailed data from peer-reviewed scientific studies, specific to the project area or country are available, such data must be applied. Where detailed data are unavailable, the default value

	recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Table 10.10 or 10.11, Chapter 10, Volume 4) or the most recent version of IPCC good practice guidance for AFOLU, must be followed. When data from IPCC sources are used, the project proponentmust refer to the tables in Annex 10A.1 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* to ensure that the value selected reflects the underlying animal characteristics appropriate to the selected value.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	$EF_{3,PRP,CPP}$
Data unit	kg N_2O-N/kg N input
Description	N_2O emission factor for cattle (dairy, non-dairy and buffalo), poultry and pigs manure and urine deposited on of applied to grassland
Equations	11 and 34
Source of data	Peer reviewed scientific studies or default values from *IPCC Guidelines for National Greenhouse Gas Inventories*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where detailed data from peer-reviewed scientific studies, specific to the project area or country are available, such data must be applied. Where detailed data are unavailable, the default value recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Table 10.10 or 10.11, Chapter 10, Volume 4) or the most recent version of IPCC good practice guidance for AFOLU, must be followed. When data from IPCC sources are used, the project proponent must refer to the tables in Annex 10A.1 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* to ensure that the value selected reflects the underlying animal characteristics appropriate to the selected value.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	$EF_{3,PRP,SO}$
Data unit	kg N_2O-N/kg N input
Description	N_2O emission factor for sheep and other animals manure and urine deposited on of applied to grassland
Equations	12 and 35
Source of data	Peer reviewed scientific studies or default values from *IPCC Guidelines for National Greenhouse Gas Inventories*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where detailed data from peer-reviewed scientific studies, specific to the project area or country are available, such data must be applied. Where detailed data are unavailable, the default value recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Table 10.10 or 10.11, Chapter 10, Volume 4) or the most recent version of IPCC good practice guidance for AFOLU, must be followed. When data from IPCC sources are used, the project proponentmust refer to the tables in Annex 10A.1 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* to ensure that the value selected reflects the underlying animal characteristics appropriate to the selected value.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	Nex_l
Data unit	kg N deposited/(t livestock mass * day)
Description	Nitrogen excretion of livestock type *l*
Equations	13 and 36
Source of data	Peer reviewed scientific studies or default values from *IPCC Guidelines for National Greenhouse Gas Inventories*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where detailed data from peer-reviewed scientific studies, specific to the project area or country are available, such data must be applied. Where detailed data are unavailable, the default value recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Table 10.10 or 10.11, Chapter 10, Volume 4) or the most recent version of IPCC good practice

	guidance for AFOLU, must be followed. When data from IPCC sources are used, the project proponentmust refer to the tables in Annex 10A.1 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* to ensure that the value selected reflects the underlying animal characteristics appropriate to the selected value.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	$W_{l,b}$
Data unit	Kg
Description	Average weight of livestock *l*, in baseline year *b*
Equations	
Source of data	Peer reviewed scientific literature or expert judgment.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Data from the peer-reviewed scientific literature or expert judgement that are specific to the project area.
Purpose of data	Calculation of baseline emissions
Comment	

Data Unit / Parameter	$W_{l,p}$
Data unit	Kg
Description	Average weight of livestock under project
Equations	
Source of data	Peer reviewed scientific literature or expert judgment.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Data from the peer-reviewed scientific literature or expert judgment that are specific to the project area. To ensure that the estimated N2O emission reductions from manure and urine deposited on grassland soil are conservative, the value selected for the average weight of livestock l under project ($W_{l,p}$) must be greater than the average weight of livestock l, in baseline year b ($W_{l,p}$). Moreover, the project proponent must justify why the values selected for these parameters results in emission reductions that are conservative.

Purpose of data	Calculation of project emissions
Comment	

Data Unit / Parameter	$Days_{l,b}$
Data unit	Days
Description	Grazing days for livestock type *l* in baseline year *b*
Equations	8, 13 and 15
Source of data	Documented management records or sample surveys
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Grazing days inside the project area in the baseline must be based on documented management records, averaged over the baseline period. For new management entities or where such records are unavailable, grazing days must be based on the average annual grazing days from a sample survey of livestock grazing in the project area in the year prior to the project start date. Where data from sample surveys are used, a conservative estimate must be made to enable conservative estimates of livestock enteric fermentation and manure management emissions.
Purpose of data	Calculation of baseline emissions
Comment	

Data Unit / Parameter	$H_{l,b}$
Data unit	Hours
Description	Average grazing hours for livestock type *l* per day during the grazing season in baseline year *b*
Equations	13 and 15
Source of data	Documented management records or sample surveys
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	The average grazing hours per day in the baseline must be based on documented management records, averaged over the baseline period. For new management entities or where such records are unavailable, a conservative estimate of average grazing hours must be provided based on the average grazing hours in each grazing season taken from a sample survey of livestock grazing

	in the project area in the year prior to the project start date. Where data from sample surveys are used, a conservative estimate must be made to enable a conservative estimate of livestock manure management emissions.
Purpose of data	Calculation of baseline emissions
Comment	

Data Unit / Parameter	$Frac_{GAS,MD}$
Data unit	kg N volatilized/kg of N deposited
Description	Fraction of volatilization from manure and urine deposited by grazing animals as NH_3 and NO_x
Equations	13, 14, 36 and 37
Source of data	Peer reviewed scientific studies or default values from I*PCC Guidelines for National Greenhouse Gas Inventoriespeer-reviewed*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where detailed data from peer-reviewed scientific studies, specific to the project area or country are available, such data must be applied. Where detailed data are unavailable, the default value recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Table 10.10 or 10.11, Chapter 10, Volume 4) or the most recent version of IPCC good practice guidance for AFOLU, must be followed.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	EF_{lM}
Data unit	kg CH_4/(head * year)
Description	CH_4 emission factor from manure of livestock type *l*
Equations	15 and 38

Source of data	Peer reviewed scientific studies or default values from *IPCC Guidelines for National Greenhouse Gas Inventories*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where detailed data from peer-reviewed scientific studies, specific to the project area or country are available, such data must be applied. Where detailed data are unavailable, the default value recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Table 10.10 or 10.11, Chapter 10, Volume 4) or the most recent version of IPCC good practice guidance for AFOLU, must be followed.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	$FC_{p,j,k,B}$
Data unit	kg fuel/year
Description	Fuel consumption by type *k*, machine type *j*, parcel grassland *p*, in baseline
Equations	16
Source of data	Peer reviewed scientific studies or default values from *IPCC Guidelines for National Greenhouse Gas Inventories*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Documented management records or sample surveys. Fuel consumption for grassland management under the baseline scenario must be estimated on the basis of management records , such as fuel consumption logs, averaged over the baseline period. For new management entities or where such records are unavailable, a conservative estimate of fuel consumption must be provided based on a sample survey conducted in the project area regarding fuel consumption during the baseline period. Where data from sample surveys are used, a conservative estimate must be made following the guidance in Section 8.2.9. A sample survey mean may be converted to a conservative estimate by subtracting 1.96 × the standard error from the mean.
Purpose of data	Calculation of baseline emissions
Comment	

Data Unit / Parameter	$EF_{CO_2,k}$
Data unit	t CO_2/GJ
Description	CO_2 emission factor by fuel type *k*
Equations	16 and 39
Source of data	Peer reviewed scientific studies or default values from *IPCC Guidelines for National Greenhouse Gas Inventories*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where detailed emissions factors from peer-reviewed scientific studies, specific to the country are available, such data must be applied. Where detailed data are unavailable, the default value recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* or the most recent version of IPCC good practice guidance for AFOLU, must be followed.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	NCV_k
Data unit	GJ/t fuel
Description	Thermal value of fuel type *k*
Equations	16 and 39
Source of data	Peer reviewed scientific studies or default values from *IPCC Guidelines for National Greenhouse Gas Inventories*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where detailed emissions factors from peer-reviewed scientific studies, specific to the country are available, such data must be applied. Where detailed data are unavailable, the default value recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* or the most recent version of IPCC good practice guidance for AFOLU, must be followed.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	$A_{B,j,s}$
Data unit	Ha
Description	Area of trees and shrubs under baseline, for species j in stratum *s*
Equations	18
Source of data	Documented management records or sample surveys
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Area of trees and shrubs under the baseline scenario must be obtained from a field survey before the project start date.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	CF_j
Data unit	t C/t dm
Description	Carbon fraction for species *j*
Equations	18 and 41
Source of data	Default values in the CDM A/R Methodological Tool for *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*
Value applied	0.50 for tree species; 0.49 for shrub species.
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	R_j
Data unit	t dm belowground biomass/t dm aboveground biomass
Description	Root to shoot ratio of species *j*
Equations	19 and 42

Source of data	Default values in the CDM A/R Methodological Tool for *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities.*
Value applied	0.26 for tree species; 0.4 for shrub species
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	$G_{AB,B,j,s}$
Data unit	t dm/ha
Description	Average annual increase in existing aboveground woody biomass of species *j* in stratum *s*, under baseline.
Equations	19
Source of data	Use one of the methods for the estimation of carbon stocks and change in carbon stocks in trees and shrubs in the baseline outlined in the latest version of the CDM tool for *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*. Follow the measurement, sampling, modeling and default estimation procedures specified in this tool.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data	Calculation of baseline emissions
Comment	

Data Unit / Parameter	$SOC_{s,Baseline}$
Data unit	t C/ha
Description	Baseline SOC stock in the top 30 cm of soil layer (or greater depth if required) in stratum *s*
Equations	43

Source of data	Results from biogeochemical model or project measurements
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where Option 1, outlined in Section 8.2.8, is applied to estimate project removals due to changes in SOC, the project proponent must use the biogeochemical model selected under Option 1 to conservatively determine $SOC_{s,Baseline}$, by setting the value of this parameter to the computed maximum carbon stocks that occurred in the designated project area and stratum within the previous 10 years. Where Option 2 is applied to estimate project removals due to changes in SOC, the project proponent must follow the procedures for the sampling and measurement of soil properties, including bulk density and organic carbon concentrations, that are outlined in Option 2 in Section 8.2.8to determine the value of $SOC_{s,Baseline}$, less than two years prior to the project start time. The General Guidelines for Sampling and Surveys for Small-Scale CDM Project Activities should be followed to determine the sampling procedures and the sample size.
Purpose of data	Calculation of project emissions
Comment	

Data Unit / Parameter	$SOC_{m_G,s,Equil}$
Data unit	t C/ha
Description	SOC stocks, in the top 30 cm of soil layer (or greater depth if required), at equilibrium for grassland with management practice of m_G in stratum *s*.
Equations	43
Source of data	Results from biogeochemical model
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	SOC stocks at equilibrium for each management practice and stratum must be obtained from the results of the biogeochemical model.
Purpose of data	Calculation of project emissions
Comment	

Data Unit / Parameter	EF_{N_2O}
Data unit	g N_2O/kg dry matter burnt
Description	N_2O emission factor for biomass burning
Equations	7 and 30
Source of data	Peer reviewed scientific studies or default values from *IPCC Guidelines for National Greenhouse Gas Inventories*
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where detailed data from peer-reviewed scientific studies, specific to the project area or country are available, such data must be applied. Where detailed data are unavailable, the default value recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Table 2.5, Chapter 2, Volume 4) or the most recent version of IPCC good practice guidance for AFOLU, must be followed.peer-reviewed.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

Data Unit / Parameter	$D_{m_G,s}$
Data unit	Year
Description	The transition period required for SOC to be at equilibrium after a change in management practice of m_G in stratum *s*.
Equations	43
Source of data	Peer reviewed scientific studies
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	The transition period required for SOC to be at equilibrium after a change in management practice must be obtained from literature, local or regional studies or the modeling exercise. Where detailed data are unavailable, the project must apply a transition period of 20 years.
Purpose of data	Calculation of project emissions
Comment	

Data Unit / Parameter	f

Data unit	Year
Description	SOC monitoring frequency
Equations	50
Source of data	Project records
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Where the project applies option 2 to directly measure SOC, the frequency of SOC measurements must be at least once every five years.
Purpose of data	Calculation of project emissions
Comment	

9.2 Data and Parameters Monitored

Data Unit / Parameter	$M_{SNi,t}$
Data unit	t fertilizer
Description	Mass of synthetic N fertilizer type *i* applied in year *t*
Equations	24
Source of data	Project records
Description of measurement methods and procedures to be applied	The mass must be recorded just after the application of synthetic N fertilizer for each fertilizer type applied for each year.
Frequency of monitoring/recording	Each application of fertilizer during year t
QA/QC procedures to be applied	Guidelines provided in IPCC, 2003 Chapter 5 or IPCC, 2000 Chapter 8
Purpose of data	Calculation of project emissions
Comments	

Data Unit / Parameter	$NC_{SNi,p}$
Data unit	g N/g fertilizer
Description	Nitrogen content of synthetic N fertilizer type *i* applied under project
Equations	24
Source of data	Manufacturer product label or other manufacturer data

Description of measurement methods and procedures to be applied	The nitrogen content must be recorded for each synthetic N fertilizer type *i* that has been applied in the baseline scenario or project. The value must be obtained from the product description stated by the manufacturer on the product label.
Frequency of monitoring/recording	Each application during project crediting period in year t
QA/QC procedures to be applied	Guidance provided in IPCC, 2003 chapter 5 or IPCC, 2000 chapter 8 must be applied
Purpose of data	Calculation of project emissions
Comments	

Data Unit / Parameter	$Area_{g,t}$
Data unit	ha
Description	Annual area of N-fixing species *g* in year t
Equations	27
Source of data	Project records
Description of measurement methods and procedures to be applied	Record the area of N-fixing species by all households involved in the project.
Frequency of monitoring/recording	Annually, at the beginning of growing season.
QA/QC procedures to be applied	Where the difference between the recorded and the new reading is more than 10 percent, reasons for the difference must be discussed with the staff responsible for taking both measurements, and if necessary the $Area_{g,p,t}$ should be re-measured.
Purpose of data	Calculation of project emissions
Comments	

Data Unit / Parameter	$Crop_{g,t}$
Data unit	t dm/ha
Description	Annual dry matter, including aboveground and below ground, returned to grassland soils for N-fixing species *g* in year t.
Equations	27
Source of data	Project records
Description of measurement	Measure annual dry matter, including aboveground and below

methods and procedures to be applied	ground, returned to grassland soils for N-fixing species g in year t. The sample size of household number must ensure precision at 95±15 precision.
Frequency of monitoring/recording	Annually, at the end of growing season.
QA/QC procedures to be applied	The sample collection should be carried out by experts or well-trained staff. Where the difference between the recorded and the new reading is more than 10 percent, reasons for the difference must be discussed with the staff responsible for taking both measurements, and if necessary the $Crop_{g,t}$ should be re-measured.
Purpose of data	Calculation of project emissions
Comments	

Data Unit / Parameter	$N_{content,g}$
Data unit	t N/t dmt N
Description	Fraction of N in dry matter for N-fixing species g under project
Equations	27
Source of data	Project records
Description of measurement methods and procedures to be applied	Where detailed data from peer-reviewed scientific studies, specific to the project area or country are available, such data must be applied. Where detailed data are unavailable, an peer-reviewedexpert survey within the project area must be performed before the start of the project. Data must be surveyed by collecting biomass (aboveground and below ground) from at least three plots (1m*1m) of each N-fixing species in each sampled household. Send the samples to a qualified laboratory to analyze the N content in the biomass.
Frequency of monitoring/recording	Annually
QA/QC procedures to be applied	A sufficient number of plots for sampling $N_{content,\mathrm{p},g}$ must be used to ensure that a precision of 15 percent at the 95 percent confidence level is attained. Guidance provided in IPCC, 2003 chapter 5 or IPCC, 2000 chapter 8 must be applied must be applied for guidance on sampling methods and QA/QC procedures. The sample collection must be carried out by appropriately trained staff. The measurement of the N content in the biomass must be carried out by a laboratory that can

	demonstrate adherence to the principles of good laboratory practices, outlined in OECD (1998).
Purpose of data	Calculation of project emissions
Comments	

Data Unit / Parameter	$A_{B,t}$
Data unit	Ha
Description	Area burnt in year t during the project crediting period
Equations	29 and 30
Source of data	Project records
Description of measurement methods and procedures to be applied	Measure and record the area burnt after the fire occurrence
Frequency of monitoring/recording	Each burning activity in year t during project crediting period
QA/QC procedures to be applied	Where the difference between the recorded burnt area and the new reading is more than 10 percent, reasons for the difference must be discussed with the staff responsible for taking both measurements, and if necessary the burnt area should be re-measured.
Purpose of data	Calculation of project emissions
Comments	

Data Unit / Parameter	$M_{B,t}$
Data unit	t biomass/ha
Description	Aboveground biomass burnt, excluding litter and dead wood under project in year t.
Equations	29 and 30
Source of data	Project records
Description of measurement methods and procedures to be applied	Measure the aboveground biomass of grassland before and after the fire management for at least three plots (1m*1m). The difference of the aboveground biomass is the aboveground biomass burnt.
Frequency of monitoring/recording	Each burning activity in year t during the project crediting period
QA/QC procedures to be	A sufficient number of plots for sampling $M_{B,p,t}$ must be used

applied	to ensure that a precision of 15 percent at the 95 percent confidence level is attained. Guidance provided in IPCC, 2003 chapter 5 or IPCC, 2000 chapter 8 must be applied must be used for guidance on sampling methods and QA/QC procedures.
Purpose of data	Calculation of project emissions
Comments	

Data Unit / Parameter	$P_{l,t}$
Data unit	*head*
Description	Population of livestock type *l* under project in year t
Equations	31, 36 and 38
Source of data	Project records
Description of measurement methods and procedures to be applied	Record numbers of grazing livestock by type. The sample size of household number must ensure that a precision of 15 percent at the 95 percent confidence level is attained. The value must be based on the grazing numbers; annual or seasonal average population of grazing livestock by type.
Frequency of monitoring/recording	Annually
QA/QC procedures to be applied	Guidance provided in IPCC, 2003 chapter 5 or IPCC, 2000 chapter 8 must be applied
Purpose of data	Calculation of project emissions
Comments	

Data Unit / Parameter	$H_{l,t}$
Data unit	Hours
Description	Average grazing hours per day of livestock type *l* during grazing season in year t
Equations	36 and 38
Source of data	Project records
Description of measurement methods and procedures to be applied	Record the average number of grazing hours per day during grazing season in year t. The sample size of household number must ensure that a precision of 15 percent at the 95 percent confidence level is attained.
Frequency of	Annually

monitoring/recording	
QA/QC procedures to be applied	Guidance provided in IPCC, 2003 chapter 5 or IPCC, 2000 chapter 8 must be applied
Purpose of data	Calculation of project emissions
Comments	

Data Unit / Parameter	$Days_{l,t}$
Data unit	Days
Description	Grazing days of livestock *l* in year t under project
Equations	31, 36 and 38
Source of data	Project records
Description of measurement methods and procedures to be applied	Record the grazing days in year t. The sample size of household number must ensure that a precision of 15 percent at the 95 percent confidence level is attained.
Frequency of monitoring/recording	At the end of every grazing season in year t
QA/QC procedures to be applied	Guidance provided in IPCC, 2003 chapter 5 or IPCC, 2000 chapter 8 must be applied
Purpose of data	Calculation of project emissions
Comments	

Data Unit / Parameter	$G_{AB,j,s,t}$
Data unit	t dm/ha
Description	Average increase in existing aboveground woody biomass of species *j*, in stratum *s*, under project for year *t*.
Equations	42
Source of data	Project records
Description of measurement methods and procedures to be applied	Use one of the methods for estimating changes in carbon stock of trees and shrubs between two points in time for project activities outlined in the latest version of the CDM tool for *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*. Follow the sampling, measurement, modeling, and monitoring procedures specified in this tool.
Frequency of monitoring/recording	At the end of every monitoring period

QA/QC procedures to be applied	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory must be applied. Where such procedures are not available, QA/QC procedures from published handbooks, or from the IPCC, 2003 *Good Practice Guidance for Land Use, Land Use Change and Forestry* (or the most recent version of IPCC good practice guidance for AFOLU) must be applied.
Purpose of data	Calculation of project emissions
Comments	

Data Unit / Parameter	$FC_{p,j,k,t}$
Data unit	Kg fuel
Description	Fuel consumption by type k, machine type *j*, parcel grassland *p*, in year t under project
Equations	39
Source of data	Project records
Description of measurement methods and procedures to be applied	Record fuel consumption by type *k*, machine type *j*, parcel grassland *p* of each household.
Frequency of monitoring/recording	Record fuel consumption just after the application of machine.
QA/QC procedures to be applied	Guidance provided in IPCC, 2003 chapter 5 or IPCC, 2000 chapter 8 must be applied
Purpose of data	Calculation of project emissions
Comments	

Data Unit / Parameter	$A_{P,j,s,t}$
Data unit	Ha
Description	Area of trees and shrubs of species *j* in stratum *s* under project in year *t*
Equations	41
Source of data	Project records
Description of measurement methods and procedures to be applied	Maps, orthorectified images, or field-based GPS measurements must be applied. Horizontal projected area required.
Frequency of	Annually, at the beginning of growing season in year t

monitoring/recording	
QA/QC procedures to be applied	Where the difference between the recorded area of trees and shrubs and the new reading is more than 10 percent, reasons for the difference must be discussed with the staff responsible for taking both measurements, and if necessary the area of trees and shrubs should be re-measured.
Purpose of data	Calculation of project emissions
Comments	

Data Unit / Parameter	$PA_{m_G,s,t}$
Data unit	Ha
Description	Project areas of grassland with management practice *Mg* in stratum *s* in year *t*
Equations	44 and 47
Source of data	Project records
Description of measurement methods and procedures to be applied	Record the area of grassland with management practice *Mg* in stratum *s*.
Frequency of monitoring/recording	Record the area and management practice just after the management practice has taken place and report annually
QA/QC procedures to be applied	Guidance provided in IPCC, 2003 chapter 5 or IPCC, 2000 chapter 8 must be applied
Purpose of data	Calculation of project emissions
Comments	

Data Unit / Parameter	$SOC_{m_G,s,i,t}$
Data unit	g C/kg soil
Description	SOC stock in the top 30 cm of soil (or greater depth if required) for management practice m_G, stratum *s* (or greater depth if desired), sampling site *i*
Equations	45
Source of data	Project records
Description of measurement methods and procedures to be applied	Measurement methods and procedures described in Section 8.2.8 of this methodology must be applied.
Frequency of	At least once every five years, at the end of growing season in

monitoring/recording	the year measured, until the end of the project crediting period
QA/QC procedures to be applied	Soil sampling, sampling intensity, handling and storage, processing and measurement of $SOC_{m_G,s,i,t}$, and quality control must follow the guidance, methods and procedures as described in Section 8.2.8 of this methodology.The collection of soil samples for measuring SOC must be carried by suitably trained staff. The measurement of SOC must be carried out by a laboratory that can demonstrate adherence to the principles of good laboratory practices, outlined in OECD (1998).
Purpose of data	Calculation of project emissions
Comments	

Data Unit / Parameter	$BD_{m_G,s,i,t}$
Data unit	g soil/cm^3
Description	Soil bulk density in the top 30 cm of soil (or greater depth if required) for management practice m_G, stratum *s* (or greater depth if desired), sampling site *i*
Equations	45
Source of data	Project records
Description of measurement methods and procedures to be applied	Measurement methods and procedures described in Section 8.2.8 of this methodology must be applied.
Frequency of monitoring/recording	At least once every five years, at the end of growing season in the year measured, until the end of the project crediting period
QA/QC procedures to be applied	Soil sampling, sampling intensity, handling and storage, processing and measurement of $BD_{m_G,s,i,t}$, and quality control must follow the guidance, methods and procedures as described in Section 8.2.8 of this methodology. The collection of soil samples for measuring soil bulk density must be carried by suitably trained staff. The measurement of soil bulk density must be carried out by a laboratory that can demonstrate adherence to the principles of good laboratory practices, outlined in OECD (1998).
Purpose of data	Calculation of project emissions
Comments	

Data Unit / Parameter	$FC_{m_G,s,i,t}$

Data unit	percent
Description	Percentage of rocks with a diameter larger than 2mm, roots, and other dead residues in the top 30 cm of soil (or greater depth if desired), for management practice m_G, stratum *s*, sampling site *i*
Equations	45
Source of data	Project records
Description of measurement methods and procedures to be applied	Measurement methods and procedures described in Section 8.2.8 of this methodology must be applied.
Frequency of monitoring/recording	At least once every five years, at the end of growing season in the year measured, until the end of the project crediting period
QA/QC procedures to be applied	Soil sampling, sampling intensity, handling and storage, processing and measurement of $FC_{m_G,s,i,t}$, and quality control must follow the guidance, methods and procedures as described in Section 8.2.8 of this methodology. The collection of soil samples for measuring $FC_{m_G,s,i,t}$ must be carried by suitably trained staff. The measurement of $FC_{m_G,s,i,t}$ must be carried out by a laboratory that can demonstrate adherence to the principles of good laboratory practices, outlined in OECD (1998).
Purpose of data	Calculation of project emissions
Comments	

Data Unit / Parameter	$Depth$
Data unit	cm
Description	Total soil depth, for calculating grassland SOC stock in the top 30 cm of soil (or greater depth if required)
Equations	45
Source of data	Project records
Description of measurement methods and procedures to be applied	The value for soil depth must be consistent with the measurements taken. Soil properties must be measured to the full depth of affected soil layers. Where the full depth of affected soil layers is not known, a minimum depth of 30 cm must be applied.
Frequency of monitoring/recording	Recorded with each measurement taken

QA/QC procedures to be applied	
Purpose of data	Calculation of project emissions
Comments	

9.3 Description of the Monitoring Plan

The monitoring plan must include a statement of the purpose(s) of monitoring, and describe monitoring procedures adequate for obtaining, recording, compiling and analyzing data and information important for quantifying and reporting GHG emissions and/or removals relevant for the project (including leakage) and baseline scenario and for meeting any other stated purposes of monitoring. All data collected as part of monitoring must be archived electronically and be kept at least for two years after the end of the project crediting period.

9.3.1 Monitoring of Project Implementation

Information must be provided, and recorded in the project description to establish:

- A record of the grazing agents (eg, herder households) involved the project.
  - The project proponent should record each household involved in the sustainable grassland management project.
  - Each household should be given a unique ID. Their name, location of their land, and date of entering into the agreement and leaving the agreement should be recorded.
- A record of the geographic location of the project area for all areas of grassland;
  - The geodetic coordinates of the project area (and any stratification inside the area) must be established, recorded and archived. This can be achieved by field survey (eg, using GPS), or by using geo-referenced spatial data (eg, maps, GIS datasets).
- A record of grassland management
  - The grassland management plan, together with a record of the plan as actually implemented during the project crediting period must be available for validation and verification.

9.3.2 Validation of Biogeochemical Model

As set out in the applicability conditions, if a biogeochemical model is selected for estimation of change in soil carbon stocks, the model must meet with the requirements for models as set out in the VCS rules.

If a biohgeochemical model is used, it must be validated for the region within which the project is situated based on studies by appropriately qualified experts (eg, scientific journals, university theses, local research studies or work carried out by the project proponent) that demonstrate that the use of the selected biogeochemical model is appropriate. This can be done using one of the approaches described below:

- Approach 1: The studies used in support of the project must meet the guidance on model applicability as set out in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* in order to show that the model is applicable for the relevant IPCC climatic region. The guidance notes that an appropriate model should be capable of representing the relevant management practices and that the model inputs (ie, driving variables) are validated from country or region-specific locations that are representative of the variability of climate, soil and management systems in the country.
- Approach 2: Where available, national, regional or global level agroecological zone (AEZ) classification can be used to to show that the model has been validated for similar AEZs. It is recognized that national level AEZ classifications are not readily available, and therefore this methodology allows the use of the global and regional AEZ classification.
- Approach 3: Where a project area consists of multiple sites, it is recognized that studies demonstrating model validity using either Approach 1 or Approach 2 may not be available for each of the sites in the project area. In such cases the study used must be capable of demonstrating that the following two conditions are met:
    - o The model is validated for at least 50 percent of the total project area where the project area covers up to and including 50,000 ha; or at least 75 percent of the total project area where project area covers greater than 50,000 ha; and
    - o The area for which the model is validated generates at least two-thirds of the total project emission reductions.

9.3.3 Sampling Design and Stratification (Option 2)

Stratification of the project area into relatively homogeneous units can either increase the measuring precision without increasing the cost unduly, or reduce the cost without reducing measuring precision because of the lower variance within each homogeneous unit.

The project proponent must present in the project description an ex-ante stratification of the project area or justify the lack of stratification. The number and boundaries of the strata defined ex-ante may change during the project crediting period (ex-post). Four main requirements should be met before the stratified sampling is chosen:

- Population must be stratified in advance of the sampling.
- Classes must be exhaustive and mutually exclusive (ie, all elements of the population must fall into exactly one class).
- Classes must differ in the attribute or property under study, otherwise there is no gain in precision over simple random sampling.

- Selection of items to represent each class (ie, the sample drawn from each class) must be random.

Updating of strata

The ex-post stratification must be updated due to the following reasons:

- Unexpected disturbances occurring during the project crediting period (eg, due to fire, pests or disease outbreaks), affecting differently various parts of an originally homogeneous stratum;

- Grassland management activities (planting) may be implemented in a way that affects the existing stratification.

Established strata may be merged if reasons for their establishment have disappeared.

Sampling framework

To determine the sample size of each stratum, the project proponent must use the latest version of the CDM *Tool for the Calculation of the number of sample plots for measurements within A/R CDM project activities*. The targeted precision level for estimation across the project must be a precision of 15 percent at the 95 percent confidence level. Note that although the CDM tool does not allow temporary plots, such plots are permitted under this methodology.

The selection of random points in each stratum has been greatly facilitated by the widespread use of Global Positioning System (GPS) receivers in field research. The points to be sampled can be randomly selected before going to the field, downloaded into the GPS unit, and then the researcher can use the GPS to guide them to that location in the field.

9.3.4 Recording of Data and Parameters Monitored

The following parameters must be record and monitored during the project. When applying the equations provided in this methodology for the *ex-ante* calculation of net anthropogenic GHG removals by sinks, the project proponent must provide transparent estimations for the parameters that are monitored during the project crediting period. These estimates must be based on measured or existing published data where possible and the project proponent must apply a conservative approach: that is, if different values for a parameter are equally plausible, a value that does not lead to over-estimation of net anthropogenic GHG removals by sinks must be selected.

For the estimate of annual emissions from the use of synthetic fertilizers, the following parameters must be recorded at each application during the project crediting period:

- Mass and type of synthetic N fertilizer applied;

- Nitrogen content of synthetic N fertilizer applied.

For the estimate of annual emissions from the burning of grassland, the following parameters must be recorded annually during the project crediting period:

- Annual area of N-fixing species
- Annual dry matter, including aboveground and below ground, returned to grassland soils for N-fixing species
- Fraction of N in dry matter for N-fixing species

For the estimate of annual emissions from the burning of grassland, the following parameters must be recorded at each burning activity during the project crediting period:

- Area burned in year t during the project crediting period
- Aboveground biomass burned exclude litter and dead wood

For the estimate of annual CH_4 emissions from enteric fermentation, population of livestock type *l* and grazing days of livestock type *l* must be recorded annually during the project crediting period.

For the estimate of annual CH_4 and N_2O emissions from manure deposition during grazing, grazing days of livestock of type *l*, and average grazing hours per day of livestock type *l* during the grazing season must be recorded in every grazing season, in each year during the project project crediting period.

For the estimate of annual CO_2 emissions due to the use of fossil fuels for SGM, the following parameters must be recorded at each time a management practice using machines is adopted and reported annually during the project crediting period:

- Quantity of fuel consumption;
- Fuel type;
- Machine type.

For the estimate of annual emissions and removals from woody perennials, the area of trees and shrubs of each stratum must be recorded annually during the project crediting period:

To estimate project removals due to changes in SOC with a validated model, project areas in grassland with different management practice must be recorded.

If option 2 for estimating project removals due to changes in SOC is selected, the following parameters must be monitored at least once every five years during the project crediting period. The soil sampling, handling and storage, processing and measurement, and quality control procedures implemented in soil organic carbon analysis that follow a scientific peer-reviewed or nationally approved standard.

- SOC content;
- Soil bulk density;
- Percentage of rocks with a diameter larger than 2mm, roots and other dead residues;
- Carbonate content.

For the estimate of leakage emissions, the monitoring parameters required in the VCS modules VMD033 *Estimation of Emissions from Market Leakage* and VMD040 *Estimation of Leakage Emissions from Displacement of Grazing Activity due to Implementation of Sustainable Grassland Management Activities* must be recorded annually during the project crediting period.

10 REFERENCES

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DOCUMENT HISTORY

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VCS Methodology

VM0028

Methodology for Carpooling

Version 1.0

17 April 2015

Sectoral Scope 7

Methodology developed by: Sohil Thakkar and Wai Cheng

Table of Contents

1 SOURCES

This methodology uses the latest version of the following tool:

- CDM *Tool to calculate the emission factor for an electricity system*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality	Project Method
Crediting Baseline	Project Method

This methodology provides procedures to estimate the avoided greenhouse gas (GHG) emissions from using carpools and vanpools for commuting to and from work as facilitated by the use of a carpool management application (CMA). This methodology is applicable only to carpools and vanpools used for commuting purposes; carpools or vanpools used for any other purpose are not eligible. GHG emission reductions are achieved through fewer single-occupancy vehicular trips that rely on fossil fuels or emission-intensive electricity for motive power.

Each carpool member must agree to run a CMA, which is a smartphone application used to track member and carpool vehicle information. The CMA must have the ability to record unique details about each carpool member, including historic routes to and from work and start and end points of commutes. Finally, the CMA must report trip details to a carpool server for occupancy and carpool membership detection and validation. Carpool servers hold the database of information relayed from the CMA about all carpool members and carpool trips.

Baseline emissions are quantified based upon the single-occupancy vehicular trips that would have taken place in the absence of the carpool. Project emissions are quantified by estimating the fuel consumption of eligible carpool trips. Monitoring is primarily based on the CMA's recordation of information about carpool members and trips.

3 DEFINITIONS

3.1 Defined Terms

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions apply to this methodology:

Baseline Emission Quantification Co-efficient (BEQC)
A number between 0 and 1 that represents how often a carpool member commutes by driving alone in the baseline scenario, assigned to a carpool member based on their commuting practice before joining the carpool program. BEQC adjusts the baseline emissions of a carpool member based on past commuting practice.

Carpool

A group of two or more people who share one or more vehicles during any part of their journey to and/or from work. Where referred to in this methodology, carpools also includes vanpools.

Carpool Management Application (CMA)

A software application that runs on a carpool member's smartphone, and that monitors and records trip information and reports it to the carpool server

Carpool Management and Monitoring System (CMMS)

A system consisting of carpool servers, smartphones running a CMA and OBDII dongles, which collectively enable carpool formation, management and GHG emissions monitoring

Carpool Member (Member)

An individual who participates in a carpool by providing rides with a carpool vehicle, receiving a ride from other carpool members, or both

Carpool Server (CS)

A computer system that records and manages data received from a CMA

Carpool Sub-trip

One of the following types of car trip:

- A trip by a carpool vehicle taken by one or more members of the carpool to reach a designated pick-up location
- A multi-occupancy trip by a carpool vehicle taken by members to the pick-up location of other member(s), or to the designated drop off location of one or more members, or both
- A trip by a carpool vehicle taken by the last member or members of a carpool to their final destination

Carpool Trip

The combination of one or more carpool sub-trips taken by members of a carpool to reach their final destination(s) from their point(s) of origin

Carpool Vehicle

A vehicle used in at least one carpool sub-trip

Community Area

A pre-defined geographic area(s) within which carpool activity monitoring takes place (eg, *Very Large Urban Area* and *Large Urban Area* as defined by Texas A&M Transportation Institute). The defined geographic area(s) need not be connected.

Fampool

A carpool consisting of carpool members who all reside within 200 meters of each other and commute to the same work address, or where all carpool members reside at the same residential address and commute to work addresses that are within 200 meters of each other

Fossil Fuel Vehicle (FFV)

A vehicle that relies on fossil fuel as a fuel source (eg, vehicles powered by gasoline, diesel, ethanol-gasoline mixed (E85) or compressed natural gas). Hybrid vehicles using fossil fuel as the single fuel source with regenerative braking to charge the battery are also included in this definition.

Herfindahl-Hirschman Index (HHI)

An indicator of the amount of competition among commuting modes within a specific community area derived from the market share of each commuting mode. The market share of a commuting mode is determined by the number of commuters using that commuting mode relative to that of all commuting modes within the community area.

On-Board Diagnostics II (OBDII)

On-Board Diagnostics specification, version 2 in North America. For this methodology, equivalent standards in Europe (European On Board Diagnostics - EOBD), Japan (Japan On Board Diagnostics – JODB) and Australia (Australian Design Rule 79/01-79/02, Australian OBD standard) are also referred to as OBDII. Additional standards are accepted under this definition if, at a minimum, the Vehicle Identification Number (VIN) can be directly obtained from the vehicle engine control unit (ECU).

OBDII Dongle

A device attached to the carpool vehicle’s OBDII port that allows other devices to wirelessly connect to it and access the vehicle OBDII port. Wireless connection uses short range wireless technologies such as Bluetooth or WiFi. If a vehicle manufacturer traditionally supports wireless access to the vehicle ECU using Bluetooth or WiFi without the use of an externally connected OBDII dongle, such mechanism is also referred to as an OBDII dongle for the purpose of this methodology.

Plug-in Electric Vehicle (PEV)

A vehicle that runs on electric energy stored in on-board batteries and has no other source of external energy to propel the vehicle. Batteries are charged via electricity from the grid.

Plug-in-Hybrid Electric Vehicle (PHEV)

A vehicle that is similar to a plug-in electric vehicle, but also has a fuel tank to power the vehicle beyond the battery charge. The vehicle runs on the battery until the charge is lost, at which point the vehicle runs on an internal combustion engine and the battery to propel the vehicle. The battery may be charged through regenerative braking.

Pre-program Carpool Co-efficient (PCC)

A number between 0 and 1 that represents how often a carpool member commutes by carpooling in the baseline scenario, assigned to a carpool member based on their commuting practice before joining the carpool program

Residential Address

The address of a carpool member's residence, or address of a transit stop to which the carpool member travels and then drives to their work place in the baseline scenario

Single-Occupancy Baseline Trip Distance

The distance of the single-occupancy vehicular trip a member of a carpool would have taken in the baseline scenario. The distance of such trip is calculated as the shortest time or distance between commute start and endpoints as specified in Section 8.1.2.

Single-Occupancy Baseline Trip Vehicle

The vehicle that would be used by a member of a carpool for a single-occupancy vehicular trip in the baseline scenario

Work Address

The address of a carpool member's work place, or address of a transit stop to which a carpool member drives and then takes a follow-on journey on a transit system to their work place in the baseline scenario

3.2 Acronyms

BEQC Baseline Emission Quantification Co-efficient

CMA Carpool Management Application

CMMS Carpool Management and Monitoring System

ECU Engine control unit

FFV Fossil fuel vehicle

HHI Herfindahl-Hirschman Index

IMEI International Mobile Equipment Identity

OBD On board diagnostic

OBDII On board diagnostics specification, version 2

PCC Pre-program Carpool Co-efficient

PEV Plug-in electric vehicle

PHEV Plug-in-hybrid electric vehicle

SOBT Single-occupancy baseline trip

4 APPLICABILITY CONDITIONS

This methodology applies to project activities that reduce GHG emissions by using carpools for commuting to and from work, as facilitated by the use of a CMMS that enables a community of people to more effectively engage in carpooling.

This methodology is applicable under the following conditions:

1) Each carpool member must be registered with a CMMS and be uniquely identified via smartphone identity (eg, IMEI and/or phone number). The carpool member's residential address, work address and single-occupancy baseline trip (SOBT) vehicle must be registered and confirmed by the user biennially through the CMA.
2) All carpool vehicles must support OBDII interface.
3) Each carpool member must run a CMA during all carpool trips.
4) Each carpool member must own a private vehicle that is available for their commute and register that vehicle with the CMMS.
5) Each carpool sub-trip must start and end within one of the defined community areas, though the start and end community area may be different and need not be connected.

5 PROJECT BOUNDARY

The sources of GHG emissions included within the project boundary are (1) emissions from burning of fossil fuels by fossil fuel vehicles (FFVs) and plug-in-hybrid electric vehicles (PHEVs), (2) indirect emissions from off-site generation of electricity required for charging plug-in electric vehicles (PEVs) and PHEVs, and (3) indirect emissions from off-site generation of electricity required to run the carpool server(s). The GHG sources included in and excluded from the project boundary are shown in Table 1 below.

The spatial extent of the project boundary encompasses carpool vehicles and carpool servers. Not all carpool members need to be specifically identified at the project start date. For example, a project could be defined as "the first 10,000 members in the Boston metro area" or "employees of Company X in the San Francisco Bay area, Atlanta metro area, and Boston metro area".

Table 1: GHG Sources Included in or Excluded from the Project Boundary

Source		Gas	Included?	Justification/Explanation
Baseline	Fossil fuel emissions from FFVs and/or PHEVs used in SOBTs	CO_2	Yes	Main emission source in the combustion of fossil fuel and electricity generation.
		CH_4	No	Minor source excluded for simplification; this is conservative

Source		Gas	Included?	Justification/Explanation
		N_2O	No	Minor source excluded for simplification; this is conservative
		Other	No	Not applicable
	Indirect fossil fuel emissions from electricity generation used for charging PHEVs and/or PEVs used in SOBTs	CO_2	Yes	Main emission source in the combustion of fossil fuel.
		CH_4	No	Minor source excluded for simplification; this is conservative
		N_2O	No	Minor source excluded for simplification; this is conservative
		Other	No	Not applicable
Project	Fossil fuel emissions from FFVs and/or PHEVs used in carpool trips	CO_2	Yes	Main emission source in the combustion of fossil fuel and electricity generation.
		CH_4	No	Minor source excluded for simplification.
		N_2O	No	Minor source excluded for simplification.
		Other	No	Not applicable
	Indirect fossil fuel emissions from electricity generation used for charging PHEVs and/or PEVs used in carpool trips	CO_2	Yes	Main emission source in the combustion of fossil fuel for electricity generation.
		CH_4	No	Minor source excluded for simplification.
		N_2O	No	Minor source excluded for simplification.
		Other	No	Not applicable
	Indirect fossil fuel emissions from electricity generation used for running the carpool servers	CO_2	Yes	Main emission source in the combustion of fossil fuel for electricity generation.
		CH_4	No	Minor source excluded for simplification.
		N_2O	No	Minor source excluded for simplification.
		Other	No	Not applicable

6 BASELINE SCENARIO

The baseline scenario is the most likely means by which a carpool member would have made their commute (ie, the trip from their residential address to their work address, and the trip from their work address to their residential address) in the absence of the project. To identify the most likely means by which a carpool member would have made their commute in the absence of the project, the commuting modes used in the last 12 months by the carpool member must first be specified at the time of registration with the CMMS. Such data must be updated where a member's work address, residential address or commuting vehicle ownership status changes. The carpool member must attest that all data provided is true, accurate and complete in all material respects. This attestation may be included as part of the terms and conditions of using the application or any other appropriate means.

Assuming members have had their current work and residential addresses for the last 12 months, the following information must be collected with respect to each season[1]:

a) Average number of (fractional) days per week commuting by driving alone

b) Average number of (fractional) days per week commuting by carpooling

c) Average number of (fractional) days per week using an alternative transport mode (ie, public transit, taxicab, motorcycle, walking and bicycling) to commute

d) Average number of (fractional) days per week working from home

The steps below use the information gathered above to establish the baseline transport mode for the carpool member.

Step 1. Determination of PCC and BEQC

Determine PCC and BEQC for the carpool member using the following:

$$PCC_i = \frac{\sum_m C_{i,m}}{5 * M} \tag{1}$$

$$BEQC_i = \frac{\sum_m S_{i,m}}{5 * M} \tag{2}$$

Where:

PCC_i Pre-program carpooling co-efficient of carpool member i

[1] Seasons must be defined according to local climate. For example, spring, summer, fall and winter months (ie, March-May, June-Aug, Sept-Nov, Dec-Feb respectively) could be used as a demarcation of seasons for projects located in the Northeastern United States.

$BEQC_i$ Baseline emission quantification co-efficient of carpool member i

m Season identifier (eg, spring, summer, fall and winter)

M Number of seasons

i Individual carpool member identifier

$C_{i,m}$ Number of days per 5-day week that carpool member i carpools during season m

$S_{i,m}$ Number of days per 5-day week that carpool member i commute by driving alone during season m

Step 2. Determine the most likely means by which a carpool member would have made their commute in the absence of the project (ie, *driving alone*, *carpool*, *periodic carpool*, *alternative transport mode* or *work from home*), based on the following criteria:

a) Where an alternative transport mode (eg, public transit, walking or bicycling) is available, and travel time with such alternative is no more than 15 minutes longer than driving alone, as determined using mapping software such as Google Maps[2] (see Annex 1 for additional requirements on using Google Maps or similar software), the baseline transport mode for the member is *alternative transport mode*.

b) Where a carpool member does not register their commuting vehicle or does not own one, the baseline transport mode for the member is *alternative transport mode*.

c) Where a member's BEQC is less than 0.2, the baseline transport mode for the member is *work from home*.

d) Where a member's PCC is greater than BEQC, it is assumed that the member carpools periodically in the baseline scenario, and the baseline transport mode for the member is *periodic carpool*.

e) Where a member's PCC is greater than or equal to 0.8, it is assumed that the member always carpools in the baseline scenario, and the baseline transport mode for the member is *carpooling only*.

f) Where a member's BEQC is greater than or equal to PCC, the baseline transport mode for the member is *driving alone.*

Only individuals whose baseline scenario is *driving alone* or *periodic carpool* may be included in the project; all other individuals must be excluded from the quantification of emission reductions.

Note that an ineligible member's participation in any sub-trip does not render the entire sub-trip ineligible; eligible members included in such sub-trip may still be included in the quantification of emission reductions. In addition, where a previously ineligible member demonstrates that their commuting practices in the past 12 months have changed such that they now exhibit an eligible baseline scenario, such members may be added to the project.

[2] Software available at www.google.com/maps

7 ADDITIONALITY

This methodology uses a project method for demonstrating and assessing additionality of the project. The project proponent must follow the three-step procedure set out below for this purpose. Where multiple community areas are included in the project, a separate analysis must be undertaken for each community area and only community areas meeting the criteria set out below may be included as part of the project.

Step 1. Regulatory Surplus

The project proponent must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the *VCS Standard.*

Where carpooling is not mandated by relevant laws, statutes, policies or other regulatory frameworks within the community area, proceed to Step 2. Where carpooling is mandated by relevant laws, statues or other regulatory frameworks within the community area, the project activity is not additional.

Step 2. Implementation Barriers

Carpooling as facilitated by use of a CMMS within a community area may face a variety of barriers to implementation. The project proponent must demonstrate the existence of one or more barriers that it faces and describe how the additional revenues associated with the sale of VCUs can help to overcome the barrier. The *VCS Standard* sets out three types of barriers, and the project proponent should identify and describe only the relevant and credible barriers they face from the list below:

- Investment barriers (eg, lack of funding for the development and implementation of application software purposed for the formation of carpool programs; sources of capital investment for similar project activities have primarily been from grants or on other non-commercial finance terms)
- Technological barriers (eg, development of software solution to facilitate the formation of carpool programs faces greater implementation risks than conventional approaches to carpool formation; novelty and complexity of software solution increases development risks)
- Institutional barriers (eg, limited inherent interest in carpooling from individuals or companies, due to low desirability of carpooling; lack of incentives to encourage a shift in commuting practices from driving alone to carpooling (eg, employer does not provide dedicated parking spot for carpool vehicles))

Where the project proponent demonstrates the existence of one or more barriers within a community area, and is able to describe how the additional revenues associated with the sale of VCUs can help to overcome the barrier, proceed to Step 3. Where the project proponent is not able to demonstrate the existence of at least one barrier within the community area, the project activity is not additional.

Step 3. Common Practice

The following two steps must be followed to demonstrate that the project activity is not common practice within a community area:

Step 3-A. Demonstration of Dominant Commuting Modes within a Community Area

Step 3-a is completed by calculating a Herfindahl-Hirschman Index (HHI)[3], which is used in economics to measure market competitiveness. The HHI must be used to determine whether the market (potential commuting modes within the community area) is an oligopoly or monopoly market dominated by few commuting modes. An HHI value of 2,500 or higher indicates that there are dominant commuting modes within a community area.

$$HHI = \sum M_k^2 \quad \textbf{(3)}$$

Where:

HHI Measurement of market competiveness

M_k Percentage market share of commuting mode k (percent)

Percentage market share of a commuting mode must be established using data from a recognized, credible source and such data must be reviewed for publication by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency.

Step 3-B. Demonstration that Carpooling is Not a Dominant Commuting Mode within a Community

Step 3-b must be completed using the square of market share values for various commuting modes. Specifically, a mode is a dominant mode where:

1) The mode has the highest market share of all modes; or
2) The sum of the square of the market shares of all the modes with market share greater than the mode in question is <2,500. For example, in a community area where mode A represents 40 percent of the commuting practices and mode B represents 60 percent of the commuting practices, to determine whether mode A is a dominant mode, all modes with larger market share (ie, mode B) must be squared and added together. In this

[3] Herfindahl index (HHI): http://www.justice.gov/atr/public/guidelines/hhi.html

example, 60^2 is 3600, which is greater than 2,500, meaning that mode A is not a dominant mode.

If carpooling is not a dominant commuting mode, it is not considered common practice.

To illustrate step 3 above, using the online tool on the United States census website[4] and data from the *2012 American Community Survey 1-year Estimate, for New York-Northern New Jersey-Long Island NY-NJ-PA metro area* study, the market share of different commuting modes in the NY-NJ-PA metro area may be derived, as shown in Table 2 below.

Table 2: Data from 2012 American Community Survey 1-year Estimate for New York-Northern New Jersey-Long Island metro area

	New York-Northern New Jersey-Long Island, NY-NJ-PA Metro Area	
	Estimate	**Margin of Error**
Total:	8,822,701	+/-28,922
Car, truck, or van:	4,989,077	+/-32,665
Drove alone	4,394,811	+/-30,999
Carpooled:	594,266	+/-16,108
In 2-person carpool	440,494	+/-14,236
In 3-person carpool	82,577	+/-5,349
In 4-or-more-person carpool	71,195	+/-5,307
Public transportation (excluding taxicab)	2,739,141	+/-22,580
Walked	538,986	+/-13,357
Taxicab, motorcycle, bicycle, or other means	191,038	+/-8,080
Worked at home	364,459	+/-9,627

Using the data in Table 2 above, and by converting numerical values into percentages, ignoring error margin and combining all “carpooled” types, the percentage market share of each commuting mode may be derived, as shown in Table 3 below.

Table 3: Percentage market share of commuting modes in NY-NJ-PA metro area

NY-NJ-PA Metro	Percentage
Drove alone	49.81%
Public transportation (excluding taxicab)	31.05%
Carpooled	6.74%

[4] US Census online tool: http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml

Walked	6.11%
Worked at home	4.13%
Other means	0.90%
Taxicab	0.63%
Bicycle	0.57%
Motorcycle	0.06%
Total:	100%

Using the percentage market share of each commuting mode, an HHI of 3,546 for commuting modes in the NY-NJ-PA metro area can be calculated, as illustrated below.

$$HHI_{ny} = \sum 49.8^2 + 31^2 + 6.74^2 + 6.11^2 + 4.13^2 + .9^2 + .63^2 + .57^2 + .06^2 = 3546$$

Since the HHI is greater than 2,500, this indicates that there are dominant commuting modes within the NY-NJ-PA metro area (step 3-a). In addition, since the sum of the square of the market shares of all the modes with market share greater than carpooling is >2500 ($49.8^2 + 31^2 = 3441$), carpooling is not considered a dominant mode (step 3-b).

Where the project proponent demonstrates that carpooling is not common practice in the community area, the project is additional. Where the project proponent is not able to demonstrate that the project is not common practice, the project activity is not additional.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

The baseline emissions of a specific carpool trip are calculated after the trip has been completed. The identity of carpool members who participated in a carpool trip must be recorded by the CMMS, and the baseline emissions are calculated assuming that in the absence of the carpool trip, each eligible carpool member would have undertaken a SOBT. Baseline emissions for a specific carpool trip are calculated by summing emissions from all carpool trips.

8.1.1 Carpool Membership Set

For each carpool trip, the carpool membership set consists of people who travelled together in at least one carpool sub-trip. Each carpool member of the set must be uniquely identified in the CMMS by an assigned number linked to their smartphone (eg, International Mobile Equipment Identity (IMEI), ESN, Mobile Equipment Identifier (MEID)), username and password, a security association (eg, Facebook login token) and/or phone number.

$$N_{y,t} = \bigcup_{j \in S_{y,t}} N_j \qquad (4)$$

Where:

$N_{y,t}$ Membership set of a carpool associated with carpool trip *t* in year *y*

$S_{y,t}$ Set of carpool sub-trips in carpool trip *t* in year *y*

N_j Carpool sub-trip j membership set (ie, set of occupants *i* on sub-trip *j*)

j Particular carpool sub-trip identifier

i Individual carpool member identifier who travelled in trip *t* in year *y*

8.1.2 Baseline Emissions Estimate for a Member of a Carpool Trip

In the absence of the carpool trip, it is assumed that each member of the carpool would have taken two individual, single-occupancy car trips. The first would be from their registered residential address to their registered work address, and the second would be to their registered residential address from their registered work address. Each of these individual trips is called a Single-Occupancy Baseline Trip (SOBT). Note that baseline emissions must be quantified separately for the trip to work and for the trip from work.

For each member in the carpool trip membership set, SOBT emissions ($BE_{i,ć}$) are the summation of emissions from fossil fuel consumption in the SOBT vehicle, and indirect emissions from electricity generation used for charging the SOBT vehicle.

The SOBT trip must be defined at the time of registration with the CMMS, and when a member updates their residential or work address. The SOBT trip must be defined as the route taking the least amount of time and which does not account for traffic. Where the CMMS is capable of obtaining the route which takes the least amount of time each time a member makes a carpool trip, such dynamic SOBT trip may be used as an alternative.

Where the carpool member's registered SOBT vehicle is a PEV, the equation below must be used to estimate the carpool member's baseline emissions:

$$BE_{i,ć} = D_i \cdot W_{ć} \cdot GE_p \qquad (5)$$

Where:

$BE_{i,ć}$ Baseline emissions for carpool member *i* in SOBT vehicle $ć$ (tCO_2e)

i Identifier for carpool member

D_i SOBT distance for carpool member i (km)

$W_{ć}$ Electric efficiency for SOBT vehicle identified by VIN number $ć$ (kWh/km)

GE_p Electricity generation GHG emission factor corresponding to project community area *p*, adjusted for transmission loss, if available (tCO_2e/kWh)

Where the carpool member's registered SOBT vehicle is an FFV, the equation below must be used to estimate the carpool member's baseline emissions:

$$BE_{i,\acute{c}} = D_i \cdot V_{\acute{c}} \cdot EF_{f(c)} \tag{6}$$

Where:

$BE_{i,\acute{c}}$ Baseline emissions for carpool member *i* in SOBT vehicle $\acute{c}$ (tCO_2e)

i Identifier for carpool member

D_i SOBT distance for carpool member i (km)

$V_{\acute{c}}$ Vehicle fossil fuel efficiency for SOBT vehicle $\acute{c}$ (L/km)

$EF_{f(c)}$ GHG emission factor of fuel used by vehicle identified by VIN number *c* (tCO_2e/L)

$\acute{c}$ VIN of SOBT vehicle

Where the carpool member's registered SOBT vehicle is a PHEV, the equation below must be used to estimate the carpool member's baseline emissions:

$$BE_{i,\acute{c}} = max(0, D_i - R_{\acute{c}}) \cdot V_{\acute{c}} \cdot EF_{f(c)} + min(D_i, R_{\acute{c}}) \cdot W_{\acute{c}} \cdot GE_p \tag{7}$$

Where:

$BE_{i,\acute{c}}$ Baseline emissions for carpool member *i* in SOBT vehicle $\acute{c}$ (tCO_2e)

i Identifier for carpool member

D_i SOBT distance for carpool member i (km)

$R_{\acute{c}}$ Vehicle all-electric range for SOBT vehicle identified by VIN $\acute{c}$ (km)

$W_{\acute{c}}$ Vehicle electric efficiency for SOBT vehicle identified by VIN $\acute{c}$ (kWh/km)

GE_p Electricity generation GHG emission factor corresponding to project community area p, adjusted for transmission loss, if any (tCO_2e/kWh)

$V_{\acute{c}}$ Vehicle fossil fuel efficiency for SOBT vehicle $\acute{c}$ (L/km)

$EF_{f(c)}$ GHG emission factor of fuel used by vehicle identified by VIN number c ($tCO_2e/liter$)

$\acute{c}$ VIN of SOBT vehicle

8.1.3 Baseline Emissions for a Carpool Trip

The baseline emissions for a carpool trip are estimated as the summation of baseline emissions for each carpool member that participated in the carpool trip as follows:

$$BE_{y,t} = \sum_{i \in N_{y,t}} BEQC_i \cdot BE_{i,ć} \tag{8}$$

Where:

$BE_{y,t}$ Baseline emissions for a carpool trip *t* in year *y* (tCO_2e)

$N_{y,t}$ Membership set of a carpool associated with the carpool trip t in year y

$BEQC_{i,}$ Baseline emission quantification co-efficient of carpool member

$BE_{i,ć}$ Baseline emissions for carpool member *i* in SOBT vehicle $ć$ (tCO_2e)

$ć$ VIN of SOBT vehicle

8.1.4 Baseline Emissions for Year *y*

Baseline emissions for year *y* are calculated by summing the baseline emissions of all carpool trips taken in year *y*.

$$BE_y = \sum_{t \in T_y} BE_{y,t} \tag{9}$$

Where:

BEy Baseline emissions for year *y* (tCO_2e)

T_y Set of all carpool trips in year *y*

$BE_{y,t}$ Baseline emissions for a carpool trip *t* in year *y* (tCO_2e)

8.2 Project Emissions

Project emissions are calculated from monitored data for each carpool trip. Project emissions for a specific carpool trip are calculated by summing emissions from all carpool sub-trips.

The emissions from each carpool sub-trip ($PE_{j,c}$) are estimated as the summation of emissions from burning fossil fuels in carpool vehicles and indirect emissions from electricity generation used for charging carpool vehicles. Note that project emissions must be quantified separately for the trip to work and for the trip from work.

A carpool trip where the carpool vehicle's internal systems are not functioning properly, as indicated by the check engine light or Malfunction Indicator Light (MIL) being on, or where the carpool vehicle does not have the OBDII dongle attached to its OBD port, is not eligible to be included in the quantification of emission reductions.

Where the carpool vehicle is a PEV, the equation below must be used to estimate project emissions for the carpool sub-trip *j*:

$$PE_{j,c} = d_j \cdot W_c \cdot GE_p \qquad (10)$$

Where:

$PE_{j,c}$ Project emissions for carpool sub-trip *j* in vehicle identified by VIN number *c* (tCO_{2e})

j Unique carpool sub-trip numerical identifier, assigned in a way so that current sub-trip identifier is greater than that of all previous sub-trips within this carpool trip

d_i CMA measured travel distance of carpool sub-trip *j* (km)

$W_ć$ Vehicle electric efficiency of a carpool vehicle identified by VIN number *c* (kWh/km)

GE_p Electricity generation GHG emission factor corresponding to project community area p, adjusted for transmission loss, if any (tCO_2e/kWh)

c VIN of carpool vehicle used in sub-trip *j*

Where the carpool vehicle is an FFV, and a fossil fuel consumption measurement is available over the OBDII interface during carpool sub-trip *j*, the equation below must be used to estimate project emissions for the carpool sub-trip *j*:

$$PE_{j,c} = FC_{j,c} \cdot EF_{f(c)} \qquad (11)$$

Where:

$PE_{j,c}$ Project emissions for carpool sub-trip *j* in vehicle identified by VIN number c (tCO_2e)

j Unique carpool sub-trip numerical identifier, assigned in a way so that current sub-trip identifier is greater than that of all previous sub-trips within this carpool

$EF_{f(c)}$ GHG emission factor of fuel used by vehicle identified by VIN number *c* (tCO_2e /liter)

$FC_{j,c}$ Measured fuel consumption (or cubic feet for natural gas) over OBDII interface during carpool sub-trip j for a carpool vehicle identified by VIN number *c* (liters)

c VIN of carpool vehicle used in sub-trip *j*

Where the carpool vehicle is an FFV, but a fossil fuel consumption measurement is not available over the OBDII interface during carpool sub-trip *j*, the equation below must be used to estimate project emissions for the carpool sub-trip *j*:

$$PE_{j,c} = d_j \cdot V_c \cdot EF_{f(c)} \qquad (12)$$

Where:

$PE_{j,c}$ Project emissions for carpool sub-trip *j* in vehicle identified by VIN number *c* (tCO_2e)

j Unique carpool sub-trip numerical identifier, assigned in a way so that current sub-trip identifier is greater than that of all previous sub-trips within this carpool

d_j CMA measured travel distance of carpool sub-trip *j* (km)

V_c Vehicle fossil fuel efficiency of a carpool vehicle identified by VIN number *c*, (L/km)

$EF_{f(c)}$ GHG emission factor of fuel used by vehicle identified by VIN number *c* (tCO_2e/L)

c VIN of carpool vehicle used in sub-trip *j*

Where the carpool vehicle is a PHEV, and a fossil fuel consumption measurement is available over the OBDII interface during carpool sub-trip *j*, the equation below must be used to estimate project emissions for the carpool sub-trip *j*:

$$\boldsymbol{PE_{j,c} = FC_{j,c} \cdot EF_{f(c)} + min\left(d_j, \max(0, R_c - dd_{j,c})\right) \cdot W_c \cdot GE_p} \quad (13)$$

Where:

$PE_{j,c}$ Project emissions for carpool sub-trip *j* in vehicle identified by VIN number *c* (tCO_2e)

j Unique carpool sub-trip numerical identifier, assigned in a way so that current sub-trip identifier is greater than that of all previous sub-trips within this carpool

$FC_{j,c}$ Measured fuel consumption (or cubic feet for natural gas) over OBDII interface during carpool sub-trip *j* for a carpool vehicle identified by VIN number *c* (liters)

$EF_{f(c)}$ GHG emission factor of fuel used by vehicle identified by VIN number *c* (tCO_2e/liter)

d_j CMA measured travel distance of carpool sub-trip *j* (km)

R_c Vehicle all electric range of a carpool vehicle identified by VIN number *c* (km)

$dd_{j,c}$ Cumulative distance travelled by a carpool vehicle c before sub-trip *j* within carpool trip *t* in year *y*

W_c Vehicle electric efficiency of a carpool vehicle identified by VIN number *c* (kWh/km)

GE_p Electricity generation GHG emission factor corresponding to project community area p , adjusted for transmission loss if any (tCO_2e /kWh)

c VIN of carpool vehicle used in sub-trip *j*

Where the carpool vehicle is a PHEV, but a fossil fuel consumption measurement is not available over the OBDII interface during carpool sub-trip *j*, the equation below must be used to estimate project emissions for the carpool sub-trip *j*:

$$PE_{j,c} = \left(\left(d_j - min\left(d_j, \max(0, R_c - dd_{j,c})\right)\right) \cdot V_c\right) \cdot EF_{f(c)} + min\left(d_j, \max(0, R_c - dd_{j,c})\right) \cdot W_c \cdot GE_p \quad (14)$$

Where:

$PE_{j,c}$ Project emissions for carpool sub-trip *j* in vehicle identified by VIN number *c* (tCO_2e)

j Unique carpool sub-trip numerical identifier, assigned in a way so that current sub-trip identifier is greater than that of all previous sub-trips within this carpool

$EF_{f(c)}$ GHG emission factor of fuel used by vehicle identified by VIN number *c* (tCO_2e/liter)

d_j CMA measured travel distance of carpool sub-trip *j* (km)

R_c Vehicle all electric range of a carpool vehicle identified by VIN number *c* (km)

$dd_{j,c}$ Cumulative distance travelled by a carpool vehicle c before sub-trip *j* within carpool trip t in year *y*

W_c Vehicle electric efficiency of a carpool vehicle identified by VIN number *c* (kWh/km)

V_c Vehicle fossil fuel efficiency of a carpool vehicle identified by VIN number *c* (l/km)

GE_p Electricity generation GHG emission factor corresponding to project community area p, adjusted for transmission loss if any (tCO_2 /kWh)

c VIN of carpool vehicle used in sub-trip *j*

Cumulative distance travelled by carpool vehicle c before sub-trip j is determined as follows:

$$dd_{j,c} = \sum_{\{j': j' \in S_{y,t}, C(j')=c, j'<j\}} d_{j'} \quad (15)$$

Where:

$C(j)$ VIN number of vehicle used in sub-trip j

8.2.1 Project Emissions for Carpool Trip

The project emissions for a carpool trip *t* in year *y* ($PE_{y,t}$) are calculated as the summation of the project emissions for each carpool sub-trip *j* included in the carpool trip t as follows:

$$PE_{y,t} = \sum_{j \in S_{y,t}} PE_{j,c} \quad (16)$$

Where:

$PE_{y,t}$ Project emissions for a carpool trip t in year y (tCO_2e)

$PE_{j,c}$ Project emission for carpool sub-trip *j* in vehicle identified by VIN number *c* (tCO_2e)

j Unique carpool sub-trip numerical identifier, assigned in a way so that current sub-trip identifier is greater than that of all previous sub-trips within this carpool

c VIN of carpool vehicle used in sub-trip *j*

8.2.2 Project Emissions from Off-site Generation of Electricity

Project emissions are calculated for the off-site generation of electricity for powering the central carpool server(s), which may or may not be owned and operated by the project proponent, using the equation below:

$$PE_{of,y} = \sum EC_{CS} \cdot GE_p \quad (17)$$

Where:

$PE_{of,y}$ Project emissions for off-site generation of electricity for powering central carpool servers (tCO_2e)

EC_{CS} Electricity consumption by the central carpools server(s) (kWh)

GE_p Electricity generation GHG emission factor corresponding to project community area p, adjusted for transmission loss if any (tCO_2 /kWh)

8.2.3 Project Emissions for Year *y*

Summation over all carpool trips in year *y* provides project emissions for year *y* (PE_y), as follows:

$$PE_y = \sum_{t \in T_y} PE_{y,t} + PE_{of,y} \quad (18)$$

Where:

PE_y Total project emissions for year y (tCO_2e)

$PE_{y,t}$ Project emissions for a carpool trip t in year y (tCO_2e)

$\boldsymbol{PE_{of,y}}$ Project emissions for off-site generation of electricity for powering central carpool servers (tCO_2e)

8.3 Leakage

Leakage is not considered an issue for this methodology, particularly because it is unlikely that individuals would move their commute outside the project boundary due to an increase in carpooling within the project boundary.

$$LE_y = 0 \quad (19)$$

Where:

LE_y Leakage emissions from the project in year *y* (tCO_2e)

8.4 Summary of GHG Emission Reductions and Removals

The net GHG emission reductions are quantified as a function of baseline emissions, project emissions and leakage, and the equation below must be used to estimate net GHG emission reductions for the project in year *y*:

$$ER_y = BE_y - PE_y - LE_y \quad (20)$$

Where:

ER_Y Net GHG emission reductions in year *y*

BE_Y Baseline emissions in year *y*

PE_y Project emissions in year *y*

LE_y Leakage in year *y*

9 MONITORING

9.1 Data and Parameters Available at Validation

Data Unit / Parameter	GE_p
Data unit	Tonnes of CO_2e per kWh
Description	Electricity generation GHG emission factor corresponding to project community area p
Equations	5, 7, 10, 13, 14, 16
Source of data	Data must be from a recognized, credible source and the data must be reviewed for publication by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency. The emission calculator from the EPA may be used for projects within the United States: http://www.epa.gov/cleanenergy/energy-resources/refs.html The most recent version of the CDM *Tool to calculate the emission factor for an electricity system* may be used when no published source is available. The project proponent must use the combined margin from this tool with preference being given to the weighted combined margin, if possible. Note that the units from the output of this tool must be converted to match the units of this parameter.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	The United States EPA maintains its calculator based on extensive research
Purpose of data	Calculation of baseline and project emissions
Comments	

Data Unit / Parameter	$EF_{f(c)}$
Data unit	Tonnes of CO_2e per liter

Description	GHG emission factor of fuel used by vehicle identified by VIN *c*
Equations	6, 7, 11, 12, 13, 14
Source of data	Data must be from a recognized, credible source and the data must be reviewed for publication by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency. The emission calculator from EPA may be used for projects within the United States: http://www.epa.gov/cleanenergy/energy-resources/refs.html
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	The United States EPA maintains its calculator based on extensive research
Purpose of data	Calculation of baseline and project emissions
Comments	The appropriateness of this value must be reviewed at each project crediting period renewal

Data Unit / Parameter	R_c
Data unit	Kilometers
Description	All electric range of vehicle identified by VIN *c*
Equations	7, 13, 14
Source of data	Manufacturer or government published data. In the United States, values from the following website may be used: http://www.fueleconomy.gov
Valued applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	The government or manufacturer published fuel economy value must be converted to kilometers to match the calculation units. Where city and highway values are provided by the source of the fuel economy data, the average of the two must be used.
Purpose of data	Calculation of baseline and project emissions
Comments	The value of this parameter must be established ex-post if the model of vehicle *c* was not released until after validation or if new vehicle models join the project after validation

Data Unit / Parameter	M_k
Data unit	Percent
Description	Percentage market share of commuting transport mode *k* in the carpool community area
Equations	3
Source of data	Data must be from a recognized, credible source and the data must be reviewed for publication by an appropriately qualified, independent organization or appropriate peer review group, or be published by a government agency. In the United States, the United States Census website may be used: http://factfinder2.census.gov.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	The United States Census is an authoritative source of data. The online tool provides easy access to a specific population's commuting data for customizable geographic areas.
Purpose of data	Demonstration of additionality
Comments	

Data Unit / Parameter:	j
Data unit	Unitless
Description	Unique carpool sub-trip numerical identifier, assigned in a way so that the current sub-trip identifier is greater than that of all previous sub-trips within a specific carpool
Equations	4, 10, 11, 12, 13, 14, 15
Source of data	Member's CMA
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	N/A
Purpose of data	Calculation of baseline and project emissions
Comments	

Data Unit / Parameter	m
Data unit	Unitless

Description	Season identifier
Equations	1, 2
Source of data	Project proponent
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	The project proponent must justify the choice of the number of seasons
Purpose of data	Demonstration of additionality
Comments	

Data Unit / Parameter	p
Data unit	Unitless
Description	Geographic area (community area) within which all or part of carpool or SOBT trip takes place.
Equations	5, 7, 10, 13, 14, 16
Source of data	Project proponent
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	N/A
Purpose of data	Demonstration of additionality
Comments	

9.2 Data and Parameters Monitored

Data Unit / Parameter	V_c
Data unit	Liters per kilometer
Description	Fossil fuel efficiency of carpool vehicle identified by VIN *c*
Equations	12, 14
Source of data	Government or manufacturer public fuel economy statistics
Description of measurement methods and procedures to be applied	The government or manufacturer published fuel economy value must be converted to kilometers to match the calculation units. Where city and highway values are provided by the source of the fuel economy data, the average of the two must

	be used. In the United States, data may be available at: http://www.fueleconomy.gov.
Frequency of monitoring/recording	This parameter must be added when the carpool vehicle of a specific model, make and year is not present in CMMS
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	The value of this parameter must be established *ex-post* if the model of vehicle *c* was not released until after validation or if new vehicle models join the project after validation

Data Unit / Parameter	W_c
Data unit	kWh per kilometer
Description	Electric efficiency of a carpool vehicle identified by VIN *c*
Equations	10, 13, 14
Source of data	Government or manufacturer public fuel economy statistics
Description of measurement methods and procedures to be applied	The government or manufacturer published fuel economy value must be converted to kilometers to match the calculation units. Where city and highway values are provided by the source of the fuel economy data, the average of the two must be used. In the United States, data available at http://www.fueleconomy.gov may be used.
Frequency of monitoring/recording	This parameter must be added when the carpool vehicle of a specific model, make and year is not present in CMMS
QA/QC procedures to be applied	None
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	The value of this parameter must be established *ex-post* if the model of vehicle *c* was not released until after validation or if new vehicle models join the project after validation

Data Unit / Parameter	$FC_{j,c}$

Data unit	Liters
Description	Fossil fuel consumption for sub-trip *j* in vehicle *c*
Equations	11, 13
Source of data	Member's CMA
Description of measurement methods and procedures to be applied	The CMA running on member's smartphone programmatically queries the vehicle's ECU over OBDII interface for various fuel cycle parameters to monitor fossil fuel consumption
Frequency of monitoring/recording	Every carpool sub-trip
QA/QC procedures to be applied	Check documentation supporting appropriateness of method used to calculate fuel consumption
Purpose of data	Calculation of project emissions
Calculation method	Based on reference 1 identified in Section 10 below, or based on a similar calculation method found in a study that was reviewed for publication by an appropriately qualified, independent organization or appropriate peer review group, or published by a government agency
Comments	

Data Unit / Parameter	$V_{\acute{c}}$
Data unit	Liters per kilometer
Description	Fossil fuel efficiency of SOBT vehicle identified by VIN $\acute{c}$
Equations	6, 7
Source of data	There are two possible sources for this parameter, listed in order of preferred use: 1) Average of last 3 months of measured values 2) Government or manufacturer public fuel economy statistics
Description of measurement methods and procedures to be applied	Depending on the capabilities of the OBDII dongle, CMA, carpool member's smartphone and vehicle ECU, if measured values of fuel consumption and trip distance are available, the vehicle fossil fuel efficiency is calculated as the last 3 months of measured fuel consumption divided by trip distance. If measured values are not available, government or manufacturer values may be used. The government or manufacturer published fuel economy value must be converted to kilometers to match the calculation units. Where city and highway values are provided by the source of the fuel

	economy data, the average of the two must be used. In the United States, data may be available at http://www.fueleconomy.gov.
Frequency of monitoring/recording	Where measured values are available, measured fuel efficiency must be updated after every carpool trip of the member. Otherwise, only update when the model, make and year of SOBT vehicle was not present in CMMS.
QA/QC procedures to be applied	Verify that the CMAs and the CS software product is a released product, a released product with a patch or a beta version, and are at least within two major revisions of latest released code version supported on underlying hardware
Purpose of data	Calculation of baseline emissions
Calculation method	Where using the average of 3 months of data, individual values are obtained by dividing $FC_{j,c}$ by d_j
Comments	The value of this parameter must be established *ex-post* if the model of vehicle *c* was not released until after validation or if new vehicle models join the project after validation

Data Unit / Parameter	$W_{\acute{c}}$
Data unit	kWh per kilometer
Description	Electric efficiency of SOBT vehicle identified by VIN $\acute{c}$
Equations	5, 7
Source of data	Government or manufacturer public fuel economy statistics
Description of measurement methods and procedures to be applied	The government or manufacturer published fuel economy value must be converted to kilometers to match the calculation units. Where city and highway values are provided by the source of the fuel economy data, the average of the two must be used. In the United States, data available at http://www.fueleconomy.gov may be used.
Frequency of monitoring/recording	This parameter must be added when the carpool vehicle of a specific model, make and year is not present in CMMS
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of baseline emissions
Calculation method	N/A
Comments	The value of this parameter must be established *ex-post* if the

	model of vehicle *c* was not released until after validation or if new vehicle models join the project after validation

Data Unit / Parameter	d_j
Data unit	Kilometers
Description	Distance travelled during sub-trip *j*
Equations	10, 12, 13, 14
Source of data	One or more members of the CMA
Description of measurement methods and procedures to be applied	The CMA running on each member's smartphone records geodetic coordinates at periodic intervals and reports to the CS as part of the trip report. Alternatively, the CMA may also query the carpool vehicle ECU to obtain the distance traveled.
Frequency of monitoring/recording	Every sub-trip
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	A carpool trip consists of associated sub-trips reported from one or more CMA. The CMA reports can be used to validate this sub-trip distance parameter.

Data Unit / Parameter	$dd_{j,c}$
Data unit	Kilometers
Description	Cumulative distance travelled by a carpool vehicle c before sub-trip *j* within carpool trip t in year *y*
Equations	13, 14
Source of data	One or more member's CMA
Description of measurement methods and procedures to be applied	The CMA running on each member's smartphone records geodetic coordinates at periodic intervals and reports to the CS as part of the trip report. Alternatively, the CMA may also query the carpool vehicle ECU to obtain the distance traveled.
Frequency of monitoring/recording	Every sub-trip
QA/QC procedures to be applied	N/A

Purpose of data	Calculation of project emissions
Calculation method	Determined as the sum of the distance of all carpool sub-trips prior to the current carpool sub-trip for a given carpool trip
Comments	

Data Unit / Parameter	$S_{i,m}$
Data unit	Unitless
Description	Number of days a carpool member i drove alone during seasons m before registering with carpool program
Equations	2
Source of data	Member registration process
Description of measurement methods and procedures to be applied	Members provide this information at the time of registration. Seasons must be defined according to local climate. For example, spring, summer, fall and winter months (ie, March-May, June-Aug, Sept-Nov, Dec-Feb respectively) could be used as a demarcation of seasons for projects located in the Northeastern United States. Number of days can be whole or fractional number between 0 and 5.
Frequency of monitoring/recording	Once at the time of registration
QA/QC procedures to be applied	Due to cost and privacy concerns, individual member review may not be feasible for validation/verification bodies to perform quality check. Instead, mean, variance and distribution of all or randomly sampled new member registration data for given year may be reviewed to ensure quality.
Purpose of data	Calculation of baseline emissions
Calculation method	N/A
Comments	

Data Unit / Parameter	$C_{i,m}$
Data unit	Unitless
Description	Number of days a carpool member i commuted to work as part of a carpool during seasons m before registering with the carpool program

Equations	1
Source of data	Member registration process
Description of measurement methods and procedures to be applied	Members provide this information at the time of registration. Seasons must be defined according to local climate. For example, spring, summer, fall and winter months (ie, March-May, June-Aug, Sept-Nov, Dec-Feb respectively) could be used as a demarcation of seasons for projects located in the Northeastern United States. Number of days can be whole or fractional number between 0 and 5.
Frequency of monitoring/recording	Once at the time of registration
QA/QC procedures to be applied	Due to cost and privacy concerns individual member review may not be feasible for validation/verification bodies to perform quality check. Instead mean, variance and distribution of all or randomly sampled new member registration data for given year may be reviewed to ensure quality.
Purpose of data	Calculation of baseline scenario
Calculation method	N/A
Comments	

Data Unit / Parameter	c
Data unit	Unitless
Description	VIN of vehicle used for sub-trip j
Equations	10, 11, 12, 13, 14, 15
Source of data	One or more member's CMA
Description of measurement methods and procedures to be applied	A CMA running on a member's smartphone programmatically queries vehicle's ECU over OBDII interface for VIN of the carpool vehicle. Must be queried at periodic intervals and reported to the CS as a part of the trip report. At least one member's CMA must report the VIN of the carpool vehicle in every sub-trip.
Frequency of monitoring/recording	Every sub-trip
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of project emissions

Calculation method	N/A
Comments	A carpool trip consists of associated sub-trip reported from one or more CMA. Examine the CMA report to validate the sub-trip of the carpool vehicle's VIN.

Data Unit / Parameter	N_j
Data unit	Unitless
Description	Set of members i carpooling together in sub-trip j. Each member is identified using meta-data (eg, phone number or username).
Equations	4
Source of data	One or more member's CMA
Description of measurement methods and procedures to be applied	A CMA running on member's smartphone reports the wirelessly detected OBDII dongle ID associated to the carpool vehicle in the trip report. CS determines co-occupancy of members by checking for members who report the same OBDII device ID with appropriate timestamp.
Frequency of monitoring/recording	Every sub-trip
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of baseline emissions
Calculation method	N/A
Comments	A carpool trip consists of associated sub-trip reports from one or more CMA. Examine CMA reports to validate sub-trip membership.

Data Unit / Parameter	D_i
Data unit	Kilometers
Description	Single-occupancy baseline trip distance of member i
Equations	5, 6, 7
Source of data	Mapping or navigational software (eg, Google Maps) or member provided
Description of measurement methods and procedures to be applied	Where CMMS is capable of obtaining the shortest time in-traffic route every time a member makes a carpool trip, such a dynamic SOBT trip distance may be used. Otherwise, SOBT

	trip distance along the shortest time with no traffic route must be used. Where the project proponent can justify that the shortest time distance cannot be established using a mapping software, this parameter may be based on member provided SOBT trip distance at time of registration.
Frequency of monitoring/recording	Where CMMS is capable, this parameter must be determined at start of the carpool trip. Otherwise, it must be determined at the time of registration and again when a member updates their residential or work address.
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of baseline emissions
Calculation method	N/A
Comments	

Data Unit / Parameter	$S_{y,t}$
Data unit	Unitless
Description	Set of sub-trips making up carpool trip t in year *y*
Equations	4
Source of data	One or more member's CMA
Description of measurement methods and procedures to be applied	The CMA running on a member's smartphone records geodetic co-ordinates and/or the detected OBDII device ID attached to the vehicle and corresponding timestamp at periodic intervals for the trip report. Upon receiving the trip report, the CS determines the nature of sub-trip as: carpool multi-occupancy sub-trip, carpool single-occupancy sub-trip or not a carpool sub-trip.
Frequency of monitoring/recording	Every carpool trip
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	A carpool trip consists of associated sub-trip reports from one or more CMA. Examine all CMA reports to validate carpool trip.

Data Unit / Parameter	i
Data unit	Unitless
Description	CMMS assigned unique identifier for a member
Equations	1, 2, 4, 5, 6, 7
Source of data	Member registration process
Description of measurement methods and procedures to be applied	CMMS-assigned unique identifier for a member identified by username and password, social media security-token (eg, facebook), phone number and/or smartphone IMEI. The information to identify unique members (eg, username and password) must be obtained during registration and stored in CMMS.
Frequency of monitoring/recording	Once at the time of registration with the CMA
QA/QC procedures to be applied	N/A
Purpose of data	Determination of baseline scenario and calculation of baseline emissions
Calculation method	N/A
Comments	

Data Unit / Parameter	$\acute{c}$
Data unit	Unitless
Description	VIN of SOBT vehicle registered to member i
Equations	6, 7, 8
Source of data	Member registration process and/or wirelessly transmitted to the CMA via OBDII dongle
Description of measurement methods and procedures to be applied	During member registration process, where a member owns a private SOBT vehicle, an identifier assigned by CMMS for that SOBT vehicle based on vehicle registration number (ie, vehicle tag plate and/or license plate) and/or year, make, model and/or trim entered by the member. This identifier may be updated to actual vehicle VIN if member uses the same vehicle for carpooling and actual vehicle VIN is reported by CMA.
Frequency of monitoring/recording	At registration with the CMA and updated by the member as necessary.
QA/QC procedures to be	N/A

applied	
Purpose of data	Calculation of baseline emissions
Calculation method	N/A
Comments	Where members do not use their SOBT vehicle for the carpool trips, actual vehicle VIN may not be available to obtain vehicle make, year and model from the VIN number. In such cases, where free or low cost programmatic interface to motor vehicle department registration is available, such facility may be used by project proponent or VVBs to verify the vehicle year, make and model provided by the member during registration.

Data Unit / Parameter	EC_{CS}
Data unit	kWh
Description	Electricity consumption of the central carpools server(s)
Equations	16
Source of data	Project proponent
Description of measurement methods and procedures to be applied	Where the CS hardware is owned and operated by the project proponent, the electricity consumption of the CS is either measured (eg, using an electricity meter), or estimated based on the rated power of the CS and its operating hours. Where the CS hardware is not owned or operated by the project proponent (ie, is deployed in public or private cloud), then the kWh attributable to the CS are estimated based on the server usage (or allocated server sizing) information. In case of public hosting, such information may be obtained from the invoices from the external CS service provider.
Frequency of monitoring/recording	Either monthly or dependent on the frequency of external CS service provider invoices
QA/QC procedures to be applied	Electric meter and usage logs, hardware or CS sizing documentation
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	

9.3 Description of the Monitoring Plan

The project proponent must establish, maintain and apply a monitoring plan and GHG information system that includes criteria and procedures for obtaining, recording, compiling and analyzing data, parameters and other information important for quantifying and reporting GHG emissions.

Key data for calculating the baseline and project emissions must be centrally managed and stored by the project proponent.

Each carpool member participating in the project must download the CMA on their smartphone, and provide the following information:

1) Personal identifying information (eg, name, address, phone number, etc)
2) Details of one or more single-occupancy trip (SOBT):
    a) End-points (ie, residential and work addresses)
    b) Vehicle ID (ie, vehicle identification number (VIN))
    c) A carpool vehicle if that vehicle is only used for carpooling (eg, if an employer provided or arranged vans for vanpool).

The CMA running on a carpool member's smartphone must perform the following operations:

1) Detect and record identity of OBDII device in the vehicle. Medium Access Address (MAC address) uniquely identifies each OBDII device (other temper proof IDs may also be used).
2) Calculate and record time, distance and trip endpoints using smartphone geodetic function or querying vehicle ECU over OBDII device
3) When authorized, establish a wireless link to the OBDII device, query and record VIN, create a trip report that includes all required parameters and send it to the carpool server

The CMA may also estimate and record fuel consumption along trip endpoints by reading fuel cycle parameters from vehicle ECU through OBDII device. Depending on available fuel cycle parameters, fuel consumption is estimated using the most suitable method.

Upon receiving a trip report from two or more CMAs, the carpool server must establish the following:

1) The carpool membership set
2) The carpool GHG emissions based on carpool sub-trip's fuel consumption data reported by CMAs
3) Carpool sub-trip distance
4) Vehicle VINs combined with EPA/manufacturer fuel efficiency. Vehicle VIN enables determination of vehicle EPA/manufactures estimated fossil fuel efficiency to estimate fuel consumption when OBDII based fuel consumption is not reliable or feasible.
5) The baseline emissions by assuming SOBT trips in absence of the carpool trip, based on the membership set and their registered SOBTs

All monitored data for emission reduction calculations must be archived in a secure and retrievable manner for at least two years after the end of the project crediting period.

10 REFERENCES

Consumption calculation of vehicles using OBD data by Adriano Alessandrini, Francesco Filippi, Fernando Ortenzi, AT Centre For Transport and Logistics, University of Rome “La Sapienza” Accessed at: http://www.epa.gov/ttnchie1/conference/ei20/session8/aalessandrini.pdf

Herfindahl index (HHI): http://www.justice.gov/atr/public/guidelines/hhi.html

US Census online tool: http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml

APPENDIX 1: USE OF GOOGLE MAPS OR SIMILAR SOFTWARE

Google Maps provides multiple route options between source and destination addresses with an estimate of travel time in current traffic conditions, travel time with no traffic and travel time with public transportation, walking or biking.

At the time of registration with the CMMS, or when an update to residence and/or work address is enacted by the member, the travel time and distance of the member's commute (ie, the trip from residential address to work, and back) may be obtained using Google Maps or similar software that is capable of providing the same information required by this annex. In order to obtain this information, the project proponent must select the route which provides the shortest travel time without traffic as the commuting route from the registered residential to the work address and the return trip. The travel time obtained from the commuting route must be compared with that from using public transportation, walking and biking (alternate transportation mode). Note that the query to Google Maps (or similar service) must be performed during typical member commute hours to obtain accurate and shorter travel times for the public transport modes. If the travel time using one of the alternate transportation modes is no more than 15 minutes compared to the commute using a car either to work or from work, *alternate transportation mode* is the mode of transportation in the baseline scenario for the member (see Section 6 above).

Where the CMMS is capable of querying services like Google Maps in real time during members' carpool trips, the CMMS may use the shortest in-traffic travel route as the SOBT route for the baseline scenario for the corresponding carpool trip. Note that the SOBT route is determined every time a carpool trip is made and may be different from time to time. This puts additional scalability requirement on CMMS and additional cost for the project proponent to subscribe to use some services. Results of such queries must be stored as part of the carpool trip data for review and data integrity checks.

DOCUMENT HISTORY

Version	Date	Comment
v1.0	17 April 2015	Initial version

VCS Methodology

VM0030

Methodology for Pavement Application using Sulphur Substitute

Version 1.0

15 May 2015

Sectoral Scopes 4, 6 & 7

Methodology developed by:

Shell Malaysia Trading Sdn Bhd

In parternship with:

Cap-Op Energy Inc.

Viresco Solutions Inc.

Table of Contents

1 SOURCES

This methodology is based on the *Quantification Protocol for the Substitution of Bitumen Binder in Hot Mix Asphalt Production and Usage v1.0*, issued under the Alberta Specified Gas Emitters Regulation. The methodology uses the latest version of the following CDM tools:

- *Combined tool to identify the baseline scenario and demonstrate additionality*
- *Tool for the demonstration and assessment of additionality*

In addition, technical and good practice guidance was obtained from Environment Canada's annual greenhouse gas (GHG) reporting, the US Envirnmental Protection Agency's (EPA) Emission Inventory, the Intergovernmental Panel on Climate Change (IPCC), the Canadian Association of Petroleum Producers (CAPP) and various other reliable sources of information pertaining to the hot mix asphalt industry. The good practice guidance and scienctific literature used to develop the methodology are presented in Section 10.

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

This methodology quantifies the GHG emission reductions achieved by the substitution of a proportion of the bitumen binder used in conventional hot asphalt paving with a sulphur product. The use of a sulphur product in place of a portion of bitumen binder reduces required quantities of aggregate and bitumen, reduces fuel usage due to reduced mix production temperatures and reduces GHG emissions from the hot mix plant stack and paving.

The sulphur product being substituted for asphalt must be either sulphur extended asphalt modifier (SEAM) pellets or a similar solid sulphur modifier composed of sulphur and small quantities of plasticizer and H_2S scavenger additives. Other additives such as carbon black could be used to impart particular characteristics to the final product. The product may also contain wax additives, used to further reduce hot mix production and compaction temperatures. This methdology applies to hot mix facilities using either formulation of SEAM (with and without wax additives). This methodology is not applicable to project proponents substituting other products for asphalt binder in paving mix. The methodology applies to new construction and overlaying of existing roads. Inclusion of reclaimed asphalt pavement (RAP) would reduce the need for virgin asphalt, so it is possible to combine RAP and SEAM.

A project applying this methodology is considered to be the GHG emissions reductions achieved from the production of sulphur extended asphalt for use in the paving of one or more paving segments. Projects that are applying thismethodology may include hot mix production facilities that do not exclusively produce sulphur-modified asphalts. However, any conventional hot mix asphalt procuded during the crediting period is not eligible for inclusion with the project. (

The project proponent may be the technology owner, hot mix asphalt producer/manufacturer, road owner, or other party associated with the production of sulphur-extended asphalt or development of paving segments paved with sulphur-extended asphalt.

Given that the project proponent could any one of entities listed above, clear right of use must be demonstrated through contractual agreement, or otherwise, in order to to avoid the risk of double counting with other participants in the supply chain.

The project proponent must develop the baseline scenario appropriately for projects that include multiple project activity instances (ie, multiple paving segments), ensuring that the baseline selected is appropriate for all projects to be included in the aggregated quantification.

The baseline scenario would be the production and use of conventional hot mix asphalt, whose composition of aggregate versus bitumen binder will vary depending on the type of road paved (eg, highway versus city street). The project activity could be implemented at existing hot mix facilities or implemented at new facilities as a best practice technology.

Note that as emission reductions generated by projects that apply this methodology are attributed partly to indirect emission from electricity production, projects developed in jurisdictions that have cap-and-trade programs require assessment to ensure double counting does not occur. Therefore, project proponents should be aware of the VCS rules on double counting when a proposed project occurs in a jurisdiction with a cap and trade program covering the electrivity sector, which might render the project unviable.

3 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions apply to this methodology:

Additive
Materials or substances that are included in an asphalt product which do not serve to bind the aggregate, rather they facilitate or modify the binder (or binder substitute) properties to better meet production requirements or product specifications

Aggrerate
Coarse particulate material including sand, gravel, crushed stone, slag, and recycled concrete which may be sourced from gravel pits, quarries and other local areas surrounding the hot mix facility

Binder

A waterproof adhesive that binds the aggregate together. Conventional binder is comprised of bitumen, but for the purposes of this methodology, the word binder may refer to a mix of bitumen and binder substitute.

Binder Substitute

Materials that serve to displace bitumen (the primary conventional binder used for hot mix asphalt production). These substitutes help extend supplies of non-renewable fossil fuels and may also provide other benefits (molten sulphur is an example of a binder substitute which provides lower mix plant temps as a benefit). Binder substitute may be sulphur extender, or an equivalent product.

Bitumen

A viscous liquid petroleum-based product, produced from the heavy crude oil refining and distillation process. Bitumen is also known as asphalt in some parts of the world.

Bitumen Handling Emissions

Intentional and unintentional GHG emissions during bitumen production, handling and storage from the joints, seals and other components of processing, piping and treatment equipment

Conventional Hot Mix Aphalt

A common mixture of asphalt binder and coarse and fine aggregate delivered from the hot mix facility to the silo or truck for load-out and delivery to the paving site. The majority of roads are constructed with conventional hot mix asphalt and operating temperature varying by local project conditions.

Paving Segment

The surface (road, trail, parking lot or other type of surface), specifiable in geographic extent, that is paved with the materials produced from the project activity

Reclaimed Asphalt Pavement (**RAP**)

Asphalt that is produced from feedstocks recovered from existing paved surfaces. RAP can be applied in-situ or recycled through a hot mix facility where it is blended with conventional hot mix asphalt or with a mix including sulphur solid modifers.

Solid Sulphur

The solid state form of elemental sulphur, with the chemical furmula S_8. Solid sulphur is a by-product of industrial processes, such as the desulphurization of natural gas and other hydrocarbon resources. Stockpiles of excess sulphur exist in hydrocarbon-producing regions of the world. Solid sulphur is not SEAM.

Sulphur Extended Asphalt Modifier (**SEAM**)

A solid sulphur extender that is composed of minimum 98 percent sulphur and small quantities of plasticizer and H_2S scavenger additives. SEAM is also referred to as sulphur modifier.

4 APPLICABILITY CONDITIONS

This methodology is applicable to the production and use of hot mix asphalt using a sulphur extender in the asphalt paving process, where the following conditions are met:

1. The baseline scenario is the production and use of hot mix asphalt for paving, and where solid sulphur is not used for paving or as any part of the paving process.
2. Under the baseline scenario, sulphur used in the project to produce hot mix asphalt is a byproduct of other industrial processes and is not produced for use as an extender or modifier in the paving process.
3. Project activities can be undertaken at either a new facility (greenfield site) or existing facility (brownfield site).
4. A proportion of the bitumen binder used in conventional hot mix asphalt production has been substituted with SEAM. This methodology is not applicable to activities that use other binder substitute products that replace bitumen; however, additives which facilitate the substitution of bitumen with SEAM are acceptable.
5. Production procedures must ensure a safe and functionally equivalent product to hot mix asphalt. This requires adherence to procedures issued by the SEAM manufacturer for the handling and storage of solid sulphur, handling and use of the SEAM, construction specifications and mix design. These specifications include appropriate handling temperatures and mix production temperatures. Additionally, any mix produced at temperatures exceeding the maximum allowable mix temperatures specified by the sulphur exptender manufacturer must be safely disposed of.
6. Asphalt products must meet all applicable legal and technical requirements. In the absence of technical specifications for asphalt, the project proponent must demonstrate that asphalt produced under the project scenario provides the equivalent function to asphalt that would have been produced under the baseline scenario.
7. The proportion of RAP used in the project scenario is equivalent to or less than the proporption of RAP used in the baseline scenario. RAP must be mixed at a hot mix facility (not insitu).
8. For projects that consist of multiple project activity instance (ie, multiple paving segments), all of the hot mix asphalt used in the project must have been produced at the same facility.

5 PROJECT BOUNDARY

The project boundary encompases the hot mix facility where the sulphur extended asphalt is produced, as well as the production and processing of bitumen and its additives.

Sources, sinks and reservoirs (SSRs) included in the project and baseline quantification include those that are within the hot mix facility , as well as others that are related to the processing and production of bitumen, bitumen extender, and the associated additives. A generalized process flow diagram of a typical project and baseline are presented below in Figures 1 and 2, respectively.

Figure 1: Project Process Flow Diagram

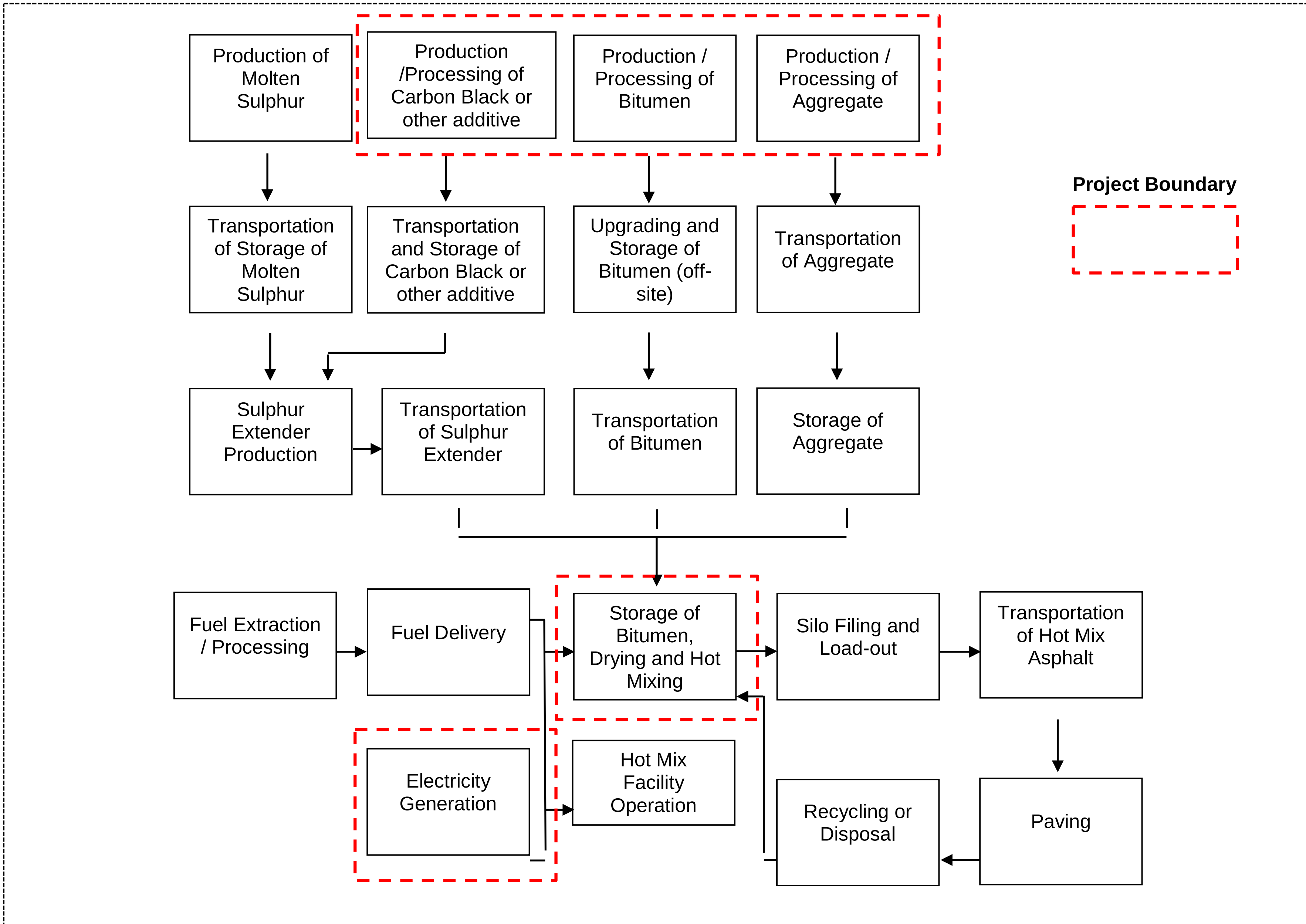


Figure 2: Baseline Process Flow Diagram

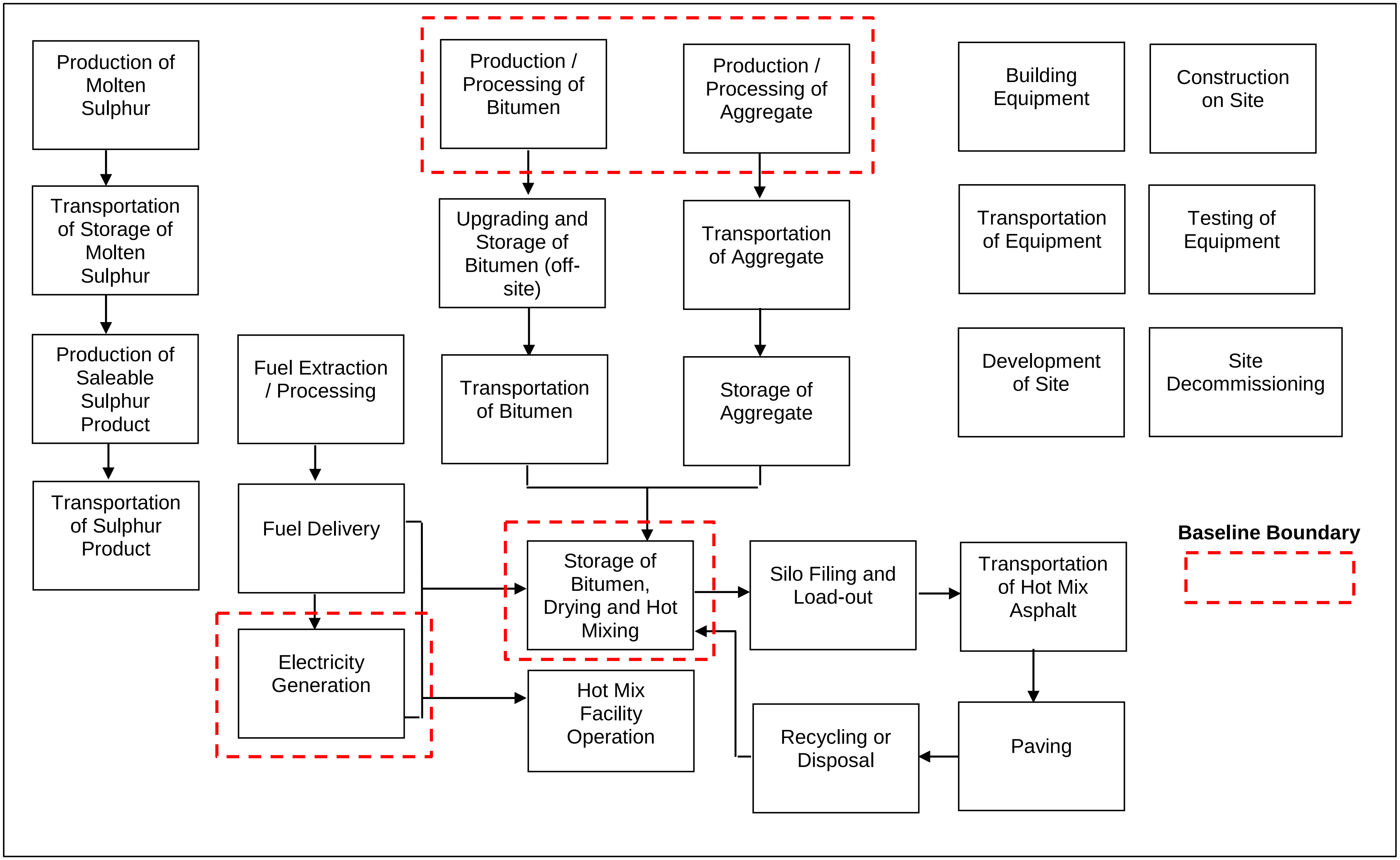


Table 1 below provides justification for the inclusion or exclusion of each of the potential SSRs in the project and baseline scenarios. The project proponent must justify the baseline and project SSRs selected for quantification in the project.

Table 1: GHG Sources, Sinks and Reservoirs

Source		Controlled, Related, or Affected	Gas*	Included	Justification/Explanation
Baseline	Production of molten sulphur	Related	CO_2	No	Excluded as the quantity of molten sulphur produced in the project and baseline scenarios are functionally equivalent. Sulphur is a by-product of gas processing and petroleum refining and would be produced in both the project and baseline scenarios in the same quantity.
			CH_4	No	
			N_2O	No	
	Production/ processing of bitumen	Related	CO_2	Yes	Emissions from the production/processing of bitumen used in asphalt production may be material and can be quantified.
			CH_4	Yes	
			N_2O	Yes	
	Production/Processing of Aggregate	Related	CO_2	Yes	Emissions from the production/processing of aggregate used in asphalt production may be material and may be quantified.
			CH_4	Yes	
			N_2O	Yes	
	Transportation and storage of molten sulphur	Related	CO_2	No	Emissions are based on the quantity of sulphur used in the project scenario, therefore an equivalent quantity of sulphur would be transported in both the project and baseline scenarios. The emissions under this SSR will be functionally equivalent in the project and baseline, as the emissions resulting from transporting the sulphur to the hot mix facility compared to the baseline storage location are negligible.
			CH_4	No	
			N_2O	No	
	Upgrading and storage of bitumen (off-site)	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario. This applies to fuel usage and fugitive emissions attributed to this SSR.
			CH_4	No	
			N_2O	No	

	Transportation of aggregate	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Production of saleable sulphur product	Related	CO_2	No	Emissions are based on the quantity of sulphur used in the project scenario, therefore an equivalent quantity of sulphur would be produced in both the project and baseline scenarios. The emissions under this SSR will be functionally equivalent in the project and baseline, as the production by sulphur processing facilities will remain the same.
			CH_4	No	
			N_2O	No	
	Transportation of sulphur product	Related	CO_2	No	Excluded as the emissions from transportation are negligible.
			CH_4	No	
			N_2O	No	
	Transportation of Bitumen	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Fuel Extraction/Processing	Related	CO_2	No	Excluded for conservativeness to ensure emission reductions from indirect emission sources are not credited to the project
			CH_4	No	
			N_2O	No	
	Transportation of Bitumen	Related	CO_2	No	Excluded for conservativeness to ensure emission reductions from indirect emission sources are not credited to the project
			CH_4	No	
			N_2O	No	
	Fuel delivery	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Electricity generation	Related	CO_2	Yes	Indirect emissions from electricity use may be a material source of emissions. The project proponent must include electricity in the methodology if it is demonstrated to be conservative.
			CH_4	Yes	
			N_2O	Yes	
	Storage of aggregate	Controlled	CO_2	No	Excluded for simplification. This is conservative as the emissions are
			CH_4	No	

			N_2O	No	higher under the baseline scenario.
	Storage of bitumen, drying and hot mixing	Controlled	CO_2	Yes	Included as the emissions may be material and may be quantified. Emissions are dependent on the hot mix temperatures and will therefore vary between the baseline and project scenarios. N_2O emissions are relevant for fuel combustion emissions quantified in this SSR.
			CH_4	Yes	
			N_2O	Yes	
	Hot mix facility operation	Controlled	CO_2	No	Excluded as the hot mix facility's operations will not be impacted by the project activity and will therefore be functionally equivalent in the project and baseline scenarios.
			CH_4	No	
			N_2O	No	
	Silo filling and load-out	Controlled	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Transportation of hot mix asphalt	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Paving	Controlled	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Recycling or disposal	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Building equipment	Related	CO_2	No	Emissions from building equipment are not material given the long project life, and the minimal building equipment typically required.
			CH_4	No	
			N_2O	No	
	Transportation of equipment	Related	CO_2	No	Emissions from transportation of equipment are not material given the long project life, and the minimal transportation of equipment typically required.
			CH_4	No	
			N_2O	No	
	Development of site	Related	CO_2	No	Emissions from development of site are not material given the long project
			CH_4	No	

			N_2O	No	life, and the minimal development of site typically required.
	Construction of site	Related	CO_2	No	Emissions from construction of site are not material given the long project life, and the minimal construction of site typically required.
			CH_4	No	
			N_2O	No	
	Testing of equipment	Related	CO_2	No	Emissions from testing of equipment are not material given the long project life, and the minimal testing of equipment typically required.
			CH_4	No	
			N_2O	No	
	Site decommissioning	Related	CO_2	No	Emissions from decommissioning are not material given the long project life, and the minimal decommissioning typically required.
			CH_4	No	
			N_2O	No	
Project	Production of molten sulphur	Related	CO_2	No	Excluded as the quantity of molten sulphur produced in the project and baseline scenarios are functionally equivalent. Sulphur is a by-product of gas processing and would be produced in both the project and baseline scenarios in the same quantity.
			CH_4	No	
			N_2O	No	
	Production/processing of carbon black or other additives	Related	CO_2	Yes	Emissions from the production of additives used in the sulphur extender product may be material and may be quantified.
			CH_4	Yes	
			N_2O	No	Emissions are negligible.
	Production/ processing of bitumen	Related	CO_2	Yes	Emissions from the production/processing of bitumen used in asphalt production may be material and may be quantified.
			CH_4	Yes	
			N_2O	Yes	
	Production/processing of aggregate	Related	CO_2	Yes	Emissions from the production/processing of aggregate used in asphalt production may be material and may be quantified.
			CH_4	Yes	
			N_2O	Yes	
	Transportation and storage of molten sulphur	Related	CO_2	No	Emissions are based on the quantity of sulphur used in the project scenario, therefore an equivalent quantity of sulphur would be transported in both the project and baseline scenarios.
			CH_4	No	
			N_2O	No	

					The emissions under this SSR will be functionally equivalent in the project and baseline, as the emissions resulting from transporting the sulphur to the hot mix facility compared to the baseline storage location are negligible.
	Transportation and storage of carbon black or other additives	Related	CO_2	No	Excluded as the emissions are negligible given the small quantities of additive consumed.
			CH_4	No	
			N_2O	No	
	Upgrading and storage of bitumen (off-site)	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario. This applies to fuel usage and fugitive emissions attributed to this SSR.
			CH_4	No	
			N_2O	No	
	Transportation of aggregate	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Sulphur extender production	Related	CO_2	No	Excluded for simplification. Since the emissions are based on the quantity of sulphur extender used, the emissions would be functionally equivalent under the baseline and project scenarios. The production process includes mixing and solidification of elemental sulphur which occurs in the baseline, therefore emissions are considered to be equivalent between project and baseline.
			CH_4	No	
			N_2O	No	
	Transportation of sulphur extender	Related	CO_2	No	Excluded as the emissions from transportation are negligible.
			CH_4	No	
			N_2O	No	
	Transportation of Bitumen	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Fuel Extraction/Proces	Related	CO_2	No	Excluded for conservativeness to ensure emission reductions from
			CH_4	No	

	sing		N_2O	No	indirect emission sources are not credited to the project
	Fuel Delivery	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Electricity generation	Related	CO_2	Yes	Indirect emissions from electricity use may be a material source of emissions. The project proponent must include electricity in the methodology if it is demonstrated to be conservative.
			CH_4	Yes	
			N_2O	Yes	
	Storage of aggregate	Controlled	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Storage of bitumen, drying and hot mixing	Controlled	CO_2	Yes	Included as the emissions may be material and may be quantified. Emissions are dependent on the hot mix temperatures and will therefore vary between the baseline and project scenarios. N_2O emissions are relevant for fuel combustion emissions quantified in this SSR.
			CH_4	Yes	
			N_2O	Yes	
	Hot mix facility operation	Controlled	CO_2	No	Excluded as the hot mix facility's operations will not be impacted by the project activity and will therefore be functionally equivalent in the project and baseline scenarios.
			CH_4	No	
			N_2O	No	
	Silo filling and load-out	Controlled	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Transportation of hot mix asphalt	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Paving	Controlled	CO_2	No	Excluded for simplification. This is conservative as the emissions are higher under the baseline scenario.
			CH_4	No	
			N_2O	No	
	Recycling or disposal	Related	CO_2	No	Excluded for simplification. This is conservative as the emissions are
			CH_4	No	

			N_2O	No	higher under the baseline scenario.

*Gas types listed are those that are relevant at least once to the project or baseline scenario. No refrigerants are relevant to this methodology.

The temporal project boundary includes the operation of a new or existing hot mix facility during the incorporation of a sulphur extender project. SSRs related to the construction and decommissioning of the hot mix facility are considered outside the scope of this methodology and have been excluded from quantification. This is reasonable given the minimal emissions associated with the construction and decommissioning phases and the long operational life of hot mix facilities.

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

The baseline scenario for projects applying this methodology is the production of conventional hot mix asphalt. The project proponent must demonstrate that this is the most plausible baseline for the project using the most recent version of the CDM *Combined tool to identify the baseline scenario and demonstrate additionality*. The project proponent must use the tool to identify all realistic and credible baseline alternatives, to identify barriers and to assess which alternatives are prevented by these barriers. In doing so, relevant local regulations governing the use of different technologies and technical specifications of concrete products must be taken into account.

Baseline scenarios that include RAP may be considered if the baseline scenario is one with an equivalent or lower proportion of RAP. The project proponent must demonstrate that the use of sulphur extender displaces conventional hot mix bitumen in the baseline scenario. The quantification methods provided in this document do not account for sulphur displacing RAP. Projects using RAP may adjust the volumes or proportions of bitumen displacement with justification, based on the results of the baseline analysis, to ensure a conservative assertion.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

Additionality must be assessed and demonstrated using the most recent version of the CDM *Combined tool to identify the baseline scenario and demonstrate additionality* or the CDM *Tool for the demonstration and assessment of additionality*.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

Emissions under the baseline scenario (in tonnes CO_2e) are determined using the following equation:

$$BE_y = \frac{(BE_{Bitumen} + BE_{Aggregate} + BE_{Production} + BE_{Electricity})}{1000} \quad (1)$$

Where:

BE_y = Baseline emissions in a given year y (t CO_2e)

$BE_{Bitumen}$ = Emissions due to the production and processing of bitumen (kg CO_2e)

$BE_{Aggregate}$ = Emissions due to the production and processing of aggregate (kg CO_2e)

$BE_{Production}$ = Emissions due to the storage of bitumen, drying and hot-mixing (k CO_2e)

$BE_{Electricity}$ = Emissions due to the generation of electricity for operating the hot mix facility (kg CO_2e)

The emissions due to the production and processing of bitumen are calculated as follows:

$$BE_{Bitumen} = \sum_x \left(MF_{Bitumen\ B} \times Mass_{Paving} \times EF\ Bit\ Production_x \times GWP_x\right) \quad (2)$$

Where:

$BE_{Bitumen}$ = Emissions due to the production and processing of bitumen (kg CO_2e)

$MF_{Bitumen\ B}$ = Mass fraction of bitumen consumed (kg / t of hot mix produced)

$Mass_{Paving}$ = Mass of hot mix asphalt produced (t)

$EF\ Bit\ Production_x$ = Emissions factor for bitumen production and processing for each GHG listed (kg GHG / kg bitumen)

GWP_x = Global warming potential for each GHG

x = Value for each GHG

The emissions due to the production and processing of aggregate are calculated as follows:

$$BE_{Aggregate} = \sum_x \left(MF_{Aggregate\ B} \times Mass_{Paving} \times EF\ Aggregate_x \times GWP_x\right) \quad (3)$$

Where:

$BE_{Aggregate}$ = Emissions due to the production and processing of aggregate (kg CO_2e)

$MF_{Aggregate\ B}$ = Mass fraction of aggregate consumed (kg / t of hot mix produced)

$Mass_{Paving}$ = Mass of hot mix asphalt produced (t)

$EF\ Aggregate_x$ = Emissions factor for aggregate production and processing for each GHG listed (kg GHG / kg aggregate)

GWP_x = Global warming potential for each GHG

x = Value for each GHG

The emissions due to the storage of bitumen, drying and hot mixing are calculated using the following equations.

$$BE_{Production} = BE_{Hot\ mix\ stack} + BE_{Fuel\ usage} \quad (4)$$

Where:

$BE_{Production}$ = Emissions due to the storage of bitumen, drying and hot-mixing (kg CO_2e)

$BE_{Hot\ mix\ stack}$ = Emissions from hot mix stack (kg CO_2e)

$BE_{Fuel\ usage}$ = Emissions from fuel usage (kg CO_2e)

The emissions from the hot mix stack are calculated as follows:

$$BE_{Hot\ mix\ stack} = MF_{BitumenB} \times Mass_{Paving} \times EF\ Mixer_{CH4} \times GWP_{CH4} \quad (5)$$

Where:

$BE_{Hot\ mix\ stack}$ = Emissions from hot mix stack (kg CO_2e)

$MF_{Bitumen\ B}$ = Mass fraction of bitumen consumed (kg / t of hot mix produced)

$Mass_{Paving}$ = Mass of hot mix asphalt produced (t)

$EF\ Mixer_{CH4}$ = Emissions factor for CH4 during mixing (kg CH4 / kg bitumen)

GWP_{CH4} = Global warming potential CH4

The emissions due to fuel usage during hot mixing are calculated as follows:

$$BE_{fuel\ usage} = \sum_{i,x} \left(Mass_{Paving} \times Vol\ Fuel\ Mixing_{i,B} \times EF\ Fuel_{i,x} \times GWP_x \right) \quad (6)$$

Where:

$BE_{fuel\ usage}$ = Emissions from fuel usage (kg CO_2e)

$Mass_{Paving}$ = Mass of hot mix asphalt produced (t)

$Vol\ Fuel\ Mixing_{i,\ B}$ = Volume of each type of fuel combusted (L, m3 or other / t of asphalt produced)

$EF\ Fuel_{i,\ x}$ = Emissions factor for fuel combustion (kg GHG / L, m3 or other)

x = Value for each GHG

i = Value for each fuel type applicable to project

The volumes of each type of fuel combusted during hot mixing are calculated based on the heating requirements for hot mixing and the theoretical volume of fuel needed to produce this heat, using the following equations:

$$Vol\ Fuel\ Mixing_i = Vol\ Fuel\ Mixing_{i\ Aggregate} + Vol\ Fuel\ Mixing_{i\ Bitumen} \quad (7)$$

$$Vol\ Fuel\ Mixing_{i\ Aggregate} = \frac{MF_{Aggregate,B} \times Mass_{Paving} \times C_{Aggregate} \times \left(T_{Hot\ mix} - T_{Aggregate}\right)}{HV_{Fuel\ i} \times Eff} + MF_{Aggregate,B} \times Mass_{Paving} \times Vol\ Fuel_{agg\ i} \quad (8)$$

$$Vol\ Fuel\ Mixing_{i\ Bitumen} = \frac{MF_{Bitumen,B} \times Mass_{Paving} \times\ C_{Bitumen} \times (T_{Hot\ mix} -\ T_{Bitumen})}{HV_{Fuel\ i} \times Eff} \quad (9)$$

Where:

Vol Fuel Mixing$_i$	=	Emissions from fuel usage (kg CO_2e)
Vol Fuel Mixing$_{i\ Aggregate}$	=	Mass of hot mix asphalt produced (t)
Vol Fuel Mixing$_{i\ Bitumen}$	=	Volume of each type of fuel combusted (L, m3 or other / t of asphalt produced)
EF Fuel$_{i,\ x}$	=	Emissions factor for fuel combustion (kg GHG / L, m3 or other)
x	=	Value for each GHG
i	=	Value for each fuel type applicable to project
MF$_{Aggregate,B}$	=	Mass fraction of aggregate consumed (kg / t of hot mix produced)
MF$_{Bitumen,\ B}$	=	Mass fraction of bitumen consumed (kg / t of hot mix produced)
Mass$_{Paving}$	=	Mass of hot mix asphalt produced (t)
C$_{Aggregate}$	=	Specific heat capacity of aggregate (kJ / kg °C)
C$_{Bitumen}$	=	Specific heat capacity of bitumen (kJ / kg °C)
T$_{Hotmix}$	=	Temperature of hot mix asphalt production (°C)
T$_{Aggregate}$	=	Temperature of aggregate (°C)
T$_{Bitumen}$	=	Temperature of bitumen (°C)
HV$_{Fuel\ i}$	=	Heating value of fuel consumed (kJ / m^3)
Eff	=	Fuel combustion and burner efficiency (%).
Vol Fuel$_{agg\ i}$	=	Volume of fuel combusted for aggregate drying (L, m^3 or other / kg of aggregate)

For projects where site-specific stack emissions sampling data is available, the project proponent must calculate emissions due to the storage of bitumen, drying and hot mixing under the baseline scenario as follows:

$$BE_{Hot\ mix\ stack} = \left(\frac{Mass_{Paving} \times EF\ Mixer_{CH4,B,SS}}{Rate_B}\right) GWP_{CH4} + \frac{Mass_{Paving} \times EF\ Mixer_{CO2,B,SS}}{Rate_B} \quad (10)$$

Where:

Mass$_{Paving}$	=	Mass of hot mix asphalt produced (tonne)

EF $Mixer_{CH4, B, SS}$	=	Site-specific mass emission rate of CH_4 from the hot mix stack (kg / hr) during conventional hot mix production
EF $Mixer_{CO2, B,SS}$	=	Site-specific mass emission rate of CO_2 from the hot mix stack (kg / hr) during conventional hot mix production
$Rate_B$	=	Production rate of conventional hot mix asphalt during stack sampling period (tonne per hour)
GWP_{CH4}	=	Global warming potential for CH_4

The emissions due to electricity generation for operating hot mix facility are calculated as follows:

$$BE_{Electricity} = Electricity_{B} \times EF_{Elec} \quad (11)$$

Where:

$Electricity_{B}$	=	Electricity used in operating the hot mix facility in the baseline (kWh)
EF_{Elec}	=	Emissions factor for electricity (kg CO_2e/kWh)

8.2 Project Emissions

Emissions under the project scenario (in tonnes CO_2e) are determined using the following equation:

$$PE_y = \frac{(PE_{Add} + PE_{Bitumen} + PE_{Aggregate} + PE_{Production} + PE_{Electricity})}{1000} \quad (12)$$

Where:

PE_y	=	Project emissions in a given year, y (tonne CO_2e)
PE_{Add}	=	Emissions due to the production and processing of carbon black or other additives used in hot mix production (kg CO_2e)
$PE_{Bitumen}$	=	Emissions due to the production and processing of bitumen (kg CO_2e)
$PE_{Aggregate}$	=	Emissions due to the production and processing of aggregate (kg CO_2e)
$PE_{Production}$	=	Emissions due to the storage of bitumen, drying and hot-mixing (kg CO_2e)
$PE_{Electricity}$	=	Emissions due to the generation of electricity for operating the hot mix facility (kg CO_2e)

The emissions due to the production and processing of carbon black or other additives used under the project scenario must be quantified, the following equation provides guidance:

$$PE_{add} = \frac{Mass_{SE} \times \%CB \times EF\ Production_{CO2}}{100} + \frac{Mass_{SE} \times \%CB \times EF\ Production_{CH4}}{100} GWP_{CH4} \quad (13)$$

Where:

PE_{Add}	=	Emissions due to the production and processing of carbon black or other additives used in hot mix production (kg CO_2e)

$Mass_{SE}$	=	Mass of sulphur extender consumed (kg)
%CB	=	Percent of additive (ie. carbon black) in the sulphur extender used (%)
EF $Production_{CO2}$	=	CO_2 emissions factor for additive production (kg CO_2 /kg additive)
EF $Production_{CH4}$	=	CH_4 emissions factor for additive production (kg CH_4/kg additive)
GWP_{CH4}	=	Global warming potential for CH_4

The emissions due to the production and processing of bitumen are calculated as follows:

$$PE_{Bitumen} = \sum_{x}(Mass_{Bitumen} \times EF\ Bit\ Production_{x} \times GWP_{x}) \tag{14}$$

Where:

$PE_{Bitumen}$	=	Emissions due to the production and processing of bitumen (kg CO_2e)
$Mass_{Bitumen}$	=	Mass of bitumen consumed (kg)
EF Bit $Production_x$	=	Emissions factor for bitumen production and processing for each GHG listed (kg GHG/kg bitumen).
GWP_x	=	Global warming potential for each GHG (CO_2, CH_4 and N_2O)
x	=	Value for each GHG (CO_2, CH_4 and N_2O)

The emissions due to the production and processing of aggregate are calculated as follows:

$$PE_{Aggregate} = \sum_{x}\left(Mass_{Aggregate} \times EF\ Aggregate_{x} \times GWP_{x}\right) \tag{15}$$

Where:

$PE_{Aggregate}$	=	Emissions due to the production and processing of aggregate (kg CO_2e)
$Mass_{Aggregate}$	=	Mass of aggregate consumed (kg)
EF $Aggregate_x$	=	Emissions factor for aggregate production and processing for each GHG listed (kg GHG/kg of aggregate).
GWP_x	=	Global warming potential for each GHG (CO_2, CH_4 and N_2O)
x	=	Value for each GHG (CO_2, CH_4 and N_2O)

The emissions due to the storage of bitumen, drying and hot mixing are calculated as follows:

$$PE_{Production} = PE_{Hot\ mix\ stack} + PE_{Fuel\ usage} \tag{16}$$

Where:

$PE_{Production}$	=	Emissions due to the storage of bitumen, drying and hot-mixing (kg CO_2e)

$PE_{Hot\ mix\ stack}$ = Emissions from hot mix stack (kg CO2e)

$PE_{Fuel\ usage}$ = Emissions from fuel usage (kg CO2e)

The emissions from the hot mix stack are calculated as follows:

$$PE_{Hot\ mix\ stack} = Mass_{Bitumen} \times EF\ Mixer_{CH4} \times GWP_{CH4} \tag{17}$$

Where:

$PE_{Hot\ mix\ stack}$ = Emissions from hot mix stack (kg CO2e)

$Mass_{Bitumen}$ = Mass of bitumen consumed (kg)

$EF\ Mixer_{CH4}$ = CH_4 emissions factor for bitumen used in asphalt production (kg CH_4 / kg bitumen).

GWP_{CH4} = Global warming potential for CH_4

The emissions due to fuel usage during hot mixing are calculated as follows:

$$PE_{Fuel\ usage} = \sum_{i,x} \left(Vol\ Fuel\ Mixing_i \times EF\ Fuel_{i,x} \times GWP_x \right) \tag{18}$$

Where:

$PE_{Fuel\ usage}$ = Emissions from fuel usage (kg CO2e)

$Vol\ Fuel\ Mixing_i$ = Volume of each type of fuel combusted during hot mixing (L, m3 or other)

$EF\ Fuel_{i,x}$ = Emissions factor for fuel combustion for each type of fuel used and GHG listed (kg GHG / L, m^3 or other).

GWP_x = Global warming potential for each GHG (CO_2, CH_4 and N_2O)

x = Value for each GHG (CO_2, CH_4 and N_2O)

i = Value for each fuel type applicable to a project

For projects where site-specific stack emissions sampling data are available, the project proponent may calculate emissions due to the storage of bitumen, drying and hot mixing under the project scenario as follows:

$$PE_{Hot\ mix\ stack} = \frac{Mass_{Paving} \times EF\ Mixer_{CH4,SS} \times GWP_{CH4}}{Rate} + \frac{Mass_{Paving} \times EF\ Mixer_{CO2,SS}}{Rate} \tag{19}$$

Were:

$Mass_{Paving}$ = Mass of hot mix asphalt produced (tonne)

$EF\ Mixer_{CH4,\ SS}$ = Site-specific mass emission rate of CH_4 from the hot mix stack (kg/hr)

$EF\ Mixer_{CO2,\ SS}$ = Site-specific mass emission rate of CO_2 from the hot mix stack (kg/hr)

Rate = Production rate of hot mix asphalt during stack sampling period (tonne per hour)

GWP_{CH4} = Global warming potential for CH_4

The emissions due to electricity generation for operating hot mix facility are calculated as follows:

$$PE_{Electricity} = Electricity_P \times EF_{Elec} \tag{20}$$

Where:

$Electricity_P$ = Electricity used in operating the hot mix facility in the project (kWh)

EF_{Elec} = Emissions factor for electricity (kg CO_2e/kWh)

8.3 Leakage

There are no known sources of leakage for this project activity.

8.4 Summary of GHG Emission Reduction and/or Removals

The emission reductions for this project activity are calculated as follows:

$$ER_y = BE_y - PE_y \tag{21}$$

Where:

ER_Y = Net GHG emission reductions and/or removals in year y

BE_Y = Baseline emissions in year y

PE_y = Project emissions in year y

9 MONITORING

9.1 Data and Parameters Available at Validation

The following data must be made available at validation by the project proponent. Default values may vary according to the physical location of the project activity. The project proponent must provide evidence and justification that the values presented here are applicable to the project, or provide and justify project-specific values as needed.

Should the data parameters listed below not be available at the time of validation, the project proponent must provide a plan for determining and/or monitoring the data during the project. All parameters used must be reviewed at each verification period to ensure the most current and conservative value is used in calculations.

Data / Parameter	$C_{Bitumen}$
Data unit	kJ / kg C°
Description:	Specific heat capacity of bitumen
Equations	9
Source of data	Value of physical or chemical property
Value applied	2.093 kJ / kg C°

Justification of choice of data or description of measurement methods and procedures applied	Based on thermodynamic principles and the theoretical heat capacity of bitumen.
Purpose of data	Calculation of baseline emissions
Comments	The project proponent must determine if the bitumen used for the project is consistent with the definition provided in Section 3.0.

Data / Parameter	$C_{Aggregate}$
Data unit	kJ / kg C°
Description	Specific heat capacity of aggregate
Equations	8
Source of data	Value of physical or chemical property
Value applied	0.837 kJ/kg C°
Justification of choice of data or description of measurement methods and procedures applied	Based on thermodynamic principles and the theoretical heat capacity of aggregate.
Purpose of data	Calculation of baseline emissions
Comment	The project proponent must determine if the aggregate used for the project is consistent with the definition provided in Section 3

Data / Parameter	$EF_{Aggregate}$
Data unit	kg GHG/kg of aggregate
Description	Emission factors for aggregate production
Equations	3, 15
Source of data	Estimation; the emission factor must be obtained or calculated from relevant industry data according to the most conservative and regionally appropriate approach possible.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	The emissions intensity of aggregate production may vary depending on the type and source of the aggregate used. National emissions factors, or emissions factors created by local industry using internationally accepted procedures should be used preferentially. Regional emissions factors

	may be used if National or local emissions factors are unavailable. International emissions factors may be used if regional emissions factors are unavailable. In the absence of an appropriate emission factor, a zero value may be assumed. This is conservative as aggregate consumption is higher in the baseline scenario.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	$EF_{Bit\ Production}$
Data unit	kg GHG / kg Bitumen
Description	Emission factors for bitumen production
Equations	14
Source of data	Estimation; the emission factor must be obtained or calculated from relevant industry data according to the most conservative and regionally appropriate approach possible.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	National emissions factors, or emissions factors created by local industry using internationally accepted procedures should be used preferentially. Regional emissions factors may be used if national or local emissions factors are unavailable. International emissions factors may be used if regional emissions factors are unavailable. In the absence of any default value, the reference values provided by CAPP (Appendix A, Table A1) may be used.
Purpose of data	Calculation of project emissions
Comment	The project proponent must ensure that the default value is representative of the type and composition of bitumen used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	$EF_{MixerCH4}$
Data unit	kg CH_4/kg bitumen
Description	Methane emission factor for bitumen use in hot mixing
Equations	
Source of data	Estimation; the emission factor must be obtained or calculated from relevant industry data according to the most conservative and regionally appropriate approach possible.
Value applied	5 and 17
Justification of choice of data or description of measurement methods and procedures applied	Emission factors are available from equipment manufacturers or governing authorities. National emissions factors, or emissions factors created by local industry using internationally accepted procedures should be used preferentially. Regional emissions factors may be used if national or local emissions factors are unavailable. International emissions factors may be used if regional emissions factors are unavailable. In the absence of manufacturer-specific emission factors, the emission factors listed in Appendix A, Table A2 must be used
Purpose of data	Calulcation of baseline emissions Calculation of project emissions
Comment	The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	EF_{Fuel}
Data unit	kg GHG (CO_2, CH_4, N_2O) per L, m3 or other of each type of fuel used
Description	Emission factors for fuel combustion
Equations	6, 9 and 18
Source of data	Estimation; the emission factor must be obtained or calculated from relevant industry data according to the most conservative and regionally appropriate approach

	possible.In the absence of local or regional data, reference values must be obtained from the most recent version of the IPCC guidelines for National Greenhouse Gas Inventories.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	National emissions factors, or emissions factors created by local industry using internationally accepted procedures should be used preferentially. Regional emissions factors may be used if national or local emissions factors are unavailable. International emissions factors may be used if regional emissions factors are unavailable.In the absence of local or regional data, reference values must be obtained from the most recent version of the IPCC guidelines for National Greenhouse Gas Inventories
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics.This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	$T_{hot\ mix}$
Data unit	Degree Celsius
Description	Temperature of hot mix asphalt production
Equations	9
Source of data	Estimation based on product requirements, site specific technical analysis or measurement
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Default values from industry common practice or from applicable road construction standards must be used when available. Or, it may be measured at the hot mix facility prior to the use of sulphur extender.
Purpose of data	Calculation of baseline emissions
Comment	Default value is 144 deg C based on asphalt production in

	Canada. A temperature of 142 deg C may be more appropriate for softer asphalt or low-volume highways. The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as project description deviation) due to the availability of more recent information. For paving segement developers, a method may be specified to determine a parameter for aggregation of multiple paving segments rather than specifying a value for all paving segments included in the aggregation at the time of validation.

Data / Parameter	$T_{Aggregate}$
Data unit	Degree Celsius
Description	Temperature of aggregate
Equations	9
Source of data	Estimation based on product requirements, or site specific technical analysis or measurement
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	If from a brownfield site, this parameter may have been measured at the hot mix facility prior to the use of the sulphur extender. If at a greenfield site,or a brownfield site that is not able to measure then default values may be available from industry best practice.
Purpose of data	Calculation of baseline emissions
Comment	The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information. For paving segement developers, a method may be specified to determine a parameter for aggregation of multiple paving segments rather than specifying a value for all paving segments included in the aggregation at the time of validation.

Data / Parameter	$T_{Bitumen}$
Data unit	Degree Celsius
Description	Temperature of bitumen
Equation	9
Source of data	Estimation based on product requirements, site specific technical analysis or measurement
Applied value	
Justification of choice of data or description of measurement methods and procedures applied	Default values may be available from industry common practice. May also be measured at the hot mix facility prior to the use of sulphur extender.
Purpose of data	Calculation of baseline emissions
Comment	The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information. For paving segement developers, a method may be specified to determine a parameter for aggregation of multiple paving segments rather than specifying a valuefor all segments included in the aggregation at the time of validation.

Data / Parameter	HV_{Fuel}
Data unit	kJ / m^3
Description	Heating value of fuel
Equations	9
Source of data	Value of physical or chemical property
Applied value	
Justification of choice of data or description of measurement methods and procedures applied	Accepted value for the type of fuel used to power the burner.
Purpose of data	Calculation of baseline emissions
Comment	For natural gas the default value is 38 095 kJ/m^3. For other fuel types an appropriate default value should be used. The

	project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics.

Data / Parameter	Eff
Data unit	%
Description	Fuel combustion and burner efficiency
Equations	9
Source of data	Estimation based on manufacturer specification, site specific technical analysis or measurement
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Efficiencies may be available from manufacturer's specifications or as part of the facility's monitoring processes. In the absence of project-specific data, default values should be used. Default values are high and would result in a conservative estimation of emission reductions.
Purpose of data	Calculation of baseline emissions
Comment	Default values are 80% (combustion) and 80% (burner) for a total efficiency of 64%. The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	$Vol\ Fuel_{agg}$
Data unit	L, m^3 or other per kg of aggregate
Description	Volume of fuel combusted for aggregate drying
Equations	9
Source of data	Estimation based on dryer manufacturer specification, site specific technical analysis or measurement
Applied value	
Justification of choice of data or	Value may be obtained from manufacturer specifications

description of measurement methods and procedures applied	for fuel consumption.
Purpose of data	Calculation of baseline emissions
Comment	The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information. For paving segement developers, a method may be specified to determine a parameter for aggregation of multiple paving segments rather than specifying a value. for all paving segments included in the aggregation at the time of validation. This value is dependent on the moisture content (%) of the aggregate, and may be estimated based on manufacturer's specifications for fuel consumption.

Data / Parameter	EF Production
Data unit	kg (CO_2, CH_4) per kg of additive
Description	Emission factors for the production of additives
Equations	13
Source of data	Estimation based on additive manufacturer specification or project-specific technical analysis
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Reference values may be obtained from IPCC guidelines. Values are dependent on the production process.
Purpose of data	Calculation of project emissions
Comment	IPCC emission factors are provided in Appendix A, Table A3. The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	EF_{Elec}
Data unit	kg CO_2e per kWh
Description	Emissions factor for electricity
Equations	11 and 20
Source of data	Estimation, reference values must be obtained from the relevant national GHG inventory. The value used should be consistent with the source of generation. In the absence of local or regional data, reference values may be obtained from the most recent version of the IPCC guidelines for National Greenhouse Gas Inventories.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Review of best practice guidance and accepted standards. Reference values are generally available.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	$Electricity_{B}$
Data unit	kWh
Description	Electricity used for operating hot mix facility in the baseline
Equations	11
Source of data	Measurement
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Metering of electricity may be direct or by a utility provider. Measurement should be continuous, with monthly aggregation.
Purpose of data	Calculation of baseline emissions
Comment	This parameter may be updated over the course of the

	crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	EF Mixer $_{CO2, B, SS}$, EF Mixer $_{CH4, B, SS}$
Data unit	kg per hour
Description	Mass emission rate of CO_2 and CH_4 from the hot mix stack
Equestions	10 and 19
Source of data	Measurement
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Must be calculated from three years of historical data from third-party sampling of the mass emission rate when the facility was using conventional hot mix asphalt. Direct measurement and average of three years of historical data provides for reasonable quality assurance. It is the responsibility of the project proponent and third party sampler to determine the length of each test and analysis methodology that ensures the accuracy of the sampling procedure. Justification should be provided. The stack sampling of emissions should include only mixing process emissions for any type of plant design (drum or batch mix plants). At least three years of annual stack sampling data should be available from third party sampling when the facility was producing conventional hot mix asphalt for baseline quantification.
Purpose of data	Calculation of baseline emissions Calulcation of project emissions
Any comment	If sampling results are expressed as total organics, conversion to methane may be accomplished by using the default organic composition values of 27% methane for drum mix and 47% methane for batch mix plants, according to guidance provided by the US EPA. The project proponent must ensure that the default value used is representative of the type and composition of product used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	$Rate_B$
Data unit	Tonne per hour
Description	Production rate of conventional hot mix asphalt during the stack sampling period
Equations	10
Source of data	Measurement
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Must be calculated from average of three years of historical data from third-party sampling of the mass emission rate when the facility was producing conventional hot mix asphalt. Direct measurement and average of three years of historical data provides for reasonable quality assurance.
Purpose of data	Calculation of baseline emissions
Comment	This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	%CB
Data unit	Percent
Description	Percent of additive in sulphur extender
Equations	13
Source of data	Estimation, default value estimated from sulphur extender production process.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	May be determined from sulphur extender producer.
Purpose of data	Calculation of project emissions
Comment	This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data Unit / Parameter	$MF_{Bitumen\ B}$
Data unit	kg per tonne of hot mix asphalt produced under the baseline scenario

Description	Mass fraction of bitumen consumed under the baseline scenario
Equations	2, 5 and 9
Source of data	Estimation based on paving segment specifications or measurement
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Default values may be estimated based on available data. The bitumen content of conventional hot mix asphalt may be estimated using: 1. local or regional paving standards or industry data for the type of road being paved; 2. The actual mix composition for the hot mix facility if known. Note that this parameter does not include RAP.
Purpose of data	Calculation of baseline emissions
Comment	These parameters may become out of date. For paving segement developers, aggregation of multiple paving segments may specify a method to determine this parameter for each paving segment rather than specifying a value for all paving segments included in the aggregation at the time of validation.

Data / Parameter	$MF_{Aggregate\ B}$
Data unit	kg per tonne of hot mix asphalt produced under the baseline scenario
Description	Mass fraction of aggregate
Equations	3 and 9
Source of data	Estimation based on project specifications or measurement
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Default values may be obtained from local industry records for the type of road being paved, or actual mix composition for the hot mix facility may be used if known. Note that this parameter does not include RAP.
Purpose of data	Calculation of baseline emissions
Comment	The project proponent must ensure that the default value is representative of the type and composition of product used in the project. Default values must be sourced from

	recognized, credible sources and be geographically and temporally relevant to project specifics. These parameters may become out of date. For paving segement developers, aggregation of multiple paving segments may specify a method to determine this parameter for each paving segment rather than specifying a value for all paving segments included in the aggregation at the time of validation.

9.2 Data and Parameters Monitored

The following data parameters will be monitored during the project.

Data / Parameter	$Mass_{Paving}$
Data unit	tonne
Description	Mass of hot mix asphalt produced
Equations	2, 3, 5, 6, 9, 10 and 19
Source of data	Measurement
Description of measurement methods and procedures to be applied	The project proponent may measure the mass of hot mix asphalt produced in one of three ways: 1. Direct metering ; 2. Reconciliation of quantity delivered to trucks for load-out; 3. Reconciliation of mass of hot mix asphalt applied or distance paved and thickness of paving within a given time period.
Frequency of monitoring/recording	Continuous or per batch, totalized per project with monthly reconciliation if project duration is longer than one month.
QA/QC procedures to be applied	Regular calibration as per requirements of scales ensures quality metering. Cross-checking of metered mass vs. trucking manifests or logs confirms quality measurement on an on-going basis between calibration intervals.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Calculation method	N/A
Comment	None

Data / Parameter	$Vol\ Fuel\ Mixing_{Bitumen}$
Data unit	L, m^3 or other

Description	Volume of each type of fuel combusted during the project for storage of bitumen, drying and hot mixing
Equations	6 and 7
Source of data	Measurement in the project scenario, calculation in the baseline scenario
Description of measurement methods and procedures to be applied	The project proponent may measure the volume of fuel consumed in one of two ways: 1. Direct metering or reconciliation of volumes received and in storage; 2. Reconciliation of volume of fuel purchased within a given time period.
Frequency of monitoring/recording	Totalized per project with monthly reconciliation if project duration is longer than one month.
QA/QC procedures to be applied	Regular calibration and maintenance as per requirements of meter manufacturers ensures quality metering. Cross-checking of metered or purchased volumes vs. theoretical fuel use on annual or quarterly basis. Minor variations should be immaterial on an quarterly or annual basis. Long term trends should align with theoretical expectations and remain consistent on a per volume of product basis.
Purpose of data	Calculation of baseline emissions
Calculation method	N/A
Comment	Overall hot mix facility fuel usage may be used given that bitumen storage, aggregate drying and hot mixing will likely represent the majority of fuel usage for a facility.

Data / Parameter	$Mass_{SE}$
Data unit	kg
Description	Mass of sulphur extender product consumed
Equations	13
Source of data	Measurement
Description of measurement methods and procedures to be applied	The project proponent may measure the mass of sulphur extender in one of two ways: 1. Direct metering or reconciliation of mass received; 2. Reconciliation of mass of sulphur extender purchased within a given time period. This provides a reasonable estimate when direct measurement may not be used.

Frequency of monitoring/recording	Per batch or totalized per project with monthly reconciliation if project duration is longer than one month.
QA/QC procedures to be applied	Regular calibration as per requirements of scales ensures quality metering. Cross-checking of metered mass vs. trucking manifests or logs confirms quality measurement on an on-going basis between calibration intervals.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	None

Data / Parameter	$Mass_{Bitumen}$
Data unit	kg
Description	Mass of bitumen consumed
Equations	14 and 17
Source of data	Measurement
Description of measurement methods and procedures to be applied	The project proponent may measure the mass of bitumen consumed in one of two ways: 1. Direct metering of quantity of bitumen used for hot mixing; 2. Reconciliation of mass received
Frequency of monitoring/recording	Per batch or totalized per project with monthly reconciliation if project duration is longer than one month.
QA/QC procedures to be applied	Regular calibration as per requirements of scales ensures quality metering. Cross-checking of metered mass vs. trucking manifests or logs confirms quality measurement on an on-going basis between calibration intervals.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	None

Data / Parameter	$Mass_{Aggregate}$
Data unit	kg
Description	Mass of aggregate consumed
Equations	15
Source of data	Measurement

Description of measurement methods and procedures to be applied	The project proponent may measure the mass of aggregate consumed in several ways: 1. Direct metering of mass of aggregate consumed at the hot mix facility; 2. Reconciliation of mass received; 3. Calculation as the difference between the mass of hot mix asphalt produced and the sum of mass of binder and all additives consumed; or 4. Reconciliation of mass of aggregate purchased within a given time period.
Frequency of monitoring/recording	Per batch or totalized per project with monthly reconciliation if project duration is longer than one month.
QA/QC procedures to be applied	Regular calibration as per requirements of scales ensures quality metering. Cross-checking of metered mass vs. trucking manifests or logs confirms quality measurement on an on-going basis between calibration intervals.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	None

Data / Parameter	$Electricity_{P}$
Data unit	kWh
Description	Electricity used for operating hot mix facility in the project
Equations	20
Source of data	Measurement
Description of measurement methods and procedures to be applied	Metering of electricity may be direct or by a utility provider. Measurement should be continuous, with monthly aggregation.
Frequency of monitoring/recording	Totalized per project with monthly reconciliation if project duration is longer than one month.
QA/QC procedures to be applied	Electricity utility standard maintenance and calibration procedures apply. Cross-checking of metered values versus engineering estimates or theoretical electricity usage values ensures accuracy between calibration intervals.
Purpose of data	Calculation of project emissions
Calculation method	N/A

Comment	None

Data / Parameter	EF Mixer $_{CO2, SS}$, EF Mixer $_{CH4, SS}$
Data unit	kg per hour
Description	Mass emission rate of CO_2 and CH_4 from the hot mix stack
	19
Source of data	Measurement
Description of measurement methods and procedures to be applied	Sampling on an annual basis by a third party. Direct measurement with this sampling frequency provide for reasonable quality assurance. Stack monitoring should be conducted at a point that includes process emissions from mixing only, and may not include ducted emissions from fuel combustion or any other emission source from the facility.
Frequency of monitoring/recording	At least annually
QA/QC procedures to be applied	Regular calibration and maintenance as per requirements of meter manufacturers ensures quality metering. Cross-checking of metered values versus engineering estimates or theoretical emission values ensures accuracy between calibration intervals. It is the responsibility of the project proponent and third party sampler to determine the length of each test and analysis methodology that ensures the accuracy of the sampling procedure. Justification should be provided. The stack sampling of emissions should include only mixing process emissions for any type of plant design (drum or batch mix plants). At least three years of annual stack sampling data should be available from third party sampling when the facility was producing conventional hot mix asphalt for baseline quantification.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	If sampling results are expressed as total organics, conversion to methane may be accomplished by using the default organic composition values of 27% methane for drum mix and 47% methane for batch mix plants, according to guidance provided by the US EPA. The project proponent must ensure that the default value used is representative of the type and composition of product

	used in the project. Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	Rate
Data unit	Tonne per hour
Description	Production rate of hot mix asphalt during the stack sampling period
Equations	19
Source of data	Measurement
Description of measurement methods and procedures to be applied	Sampling on an annual basis by a third party. Direct measurement and this sampling frequency provides for reasonable quality assurance
Frequency of monitoring/recording	Frequency to match EF Mixer $_{CO2,\ SS}$, EF Mixer $_{CH4,\ SS}$ sampling frequency
QA/QC procedures to be applied	Regular calibration as per requirements of scales ensures quality metering. Cross-checking of metered mass vs. trucking manifests or logs confirms quality measurement on an on-going basis between calibration intervals.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	None

9.3 Description of the Monitoring Plan

The project proponent must develop a monitoring plan detailing the procedures for data capture, measurement and reporting of all the data parameters listed in Section 9.2. In general, data quality management must include sufficient data capture such that the mass and energy balances may be easily performed with the need for minimal assumptions and use of contingency procedures. The data should be of sufficient quality to fulfill the quantification requirement and be substantiated by company records for the purpose of verification.

The project proponent must establish and apply quality management procedures to manage data and information. Written procedures should be established for each measurement task outlining responsibility, timing and record location requirements. The greater the rigour of the management system for the data, the more easily an audit will be conducted for the project.

Record keeping practices must be established that include:

- Electronic recording of values of logged primary parameters for each measurement interval;
- Printing of monthly back-up hard copies of all logged data;
- Written logs of operations and maintenance of the project system including notation of all shut-downs, start-ups and process adjustments;
- Retention of copies of logs and all logged data for at least two years after the end of the crediting period; and
- Keeping all records available for review by a validation/verification body.

The project proponent must also develop a QA/QC plan to add confidence that all measurements and calculations have been made correctly. QA/QC measures that may be implemented include, but are not limited to:

- Protecting monitoring equipment (eg, temperature gauges)
- Protecting records of monitored data (hard copy and electronic storage) – appropriate record keeping and retention;
- Checking data integrity on a regular and periodic basis (manual assessment, comparing redundant metered data, and detection of outstanding data/records) done to ensure mix formulation is followed and to ensure appropriate payments are made (pay only for what is delivered to site);
- Providing sufficient training to operators to perform maintenance and calibration of monitoring devices as road building staff must have appropriate training to operate the mix plant in such a manner to ensure the right mix is created, meeting the road agency's specifications;
- Establish minimum experience and requirements for operators in charge of project and monitoring; and
- Performing recalculations to make sure no mathematical errors have been made.

In general, data accuracy is inherently addressed in this methodology because the inputs into road-building are metered to ensure mix specifications are met. There is a high degree of certainty in the measurements of binder and aggregate employed to ensure quality of product. Operating temperatures are also closely monitored due to worker health and safety regulatory requirements, and to ensure no wastage of fuel. Fuel quality specifications are provided upon purchase, and these provide the parameters necessary to calculate fuel GHG intensity. The costs of all the inputs into the road are also borne by the contractor, and are monitored and recorded to ensure appropriate payments and cost recoveries are made. The nature of road-building projects therefore provides a high degree of confidence in the data used with the methodology, and addresses significant uncertainties.

- Parameters relevant to the project quantification for which confidence intervals cannot easily be generated include those listed below. Project proponents must demonstrate the factors or values used in the project are appropriately conservative based on the uncertainty of the actual parameter during the project.$T_{hot\ mix}$
- $T_{aggregate}$
- $T_{bitumen}$
- $MF_{bit,\ B}$
- $EF_{Agg,\ x}$
- $EF_{Bit\ Production,\ x}$
- $MF_{Aggregate,\ B}$
- EF Mixer $_{CH4}$
- EF $_{Fuel,\ i,\ x}$
- Eff
- Vol Fuel $_{agg,\ i}$
- EF Production$_{x}$
- EF_{Elec}
- %CB

Methods used by the project proponent for estimating uncertainty should be based on recognized statistical approaches such as those described in the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. Where applicable, confidence deductions applied should use conservative factors such as those specified in the CDM Methodology Panel guidance on addressing uncertainty in its *Thirty Second Meeting Report*, Annex 14.

The project proponent should address uncertainties in measured values by ensuring that meters are appropriately calibrated as prescribed by the manufacturer.

10 REFERENCES

The good practice guidance and best science used to develop the quantification methodology are presented below in Table 5.

Table 2: Good Practice Guidance

Document Title	Publishing Body/Date	Description
ISO 14064-2:2006:	International	ISO 14064-2:2006 specifies principles and

Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements	Organization for Standardization (ISO)	requirements and provides guidance at the project level for quantification, monitoring and reporting of activities intended to cause greenhouse gas (GHG) emission reductions or removal enhancements. It includes requirements for planning a GHG project, identifying and selecting GHG sources, sinks and reservoirs relevant to the project and baseline scenario, monitoring, quantifying, documenting and reporting GHG project performance and managing data quality. This document was used to develop the protocol document and full life cycle analysis of the project and baseline scenarios.
National Inventory Report, 1990-2008 - Greenhouse Gas Sources and Sinks in Canada	Environment Canada, 2010	On behalf of the Government of Canada, Environment Canada develops and publishes annually Canada's GHG inventory. The inventory reporting format is based on international reporting methods agreed to by the Parties to the UNFCCC, using the procedures of the Intergovernmental Panel on Climate Change (IPCC). Emission factors for fossil fuel combustion from this document were used to quantify the emissions from hot mixing and aggregate drying in the project and baseline scenarios.
Alberta Offset System Offset Credit Project Guidance Document	Alberta Environment, 2008	This Offset Credit Project Guidance Document is one of a series of guidance documents prepared for the Specified Gas Emitters Regulatory Framework. The purpose of this Guide is to outline the process and requirements for undertaking offset projects in Alberta.
Emission Factor Documentation For AP-42 Section 11.1, Hot Mix Asphalt Production	US EPA, 2005	Discussion of GHG and VOC emissions and emissions of other air contaminations from hot mix asphalt production. Includes development of emission factors delineated for various process steps and for batch and drum hot mix facilities. Emission factors from asphalt handling were derived from this document. This document was also used to determine which emission sources and sinks at the hot mix asphalt facility would be

		the most significant.
Emission Inventory Improvement Program: Asphalt Paving, Vol. 3, Chapter 17.	US EPA, 2001	Discussion of GHG and VOC emissions and emissions of other air contaminations from hot mix asphalt production. Includes development of emission factors delineated for various process steps and for batch and drum hot mix facilities. Emission factors from asphalt handling were derived from this document. This document was also used to determine which emission sources and sinks at the hot mix asphalt facility would be the most significant.
Multi-pollutant Emission Reduction Analysis Foundation (MERAF) for the Hot-mix Asphalt Sector.	Environment Canada and the Canadian Council of Ministers of Environment (CCME), 2002	This report provides background technical information on the Canadian Hot-Mix Asphalt Sector. It includes a profile of the industry, current and projected emissions from the sector, domestic and international emission standards, best available pollution prevention and control techniques, and possible emission reduction options. This document was used to outline provincial regulations and measurement requirements, and to gain an understanding of common industry practices across Canada.
IPCC Guidelines for National Greenhouse Gas Inventories, Ch. 3, Chemical Industry Emissions.	Intergovernmental Panel on Climate Change (IPCC), 2006	This report provides guidance on estimating greenhouse gas emissions that result from the production of various inorganic and organic chemicals for which there are significant contributions to greenhouse gas emission levels. Included in this chapter are emission factors for carbon black production. Emission factors for the production of carbon black and an understanding of the production process were obtained from this document.
Performance Properties of Paving Mixtures made with Modified Sulphur Pellets. International Society for Asphalt Pavements (ISAP).	International Society for Asphalt Pavement (ISAP), 2008	Discussion of the history of sulphur extended asphalt (SEA) pavement, the development of SEAM, test results for SEAM performance, and the risks and impacts associated with its use. Description of the development of SEAM and the potential impacts and issues associated with

		its use were retrieved from this document.
Cost and Energy Audit of Sulphur Extended Asphalt Paving Construction.	SUDIC and Alberta Transportation, 1984	This report assesses the actual cost and energy usage associated with sulphur extended asphalt (SEA) pavement construction on a large scale commercial project. This document was used to compare SEAM and SEA and to gain an understanding of the potential energy requirements associated with hot mix asphalt production and paving.
Occupational Hygiene Survey: Sulphur-Extended Asphalt Paving Project.	Alberta Transportation, 1981	This report summarizes the gas emission observed during asphalt and SEAM paving projects. This document was used to compare SEAM and SEA and to gain an understanding of the potential risks associated with hot mix asphalt production and paving.
A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H_2S) Emissions by the Upstream Oil and Gas Industry	Canadian Association of Petroleum Producers (CAPP), 2004	A detailed inventory of GHG emissions from the upstream oil and gas sector in Canada with detailed explanations of the methodologies and data sources used. Provides emission factors for the production, processing and combustion of a range of fossil fuel products. Emission factors for the production of bitumen and an understanding of the production process were obtained from this document.
Emission Inventory Guidebook: Processes in Wood, Paper Pulp, Food, Drink and Other Industries, Road Paving with Asphalt	European Environment Agency (EEA), 2006	This report provides a review of the air emissions from various types of asphalt paving mix including hot mix, cutback and liquefied asphalt. This document was used to gain a better understanding of the key emission sources and sinks and potential for variation across different regions and at different sites.

Gravel and Lightly Surfaced Road Resurfacing Projects Quantification Protocol	Alberta Environment, 2008	The Alberta Offset System quantification protocol for gravel and lightly surfaced road resurfacing projects uses an emission factor for aggregate production derived from Statistics Canada, the Aggregates and Quarry Products Association and the Canadian Technical Asphalt Association. References for these documents are provided below: Statistics Canada. (1998). Canadian Minerals Handbook. Canadian Technical Asphalt Association. (2005). The Environmental Road of the Future: Analysis of Energy Consumption and Greenhouse Gas Emissions. Aggregate and Quarry Products Industry. (2006). A Sustainable Development Report from the Aggregate and Quarry Products Industry.
Handling and Storage of Solid Sulphur, Production, Handling and Use of Seam Paving Mixtures, SEAM Construction Specifications, SEAM Mix Design and completion of the Plant Site Checklist for safe plant use.	Shell Sulphur Solutions	These documents outline the requirements for safe handling and use of hot mix asphalt using SEAM as a binder. Documents were referenced and included in the methodology as a requirement for its use, to ensure safe handling and production of hot mix asphalt.
Quantification Protocol for the Substitution of Bitumen Binder in Hot Mix Asphalt Production and Usage	Alberta Environment, October 2009	The Alberta Offset System quantification protocol the substitution of bitumen binder in hot mix asphalt production and usage was used as a general guide to baseline and project process flow diagrams and relevant sources, sinks and reservoirs. Global warming potential and specific heat capacity of bitumen and aggregate figures were taken from this protocol.
Fifth edition of the US EPA's AP-42, *Compilation of Air Pollutant Emission Factors*. In Volume 1: *Stationary Point and Area Sources" - Chapter 11.1 (Hot Mix Asphalt Plants),* dated April 2004.	U.S. EPA, 2004	This document was used as a reference for projects where site-specific stack emissions sampling data are available

APPENDIX 1: EMISSIONS FACTORS

Bitumen Production

Values for bitumen production as listed below in Table A1 were obtained from volume 1 of the technical report *A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H_2S) Emissions by the Upstream Oil and Gas Industry* dated September 2004 completed by Clearstone Engineering Ltd. on behalf of the Canadian Association of Petroleum Producers (CAPP). These values were taken from Table 4, entitled 'Summary of emission intensity factors presented by sub-sector of the UOG sector for 2000'. These emissions factors are typical for bitumen production in Canada, and may vary according to geographic location and the refinery. The project proponent must ensure that the emission factors used are applicable to the project.

Table A1: Emission Intensity of Bitumen Production

Heavy Crude Thermal Production		
Emissions Factor (CO_2)	594.2	kg CO_2 / m^3
Emissions Factor (CH_4)	3.75	kg CH_4 / m^3
Emissions Factor (N_2O)	0.009	kg N_2O / m^3

Hot Mixing

Emission factors for hot mixing listed below in Table A2 were derived from the fifth edition of the US EPA's AP-42, *Compilation of Air Pollutant Emission Factors*. In Volume 1: *Stationary Point and Area Sources - Chapter 11.1 (Hot Mix Asphalt Plants),* dated April 2004. Emission factor units for methane are kg/Mg of hot mix asphalt produced.[1]

Table A2: Emission Intensity of Hot Mixing

Plant Type	CH_4	Units
Natural Gas Batch	0.0037	kg / Mg of HMA produced
Natural Gas Drum Mix	0.006	kg / Mg of HMA produced
No. 2 Fuel Oil Batch Mixer	0.0037	kg / Mg of HMA produced
No. 2 Fuel Oil Drum Mixer	0.006	kg / Mg of HMA produced

Carbon Black Production

Values for carbon black production listed below in Table A3 were obtained from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Industrial Processes and Product Use.[2]

[1] Information retrieved from Table 11.1-6 and Table 11.1-8, for batch or drum mix, respectively.
[2] Please refer to Table 3.23 and 3.24

The majority of the world's carbon black is produced by the furnace black process. Emission factors for both production methods are equivalent.

Table A3: Emission Intensity of Carbon Black Production

Production Process	CO_2			Units
	Primary Feedstock	Secondary Feedstock	Total Feedstock	
Furnace Black	1.96	0.66	2.62	kg / kg carbon black
Thermal	4.59	0.66	5.25	kg / kg carbon black
Production Process	CH_4			Units
No Thermal Treatment	0.0287			kg / kg carbon black
Thermal treatment (default)	0.00006			kg / kg carbon black

DOCUMENT HISTORY

Version	Date	Comment
v1.0	15 May 2015	Initial version

VCS Methodology

VM0031

Methodology for Precast Concrete Production using Sulphur Substitute

Version 1.0

15 May 2015

Sectoral Scopes 4 & 6

Methodology developed by:

Shell Malaysia Trading Sdn Bhd

In partnership with:

Cap-Op Energy Inc.

Viresco Solutions Inc.

Table of Contents

1 SOURCES

This methodology is based on the draft *Quantification Protocol for the Use of Sulphur Concrete in Precast Applications v0.4*, issued under the Alberta Specified Gas Emitters Regulation. The methodology references the following CDM tools:

- *Combined tool to identify the baseline scenario and demonstrate additionality*
- *Tool for the demonstration and assessment of additionality*

In addition, technical and good practice guidance was obtained from Environment Canada's annual GHG reporting, the US EPA's Emission Inventory, the Intergovernmental Panel on Climate Change (IPCC), and various other reliable sources of information pertaining to the concrete production industry. The good practice guidance and best science used to develop the quantification methodology are presented in Section 10.

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

Concrete is a commonly used material for infrastructure, industrial and construction applications, consisting of aggregate (rock and sand), water and cement. The production of calcium and/or magnesium carbonate-derived cement (often from limestone) releases significant amounts of greenhouse gases (GHG).

Traditional cementitious binders derived from limestone and clay rely on the chemical bonds formed upon contact with water to bind together aggregate material (sand and rock) to form concrete. This binder (clinker) is a key component of cement. The production of clinker results in the release of a significant amount of GHG from two main sources: process emissions and combustion emissions. Carbon dioxide process emissions occur as a by-product of the calcination process, where a calcium or magnesium carbonate such as limestone is heated with clay to form clinker (primarily calcium oxide) and carbon dioxide. Additional GHG emissions occur because heat for the calcination process is normally supplied via the combustion of fossil fuels, releasing carbon dioxide, methane and nitrous oxide as a result.

Portland cement can be completely substituted with modified heated sulphur to form a stable, hard concrete product, avoiding the process and combustion emissions associated with the manufacture of Portland cement.

This methodology is applicable to processes that involve the substitution of calcium and/or magnesium carbonate-derived cement, known as Portland cement, with an alternative binder, such as a modified heated sulphur product, during the production of concrete and other concrete-based products such as pre-cast pipe, paving stones, slabs and tanks. This methodology is not applicable to projects employing standard poured-in-place concrete production processes, or supplementary cementing material (SCM) products.

For the purposes of this methodology, a project is considered a set or series of pre-cast concrete products, produced at one facility, where the pre-cast products have similar functional specifications to the same pre-cast products in the baseline scenario. The project may consist of emission reductions from several product sets or series if they are all cast at the same facility, provided the baseline scenario selected is appropriate for all products to be included in the project.

The baseline scenario is specified as the production of concrete using traditional cementitious binders derived from limestone and clay that rely on the chemical bonds formed upon contact with water to bind together aggregate material (sand and rock). This binder (clinker) is a key component of Portland cement.

The project proponent may be the technology owner, facility owner, agent or otherwise of products produced with sulphur concrete. Right of use must be established and demonstrated at the project level as specified and required by the VCS rules. Where the project proponent is not the owner of the precast concrete facility (eg, is the technology owner, agent of the products produced, or the end user), there must exist a contractual agreement, or otherwise, between the project proponent and the relevant parties to avoid the risk of double counting with other participants in the supply chain. Note that as emission reductions generated by projects that apply this methodology are attributed partly to indirect emission from electricity production, projects developed in jurisdictions that have cap-and-trade programs require assessment to ensure double counting does not occur. Therefore, the project proponent must be aware of the VCS rules on double counting when a proposed project occurs in a jurisdiction with a cap and trade program covering the electrivity sector, which might render the project unviable.

3 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions apply to this methodology:

Aggregate
Materials or substances that are included in an concrete product which do not serve to bind the aggregate, rather they facilitate or modify the binder (or binder substitute) properties to better meet production requirements or product specifications.
Aggregates including fly ash and slag are cementitious materials partially displacing Portland cement in the baseline product, however can also be included in sulphur concrete products.

Binder
Material that serves as an adhesive that binds with the aggregate to form concrete

Concrete
Composite building material made from the combination of aggregate and a cement binder

Portland Cement
Finely ground, usually grey-coloured mineral powder that when mixed with water, acts as a glue to bind together aggregate to form concrete

Precast Products
Form of construction where concrete is cast in a reusable mould or form, which is then cured in a controlled environment. Examples of precast products include paving stones, planters, traffic barriers, holding tanks and retaining walls, among many others.

Sulphur Cement
Product composed of molten elemental sulphur and a proprietary modifier that acts as a glue to bind together aggregate to form sulphur concrete. Sulphur cement requires no water to form sulphur concrete.

4 APPLICABILITY CONDITIONS

This methodology is applicable to the production of sulphur concrete for precast applications where the following conditions are met:

1. The baseline scenario is the production of precast concrete products using Portland cement, as demonstrated using the procedure set out in Section 6.
2. The project activity may take place at existing (retrofitted) or new (greenfield) precast concrete production facilities.
3. The use of recycled concrete is not eligible in either the baseline or project scenario.
4. The handling, storage, mix production temperature and other key factors specified by the manufacturer for the proper and safe use of sulphur cement have been followed by the project proponent.
5. The resulting sulphur concrete product meets all applicable legal and technical requirements. In the absence of technical specifications for concrete, the project proponent must demonstrate that sulphur concrete produced under the project scenario provides the equivalent function to concrete that would have been produced under the baseline scenario.
6. The pouring and forming processes must be comparable between the baseline and project scenarios for an equivalent product. The quantity of aggregate used (on a mass basis) in the baseline scenario must be comparable to the quantity of aggregate used in the project scenario for an equivalent product.

7. For projects that consist of multiple project activity instances (ie, multiple pre-cast concrete production lines), all concrete used and all concrete products must have been produced from the same facility.

5 PROJECT BOUNDARY

Sources, sinks and reservoirs (SSRs) included in project and baseline quantification include those that are within the project site (the physical, geographic location of the cement production facility), as well as others that are off-site.

The project proponent must account for:

- Direct emissions avoided by displacing Portland cement production and use with sulphur cement production and use
- Direct emissions due to fuel combustion at the precast concrete facility for:
    - Heating of aggregate.
    - Additional heating of the sulphur additive.
- Direct emissions due to fuel combustion and process emissions outside the precast concrete facility for:
    - Production of the sulphur modifier;.
    - Transport of the modifier and modified sulphur product.
- Indirect emissions due to the generation of electricity generation (if applicable).
- Indirect emissions due to the degassing of sulphur (if applicable).

A generalized process flow diagram of a typical project and baseline are presented in below Figure 1 and Figure 2 respectively.

Figure 1: Flow Diagram of Baseline Emissions

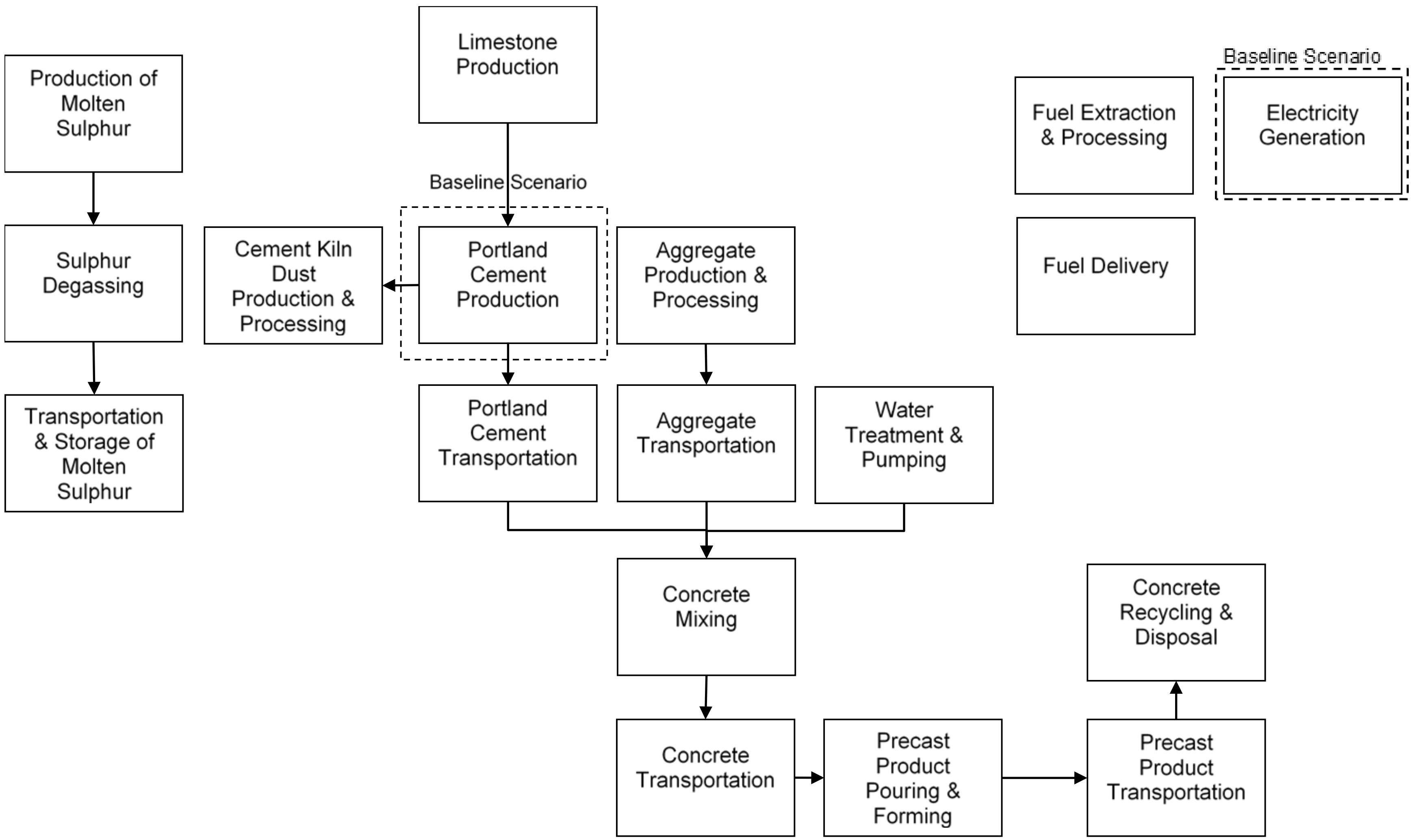
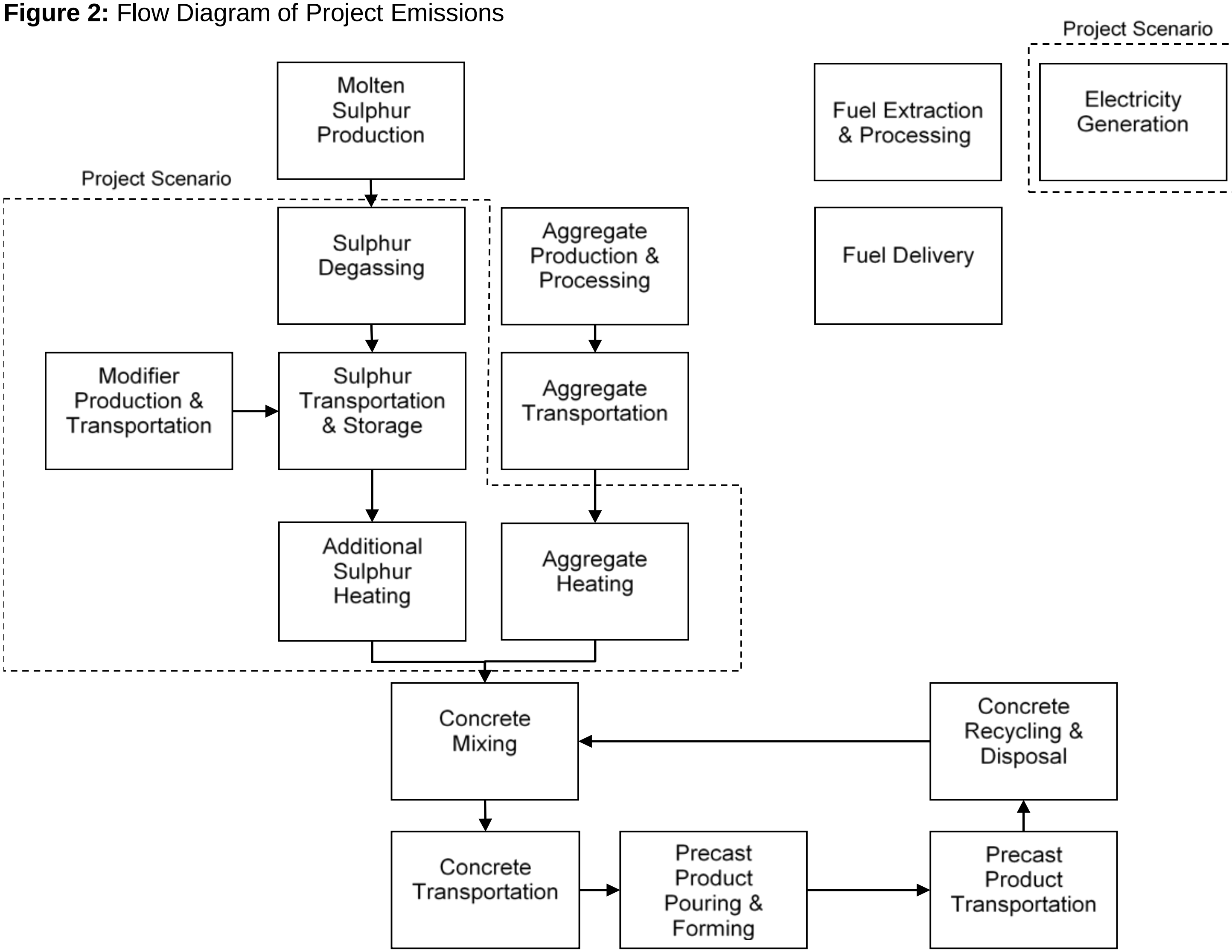


Figure 2: Flow Diagram of Project Emissions



The SSRs represented in Figures 1 and 2 above were compared and the relevancy evaluated to determine if they must be included or excluded from the quantification methodology. Table 1 below provides justification for the inclusion or exclusion of each of the potential SSRs in the project and baseline scenarios. The project proponent must justify the baseline and project SSRs selected for quantification in the project.

Table 1: GHG Sources, Sinks and Reservoirs

Source		Controlled, Related, or Affected	Gas	Included	Justification/Explanation
Baseline	Production of molten sulphur	Related	CO_2	No	Excluded as the quantity of molten sulphur produced in the project and baseline scenarios are functionally equivalent. Sulphur is a by-product of gas processing and petroleum refining and would be produced in both the project and baseline scenarios in the same quantity.
			CH_4	No	
			N_2O	No	
	Sulphur degassing	Related	CO_2	No	If sulphur degassing was occurring in the baseline scenario, it will continue under the project scenario and emissions will be equivalent. Project-specific emissions from sulphur degassing are accounted for in the project scenario, therefore it is conservative to exclude this SSR.
			CH_4	No	
			N_2O	No	
	Transportation and storage of molten sulphur	Related	CO_2	No	If transportation and storage of molten sulphur was occurring in the baseline, it will continue under the project scenario and will be equivalent. Project-specific emissions from the transportation and storage of molten sulphur are accounted for in the project scenario, therefore it is conservative to exclude this SSR.
			CH_4	No	
			N_2O	No	
	Limestone production	Related	CO_2	No	Less limestone will be produced in the project scenario and therefore emissions will be lower in the project scenario. The emissions from this SSR are relatively low and difficult to estimate accurately. Exclusion of this SSR is conservative.
			CH_4	No	
			N_2O	No	
	Portland cement	Related	CO_2	Yes	The production of Portland cement in the baseline scenario has relevant emissions and
			CH_4	Yes	

Source		Controlled, Related, or Affected	Gas	Included	Justification/Explanation
	production		N_2O	Yes	must be included.
	Cement kiln dust production and processing	Related	CO_2	No	Cement kiln dust (CKD) refers to the portion of the cement raw materials that does not become part of the clinker. CO_2 might be emitted from CKD that is not recycled to the Portland cement production process. CKD is not produced in the project scenario, therefore it is conservative to exclude its production and processing related emissions.
			CH_4	No	
			N_2O	No	
	Portland cement transportation	Related	CO_2	No	The quantity of Portland cement that is transported in the project scenario would be less than the quantity in the baseline scenario; therefore it is conservative to exclude these emissions.
			CH_4	No	
			N_2O	No	
	Aggregate production and processing	Related	CO_2	No	Excluded as the same quantity of aggregate would be produced and processed in the project and baseline scenarios.
			CH_4	No	
			N_2O	No	
	Transportation of aggregate	Related	CO_2	No	Excluded as the same quantity of aggregate would be transported in the project and baseline scenarios.
			CH_4	No	
			N_2O	No	
	Water treatment and pumping	Related	CO_2	No	Emissions from this SSR are avoided in the project scenario. This emission reduction is not the focus of this methodology. Emissions are excluded as it is conservative to do so.
			CH_4	No	
			N_2O	No	
	Fuel extraction/processing	Related	CO_2	No	Fuel production and extraction emissions are higher in the baseline than in the project and hence conservative to exclude.
			CH_4	No	
			N_2O	No	
	Fuel delivery	Related	CO_2	No	The quantity of fuel consumed in the baseline scenario for the production of Portland cement will be greater than the quantity of fuel consumed in the project scenario for mixing sulphur concrete. Emissions are excluded as it is conservative to do so.
			CH_4	No	
			N_2O	No	
	Electricity generation	Related	CO_2	Yes	Indirect emissions from electricity use may be a significant source of emissions. The project
			CH_4	Yes	

Source		Controlled, Related, or Affected	Gas	Included	Justification/Explanation
			N_2O	Yes	proponent must include electricity in the methodology if it is demonstrated to be conservative.
	Concrete mixing	Controlled	CO_2	No	The process for concrete mixing is equivalent in the baseline and project scenarios.
			CH_4	No	
			N_2O	No	
	Concrete transportation	Controlled	CO_2	No	The same quantity of concrete will be transported in the baseline and project scenarios.
			CH_4	No	
			N_2O	No	
	Precast product pouring and forming	Controlled	CO_2	No	The process for pouring and forming will not change between the baseline and project scenarios.
			CH_4	No	
			N_2O	No	
	Precast product transportation	Affected	CO_2	No	There is no difference in the transportation related emissions between the baseline and project scenarios.
			CH_4	No	
			N_2O	No	
	Concrete recycling or disposal	Affected	CO_2	No	Excluded for simplification. Recycling emission reductions are not applicable to this method and disposal emissions are equivalent between project and baseline.
			CH_4	No	
			N_2O	No	
Project	Production of molten sulphur	Related	CO_2	No	Excluded as the quantity of molten sulphur produced in the project and baseline scenarios are functionally equivalent. Sulphur is a by-product of gas processing and would be produced in both the project and baseline scenarios in the same quantity
			CH_4	No	
			N_2O	No	
	Sulphur degassing	Related	CO_2	Yes	If sulphur degassing is occurring as a result of the project and the producer would otherwise not be degassing the sulphur, the emissions will be additional to the baseline scenario.
			CH_4	Yes	
			N_2O	Yes	
	Transportation and storage of molten sulphur	Related	CO_2	Yes	Transportation and storage emissions in the project scenario are deemed to be additional to baseline scenario transportation and storage and must be included.
			CH_4	Yes	
			N_2O	Yes	
	Modifier	Related	CO_2	Yes	Emissions associated with the production and

Source		Controlled, Related, or Affected	Gas	Included	Justification/Explanation
	production and transportation		CH_4	Yes	transportation of the sulphur modifier is directly related to the project and must be included.
			N_2O	Yes	
	Aggregate production and processing	Related	CO_2	No	Excluded as the same quantity of aggregate would be produced and processed in the project and baseline scenarios.
			CH_4	No	
			N_2O	No	
	Transportation of aggregate	Related	CO_2	No	Excluded as the same quantity of aggregate would be transported in the project and baseline scenarios.
			CH_4	No	
			N_2O	No	
	Fuel extraction and processing	Related	CO_2	No	Fuel extraction and production used for Additional sulphur heating in the project will be less than baseline fuel extraction and production and therefore conservative to exclude.
			CH_4	No	
			N_2O	No	
	Fuel delivery	Related	CO_2	No	Excluded as the emissions from transportation are likely negligible.
			CH_4	No	
			N_2O	No	
	Electricity generation	Related	CO_2	Yes	Indirect emissions from electricity use may be a significant source of emissions. The project proponent must include electricity in the methodology if it is demonstrated to be conservative.
			CH_4	Yes	
			N_2O	Yes	
	Additional sulphur heating	Controlled	CO_2	Yes	Any heat derived from sources that emit greenhouse gases is additional to the baseline scenario and must be included.
			CH_4	Yes	
			N_2O	Yes	
	Aggregate heating	Controlled	CO_2	Yes	Any heat derived from sources that emit greenhouse gases is additional to the baseline scenario and must be included.
			CH_4	Yes	
			N_2O	Yes	
	Concrete mixing	Controlled	CO_2	No	The process for concrete mixing is equivalent in the baseline and project scenarios.
			CH_4	No	
			N_2O	No	
	Concrete transportation	Controlled	CO_2	No	The same quantity of concrete will be transported in the baseline and project
			CH_4	No	

Source		Controlled, Related, or Affected	Gas	Included	Justification/Explanation
			N_2O	No	scenarios.
	Precast product pouring and forming	Controlled	CO_2	No	The process for pouring and forming will not change between the baseline and project scenarios.
			CH_4	No	
			N_2O	No	
	Precast product transportation	Controlled	CO_2	No	There is no difference in the transportation related emissions between the baseline and project scenarios.
			CH_4	No	
			N_2O	No	
	Concrete recycling or disposal	Controlled	CO_2	No	Excluded for simplification. Recycling emission reductions are not applicable to this method and disposal emissions are equivalent between project and baseline.
			CH_4	No	
			N_2O	No	

*Gas types listed are those that are relevant at least once to the project or baseline scenario. No refrigerants are relevant to this methodology.

The temporal project boundary includes the operation of an existing or new precast concrete facility during the incorporation of a sulphur binder. SSRs related to the construction and decommissioning of the facility are considered outside the scope of this methodology and have been excluded from quantification. This is reasonable given the minimal emissions associated with the construction and decommissioning phases and the long operational life of the facility.

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

The baseline scenario for projects applying this methodology is the production of precast concrete products using Portland cement. The project proponent must demonstrate that this is the most reasonable and credible baseline for their project using the most recent version of the CDM tool *Combined tool to identify the baseline scenario and determine additionality*. The project proponent must use this tool to identify all realistic and credible baseline alternatives, and to identify barriers and to assess which alternatives are prevented by these barriers. In doing so, relevant local regulations governing the use of different technologies, and technical specifications of concrete products must be taken into account.

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

Additionality must be assessed and demonstrated using the latest version of the CDM tools *Combined tool to identify the baseline scenario and demonstrate additionality* or *Tool for the demonstration and assessment of additionality.*

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

The production of clinker results in the release of significant process GHG emissions and combustion GHG emissions. Carbon dioxide process emissions occur as a by-product of the calcination process, where a calcium or magnesium carbonate such as limestone is heated with clay to form clinker (primarily calcium oxide) and carbon dioxide. The heat required for the calcination process is typically supplied from the combustion of fossil fuels, resulting in the emission of further carbon dioxide as well as smaller amounts of methane and nitrous oxide.

Baseline quantification in this methodology is projection based, which uses projections of reductions or removals in the project to estimate the baseline activity that would have occurred in the absence of the project. The calculation of the emissions related to the production of Portland cement in the baseline scenario will be based on the mass of sulphur cement used in the project scenario. An equivalency factor will be used to provide functional equivalence between the mass of sulphur cement and Portland cement. Finally, an emission factor representing the mass of carbon dioxide equivalent greenhouse gas emissions per tonne of Portland cement displaced will be applied.

Emissions under the baseline scenario (in tonnes CO_2e) are determined using the following equation:

$$BE_y = \frac{BE_{Portland} + BE_{Electricity}}{1000} \quad (1)$$

Where:

BE_y = Baseline emissions in a given year (y) (t CO_2e)

$BE_{Portland}$ = Emissions due to the production of Portland cement (kg CO_2e)

$BE_{Electricity}$ = Emissions due to electricity generation for the production of Portland cement (kg CO_2e)

The emissions due to the production of Portland cement under the baseline scenario are calculated as follows:

$$BE_{Portland} = Mass_{Precast} \times \%_{PC} \times EF_{Portland\ Cement\ Production} \quad (2)$$

Where:

$BE_{Portland}$ = Emissions due to the production of Portland cement (kg CO_2e)

$Mass_{Precast}$ = Mass of finished precast products containing sulphur cement (t)

$\%_{PC}$ = Ratio of Portland cement used in the finished precast product (unitless)

$EF_{Portland\ Cement\ Production}$ = Emission factor for the production of Portland cement (kg CO_2e/t)

The emission factor for Portland cement production are calculated as follows:

$$EF_{Portland\ Cement\ Production} = \frac{Mass_{Clinker}}{Mass_{Cement}} \times EF_{Clinker} \quad (3)$$

Where:

$EF_{Portland\ Cement\ Production}$ = Emission factor for the production of Portland cement (kg CO_2e/t)

$Mass_{Clinker}/Mass_{Cement}$ = Clinker to cement ratio (unitless)

$EF_{Clinker}$ = Emission factor of clinker (kg CO_2e/t)

The emissions due to electricity generation for the production of Portland cement under the baseline scenario are as follows:

$$BE_{Electricity} = Electricity_{B} \times EF_{Elec} \quad (4)$$

Where:

$BE_{Electricity}$ = Emissions due to electricity generation for the production of Portland cement (kg CO_2e)

$Electricity_{B}$ = Electricity used for the production of Portland cement (kWh)

EF_{Elec} = Emissions factor for electricity (kg CO_2e/kWh)

8.2 Project Emissions

Emissions under the project scenario (in tonnes CO_2e) are determined using the following equation:

$$PE_y = \frac{PE_{Degassing} + PE_{Additional\ S\ Heating} + PE_{Agg\ Heating} + PE_{S\ Trans\&Storage} + PE_{Modifier} + PE_{Elec}}{1000} \quad (5)$$

Where:

PE_y = Project emissions in a given year (y)

$PE_{Degassing}$ = Emissions due to sulphur degassing (kg CO_2e)

$PE_{Additional\ S\ Heating}$ = Emissions due to the additional heating requirements of sulphur concrete (kg CO_2e)

$PE_{Agg\ Heating}$ = Emissions due to heating the aggregate (kg CO_2e)

$PE_{STrans\&Storage}$ = Emissions due to the transportation and storage of sulphur (kg CO_2e)

$PE_{Modifier}$ = Emissions due to the production and transportation of the sulphur modifier (kg CO_2e)

$PE_{Electricity}$	=	Emissions due to the generation of electricity for use in the precast sulphur concrete facility (kg CO_2e)

The emissions due to sulphur degassing under the project scenario are calculated as follows:

$$PE_{Degassing} = \sum_{x,k}\left(Vol\ Fuel_{DG,k} \times EF\ Fuel_{k,x} \times GWP_x\right) + \left(Vol_{vent\ gas} \times MF_{CO2} \times \frac{m_{CO2}}{V_{STP}}\right) \quad (6)$$

Where:

$PE_{Degassing}$	=	Emissions due to sulphur degassing (kg CO_2e)
Vol $Fuel_{k,DG}$	=	Volume of each type of fuel combusted for degassing (L, m^3 or other)
EF $Fuel_{k,x}$	=	Emissions factor for fuel combustion for each type of fuel (k) used and GHG (x) listed (kg CO_2e/L, m^3 or other)
$Vol_{vent\ gas}$	=	volume of degassing vent gas incinerated (m^3)
MF_{CO2}	=	Molar fraction of CO_2 in degassing vent gas incinerated (%)
M_{CO2}	=	Molar mass of CO_2 (kg/mol)
V_{STP}	=	Volume of one kg-mole of an ideal gas at standard temperature and pressure (m^3)
GWP_x	=	Global warming potential for each GHG (kg CO_2e)
x	=	Value for each GHG (CO_2, CH_4 and N_2O)

The emissions for additional heating of sulphur are calculated as follows:

$$PE_{Additional\ S\ Heating} = \sum_{x,k}\left(Vol\ Fuel_{AH,k} \times EF\ Fuel_{k,x} \times GWP_x\right) \quad (7)$$

Where:

$PE_{Additional\ S\ Heating}$	=	Emissions due to the additional heating requirements of sulphur concrete (kg CO_2e)
$VolFuel_{k,AH}$	=	the volume of each type of fuel combusted for additional sulphur heating (L, m^3 or other)
EF $Fuel_{k,x}$	=	the emissions factor for fuel combustion for each type of fuel (k) used and GHG (x) listed (kg CO_2e/L, m^3 or other)
GWP_x	=	Global warming potential for each GHG (kg CO_2e)
x	=	Value for each GHG (CO_2, CH_4 and N_2O)

The emissions for heating of aggregate are calculated as follows:

$$PE_{Agg\ Heating} = \sum_{x,k}\left(Vol\ Fuel_{AG,k} \times EF\ Fuel_{k,x} \times GWP_x\right) \quad (8)$$

Where:

$PE_{Agg\ Heating}$	=	Emissions due to heating the aggregate (kg CO_2e)
$VolFuel_{k,AG}$	=	Volume of each type of fuel combusted for aggregate heating (L, m^3 or other)
$EF\ Fuel_{k,x}$	=	Emissions factor for fuel combustion for each type of fuel (k) used and GHG (x) listed (kg CO_2e/L, m^3 or other)
GWP_x	=	Global warming potential for each GHG (kg CO_2e)
x	=	Value for each GHG (CO_2, CH_4 and N_2O)

The emissions due to transportation and storage of molten sulphur under the project scenario are calculated as follows:

$$PE_{S\ Trans\&Storage} = Mass\ Distance \times EF_{Transport} \quad (9)$$

Where:

$PE_{STrans\&Storage}$	=	Emissions due to the transportation and storage of sulphur (kg CO_2e)
Mass Distance	=	Mass of sulphur multiplied by the distance shipped from sulphur manufacturing facility to pre-cast manufacturing facility (t km)
$EF_{Transport}$	=	Emissions factor for transportation of sulfur (kg CO_2e/t km)

The emissions due to the production and transportation of modifier are calculated as follows:

$$PE_{Modifier} = (M_{Modifier} \times EF_{Modifier}) + (Mass\ Distance_{Modifier} \times EF_{Transport}) \quad (10)$$

Where:

$PE_{Modifier}$	=	Emissions due to the production and transportation of the sulphur modifier (kg CO_2e)
$M_{Modifier}$	=	Mass of modifier used (t)
$EF_{Modifier}$	=	Emission factor for modifier production (kg CO_2e/t)
$Mass\ Distance_{Modifier}$	=	Mass of modifier and the distance shipped from modifier manufacturing facility to facility where modifier is added to sulphur (t km)
$EF_{Transport}$	=	Emissions factor for truck transportation (kg CO_2e/ t km)

The emissions due to electricity generation for operating the sulphur concrete facility are calculated as follows:

$$PE_{Electricity} = Electricity_P \times EF_{\ Elec} \quad (11)$$

Where:

$PE_{Electricity}$	=	Emissions due to the generation of electricity for use in the precast sulphur concrete facility (kg CO_2e)
$Electricity_P$	=	Electricity used in operating the sulphur concrete facility (kWh)
EF_{Elec}	=	Emissions factor for electricity (kg CO_2e/kWh)

8.3 Leakage

No sources of leakage have been identified for this project activity.

8.4 Summary of GHG Emission Reduction and/or Removals

The emission reductions for this project activity are calculated as follows:

$$ER_y = BE_y - PE_y \quad (12)$$

Where:

ER_Y	=	Net GHG emissions reductions and/or removals in year y
BE_Y	=	Baseline emissions in year y
PE_y	=	Project emissions in year y

9 MONITORING

9.1 Data and Parameters Available at Validation

The data specified below must be made available at validation by the project proponent. Default values may vary according the physical location of the project activity. The project proponent must provide evidence and justification that the values presented here are applicable to the project activity, or provide and justify project-specific values as needed.

Should the data parameters listed below not be available at the time of validation, the project proponent must provide a plan for determination and/or monitoring the data during the project. All parameters used must be reviewed on an annual basis to ensure the most current value is used in calculations.

Data / Parameter	$EF_{Portland\ Cement\ Production}$
Data unit	kg CO_2e/t
Description	Emission factor for the production of Portland cement
Equations	2
Source of data	Calculation using site specific data if available, or reference values if no site specific data is available
Value applied	
Justification of choice of data or	The pThe project proponent mustmay use site-specific

description of measurement methods and procedures applied	emission factors for accuracy if a specific facility factor can be justified for the baseline cement production facility. Reference values may be calculated if site specific information is not available using data published by the World Business Council for Sustainable Development based on region. See Appendix A for guidance. The project proponent must justify that the $EF_{Portland\ Cement\ Production}$ in Appendix A is conservative for the project.
Purpose of data	Calculation of baseline emissions
Comment	Aggregation of multiple product types may specify a method to determine this parameter for each product type rather than specifying a value for all product types included in the aggregation at the time of validation. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter:	EF Fuel
Data unit	kg (CO_2, CH_4, N_2O) per L, m3 or other of each type of fuel used
Description	Emissions factors for fuel combustion
Equations	6, 7 and 8
Source of data	Estimation; reference values must be obtained from regional, national, or international GHG inventories. In the absence of local or regional data, reference values may be obtained from the most recent version of the IPCC guidelines for national GHG inventories.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	National emissions factors, or emissions factors created by local industry using internationally accepted procedures mustmay be used preferentially. Regional emissions factors may be used if national or local emissions factors are unavailable. International emissions factors may be used if regional emissions factors are unavailable. In the absence of local or regional data, reference values must be obtained from the most recent version of the IPCC guidelines for national GHG inventories.
Purpose of data	Calculation of project emissions

Comment	Review best practice guidance and accepted standards. Reference values are generally available. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter:	M_{CO2}
Data unit	kg/mol
Description	Molar mass of carbon dioxide
Equations	6
Source of data	General Chemistry book, 9th Edition, Ebbing & Gammon
Value applied	0.04401
Justification of choice of data or description of measurement methods and procedures applied	N/A
Purpose of data	Calculation of project emissions
Comment	This parameter is not likely to become out of date.

Data / Parameter	V_{STP}
Data unit	m^3
Description	Volume of one kg-mole of an ideal gas at standard temperature and pressure
Equations	6
Source of data	General Chemistry book, 9th Edition, Ebbing & Gammon
Value applied	23.6449
Justification of choice of data or description of measurement methods and procedures applied	The standard temperature and pressure conditions are 15°C and 101.325 kPa.
Purpose of data	Calculation of project emissions
Comment	This parameter is not likely to become out of date.

Data / Parameter	$Mass_{clinker}$ / $Mass_{Cement}$
Data unit	Percent

Description	Ratio of clinker to cement
Equations	3
Source of data	Site specific data, or reference values
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	The project proponent mustuse site-specific factors for accuracy if a specific facility can be justified for the baseline cement production facility. Reference values may be calculated using data published by the World Business Council for Sustainable Development based on region. See Appendix A for guidance. If site-specific factors are used, the project proponent must justify that the values are conservative for the project, and uncertainty is tracked where possible. The project proponent must also justify that the $EF_{Portland\ Cement\ Production}$ in Appendix A is conservative for the project.
Purpose of data	Calculation of baseline emissions
Comment	The project proponent must provide justification for factor used based on the region, kiln type and / or baseline facility records. Aggregation of multiple product types may specify a method to determine this parameter for each product type rather than specifying a value for all product types included in the aggregation at the time of validation. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	$EF_{Clinker}$
Data unit	kg CO_2e per tonne of clinker
Description	Emission factor for the production of clinker
Equations	3
Source of data	Site specific values as provided by the project proponent records, or reference values, such as those found in the World Business Council for Sustainable Development, Cement Industry Energy and CO2 Performance "Getting the Numbers Right" report.
Value applied	
Justification of choice of data or description of measurement	Proponents must use site-specific emission factors for accuracy if a specific facility can be justified for the baseline

methods and procedures applied	cement production facility. Reference values may be calculated, using data published by the World Business Council for Sustainable Development based on region. See Appendix A for guidance. The project proponent must justify that the $EF_{Portland\ Cement\ Production}$ in Appendix A is conservative for the project.
Purpose of data	Calculation of baseline emissions
Comment	The project proponent must provide justification for factor used based on the region, kiln type, fuel type and / or baseline facility records. Aggregation of multiple product types may specify a method to determine this parameter for each product type rather than specifying a value for all product types included in the aggregation at the time of validation. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	EF_{Elec}
Data unit	kg CO_2e per kWh
Description	Emissions factor for electricity
Equations	4 and 11
Source of data	Estimation; local or regional grid factors are preferable. If local factors are unavailable, reference values may be obtained from national and international GHG inventories may be used. In the absence of national data, reference values may be obtained from the most recent version of the IPCC guidelines for national GHG inventories. The value used must be consistent with the source of generation.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Review of best practice guidance and accepted standards. Reference values are generally available for each regional grid.
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	The project proponent must ensure that the default value is representative of the type and source of elecricity used in the project. Default values must be sourced from recognized, credible sources and be geographically and

	temporally relevant to project specifics. This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	Electricity $_B$
Data unit	kWh
Description	Electricity used for operating the precast concrete facility
Equations	4
Source of data	Estimation based on historical data from electrical meter
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Metering of electricity may be direct or by a utility provider. Measurement mustbe continuous, with monthly aggregation (totalized).
Purpose of data	Calculation of baseline emissions
Comment	This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter	$EF_{Transport}$
Data unit	kg CO_2e/t km
Description	Emissions factor for transportation
Equations	9 and 10
Source of data	Fleet data (such as fleet-wide average emissions per distance), or default data may be used if fleet data is unavailable.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	An emissions factor developed using internationally accepted practices may be generated for a fleet of vehicles, representing actual emissions due to fuel consumption per distance. If not available, regional data must be used and, in its absence, IPCC defaults may be used from the most recent version of IPCC Guidelines for national GHG inventories.
Purpose of data	Calculation of project emissions
Comment	Proponents may propose a fleet-specific emissions factor if

	sufficient documentation is available. The emissions factor must be reviewed at each verification period if actual fuel consumption is used in the emissions factor calculation. If retained shipping manifests, copies of shipping logs, or invoices from the supplier are used for the calculation, the resulting emissions factor must be cross checked against national or regional transport or fleet emission factors. If a default value is used, proponents mustjustify that it is conservative.

Data / Parameter	MF_{CO2}
Data unit	%
Description	Molar fraction of carbon dioxide in incinerated vent gas
Equations	8
Source of data	Facility-specific theoretical values are obtained from computer modeling or simulation, or through trial applications.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Continuous measurement of this parameter is not economically feasible and estimation must provide an accurate value, as this parameter is not likely to vary significantly over the project life.
Purpose of data	Calculation of project emissions
Comment	This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

9.2 Data and Parameters Monitored

The data parameters specified below must be monitored during the project.

Data / Parameter:	$Mass_{Precast}$
Data unit	Tonne
Description	Mass of precast products produced
Equations	2
Source of data	Measurement or calculation.
Description of measurement methods and procedures to be applied	The mass of finished products may be measured, or if measurement not feasible, the mass could be calculated based on a material balance, or could be calculated based

	on design specifications.
Frequency of monitoring or recording	Per product type
QA/QC procedures to be applied	If a measurement approach is used, then regular calibration and maintenance of scales as per requirements of meter manufacturers ensures quality weight measurements.
Purpose of data	Calculation of baseline emission
Calculation method	N/A
Comment	Aggregation of multiple product types may specify a method to determine this parameter for each product type rather than specifying a value for all product types included in the aggregation at the time of validation.

Data / Parameter	$\%_{PC}$
Data unit	Unitless
Description	Ratio of Portland cement in finished product
Equation	3
Source of data	Estimated based on design criteria of product
Description of measurement methods and procedures to be applied	This percentage represents the amount of Portland cement that would have been contained within the finished product (in the baseline) compared to other components such as aggregate, water. Design criteria must be justified based on technical specifications or performance requirements of the product. Historical production specifications may also be used for justification of design criteria. This is a unitless value.
Frequency of monitoring/recording	Per product
QA/QC procedures to be applied	This parameter varies in the project scenario and must be monitored for each product but is not actually measured. Design specifications are sufficient to ensure accuracy on this parameter.
Purpose of data	Calculation of baseline emission
Calculation method	N/A
Comment	The use of manufacturer's specifications provides a method for establishing functional equivalence between the product used in the baseline scenario and the product used in the project scenario. Aggregation of multiple product types may

	specify a method to determine this parameter for each product type rather than specifying a value for all product types included in the aggregation at the time of validation.

Data / Parameter	Vol Fuel
Data unit	L, m^3 or other
Description	Volume of fuel combusted during the project
Equations	6
Source of data	Measurement of volume of fuel used.
Description of measurement methods and procedures to be applied	The project proponent may measure the volume of fuel consumed in one of two ways: 1. Direct metering or reconciliation of volumes received and in storage; 2. Reconciliation of volume of fuel purchased within a given time period.
Frequency of monitoring/recording	Monthly
QA/QC procedures to be applied	Regular calibration and maintenance of meters as per requirements of meter manufacturers ensures quality metering. Cross-checking of metered or purchased volumes compared to theoretical fuel use must occur at each verification period. Minor variations must be immaterial on a quarterly or annual basis. Long term trends must align with theoretical expectations and remain consistent on a per volume of product basis.
Purpose of data	Calculation of project emission
Calculation method	N/A
Comment	None

Data / Parameter	Mass Distance
Data unit	t km
Description	Mass distance of sulphur transported to the concrete facility
Equations	9
Source of data	Measurement of mass of sulphur received and distance the sulphur traveled.

Description of measurement methods and procedures to be applied	Direct measurement of mass of sulphur received and distance traveled based on manifests or supplier invoices.
Frequency of monitoring/recording	Each shipment
QA/QC procedures to be applied	Regular calibration and maintenance of scales as per requirements of meter manufacturers ensures quality weight measurements. Retention of shipping manifests, copies of shipping logs, or invoices from the supplier must be cross checked against processed volumes and distances estimated based on shipping routes. Minor variations must be immaterial on a quarterly or annual basis.
Purpose of data	Calculation of project emission
Calculation method	N/A
Comment	None

Data / Parameter	$M_{Modifier}$
Data unit	t
Description	Mass of modifier used in sulphur cement
Equations	10
Source of data	Measurement of mass of sulphur modifier
Description of measurement methods and procedures to be applied	Direct measurement of mass of modifier used in the concrete facility.
Frequency of monitoring/recording	Per shipment of modifier
QA/QC procedures to be applied	Regular calibration and maintenance as per requirements of meter/scale manufacturers ensures quality metering. Mass balance of all product constituents must align with metered values and provide a suitable confirmation that measurement equipment is providing accurate information between calibration intervals. Minor variations must be immaterial on a quarterly or annual basis.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	None

Data / Parameter	$EF_{Modifier}$
Data unit	kg CO_2e/ t
Description	Emissions factor for modifier production
Equations	10
Source of data	Estimated based on manufacturer's specifications, fuel used, and electricity used.
Description of measurement methods and procedures to be applied	Value provided by the modifier manufacturer based on fuel and electricity consumed.
Frequency of monitoring/recording	Per shipment of modifier, to be updated annually by manufacturer of modifier
QA/QC procedures to be applied	Compare to historical values and analyze trends to confirm the estimate for emission factor is within a realistic range. Cross reference with manufacturer utility invoices for energy consumption to also ensure accuracy on estimate.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	None

Data / Parameter	Mass $Distance_{Modifier}$
Data unit	t km
Description	Mass distance of modifier transported to the concrete facility
Equations	10
Source of data	Measurement of mass of modifier received and the distance the modifier traveled.
Description of measurement methods and procedures to be applied	Direct measurement of mass of modifier received and distance traveled based on manifests or supplier invoices.
Frequency of monitoring/recording	Each shipment
QA/QC procedures to be applied	Regular calibration and maintenance of scales as per requirements of meter manufacturers ensures quality weight measurements. Retention of shipping manifests, copies of shipping logs, or invoices from the supplier must be cross checked against processed volumes and distances estimated based on shipping routes. Minor variations must be immaterial on a quarterly or annual basis.

Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	None

Data / Parameter	$Electricity_{P}$
Data unit	kWh
Description	Electricity used for sulphur concrete facility in the project
Equations	11
Source of data	Measurement
Description of measurement methods and procedures to be applied	Metering of electricity may be direct or by a utility provider. Measurement must be continuous, with monthly aggregation.
Frequency of monitoring/recording	Continuously aggregated (totalized) per project with monthly reconciliation if project duration is longer than one month.
QA/QC procedures to be applied	Electricity utility standard maintenance and calibration procedures apply. Cross-checking of metered values versus engineering estimates or theoretical electricity usage values ensures accuracy between calibration intervals.
Purpose of data	Calculation of project emission
Calculation method	N/A
`Comment	None

Data / Parameter	$Vol_{vent\ gas}$
Data unit	m^3
Description	Volume of degassing vent gas incinerated
Equations	6
Source of data	Measurement of the volume of vented gas (direct metering), or default value.
Description of measurement methods and procedures to be applied	Direct metering of vent gas to the incinerator, or regional or sector-wide default values (in order of preference).
Frequency of monitoring/recording	Continuously aggregated (totalized) per project with monthly reconciliation if project duration is longer than one month.
QA/QC procedures to be applied	Regular calibration for direct metering method as per requirements of meters ensures quality metering. Intermittently cross reference metered value with theoretical

	volume to periodically confirm accuracy. Minor variations must be immaterial on a quarterly or annual basis.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comment	Proponents must justify that the default value used for incinerator emissions is conservative.

9.3 Description of the Monitoring Plan

The project proponent must develop a monitoring plan detailing the procedures for data capture, measurement and reporting of the data parameters listed in Section 9.2. In general, data quality management must include sufficient data capture such that the mass and energy balances may be easily performed with the need for minimal assumptions and use of contingency procedures. The data must be of sufficient quality to fulfill the quantification requirement and be substantiated by company records for the purpose of verification.

The project proponent must establish and apply quality management procedures to manage data and information. Written procedures must be established for each measurement task outlining responsibility, timing and record location requirements. The greater the rigour of the management system for the data, the more easily an audit will be conducted for the project.

The project proponent must ensure that all documents and records are kept in a secure and retrievable manner for at least two years after the end of the project crediting period. Record keeping practices must be established that include:

- Electronic recording of values of logged primary parameters for each measurement interval;
- Written logs of operations and maintenance of the project system including notation of all shut-downs, start-ups and process adjustments relevant to the project quantification;
- Retention of copies of logs and all logged data; and
- Keeping all records available for review by a verification body.

The project proponent must also develop a QA/QC plan to add confidence that all measurements and calculations have been made correctly. QA/QC measures that may be implemented include, but are not limited to:

- Protecting monitoring equipment (sealed meters and data loggers);
- Protecting records of monitored data (hard copy and electronic storage);
- Checking data integrity on a regular and periodic basis (manual assessment, comparing redundant metered data, and detection of outstanding data/records);
- Comparing current estimates with previous estimates as a ‘reality check’;
- Provide sufficient training to operators to perform maintenance and calibration of monitoring devices;

- Establish minimum experience and requirements for operators in charge of project and monitoring; and
- Performing recalculations to make sure no mathematical errors have been made.

In general, measurement inaccuracies are inherently addressed in this methodology because the inputs into concrete production are measured or metered to ensure that concrete mix specifications are met. Therefore, there is a high degree of certainty in the measurements of associated with sulphur, aggregate, modifier, and volumes of fuel employed. However, the project proponent must address uncertainties in all measured values for all quantification parameters by ensuring that meters or scales are appropriately calibrated as prescribed by the manufacturer.

Parameters relevant to the project quantification for which confidence intervals may possibly be generated include MF_{CO2} and $Mass_{precast}$. If a direct measurement approach is employed (such as sampling the population of finished precast products in the case of $Mass_{precast}$, or trial application sampling in the case of MF_{CO2}) then a confidence interval must be determined. If the 95% confidence limits fall outside of 15% of the calculated value (as per the CDM Methodology Panel guidance), then a confidence deduction must be applied, using conservative factors such as those specified in the CDM Meth Panel guidance on addressing uncertainty in its Thirty Second Meeting Report, Annex 14.

In the situation where a computer simulation, mass balance process, or design specifications is used as a source of data (for either MF_{CO2} or $Mass_{precast}$), the uncertainty associated with each input to the simulation, or design process must be determined. If the resulting uncertainty of the simulation output falls outside of 15% of the calculated value, a confidence deduction must be applied, using conservative factors, as above. Similarly, if site-specific factors for $Mass_{clinker}$ / $Mass_{Cement}$ are employed and uncertainty is tracked, and if the resulting uncertainty falls outside of 15% of the calculated value, then a confidence deduction must be applied, using conservative factors, as above.

Parameters relevant to the project quantification for which confidence intervals cannot easily be generated include those listed below. The project proponent must demonstrate the factors or values used in the project are appropriately conservative based on the uncertainty of the actual parameter during the project.

- $Vol_{\text{vent gas}}$
- $EF_{\text{Portland Cement Production}}$
- $EF_{\text{Fuel i}}$
- $Mass_{clinker}$ / $Mass_{cement}$
- $EF_{clinker}$
- $EF_{Transport}$

- Ratio of Portland cement in finished product ($\%_{PC}$)
- $Vol_{Fuel\ i,\ DG,\ AH}$
- Mass distance of sulphur transported to the concrete facility
- $M_{modifier}$
- $EF_{modifier}$
- Mass distance of modifier transported to the concrete facility
- $EF_{Electricity}$
- $Electricity_B$
- $Electricity_P$

Methods used by the the project proponent for estimating uncertainty must be based on recognized statistical approaches such as those described in the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. Where applicable, confidence deductions applied must use conservative factors such as those specified in the CDM Methodology Panel guidance on addressing uncertainty in its Thirty Second Meeting Report, Annex 14.

10 REFERENCES AND OTHER INFORMATION

The good practice guidance and best science used to develop the quantification methodology are presented below in Table 2.

Table 2: Good Practice Guidance

Document Title	Publishing Body / Date	Description
General Protocol Guidance		
Canada's National Inventory Report: Greenhouse Gas Sources and Sinks in Canada, 1990-2010	Government of Canada (2012)	On behalf of the Government of Canada, Environment Canada releases a national inventory of greenhouse gases annually in accordance with international UNFCCC reporting standards.
Alberta Offset System Offset Credit Project Guidance Document	Alberta Environment (February 2008)	A draft guidance document outlining how to develop offset projects under the Alberta Offset System.
ISO 14064-2	International Organization for Standardization (ISO)(2006)	Provides guidance at the project level for quantification, monitoring and reporting of

Document Title	Publishing Body / Date	Description
		greenhouse gas emission reductions or removal enhancements.
Protocols Reviewed		
ACM0015 Version 3: Consolidated baseline and monitoring methodology for project activities using alternative raw materials that do not contain carbonates for clinker production in cement kilns	Clean Development Mechanism – Executive Board (March 2010)	Approved baseline and monitoring methodology for alternative raw materials for clinker production in cement kilns.
Quantification Protocol for the Substitution of Bitumen Binder in Hot Mix Asphalt Production and Usage	Alberta Environment (October 2009)	Reference for global warming potential figures.
Draft quantification protocol for the use of Sulphur concrete in precast applications	Alberta Environment (February 2010)	General guidance on selection of SSR, quantification and monitoring.
ACM0005 Version 5: Consolidated Baseline Methodology for Increasing the Blend in Cement Production	Clean Development Mechanism – Executive Board (October 2009)	Approved baseline and monitoring methodology for reducing the amount of clinker per tonne of blended cement.
Cement Reporting Protocol	California Climate Action Registry	Provides guidance on accounting and reporting GHG emissions for cement companies.
CO2 Accounting and Reporting Standard for the Cement Industry	World Business Council for Sustainable Development, Version 2.0 (June 2005)	Provides a methodology for calculating and reporting CO2 emissions.
DRAFT Quantification Protocol for the Use of Fly Ash in Concrete and Other Cement Based Products	Alberta Environment (October 2008)	Early technical work considering selection of SSRs and quantification for alternatives to cement used to produce concrete and other cement based products.

Document Title	Publishing Body / Date	Description
Other Resources		
Submission to the Prime Ministerial Task Group on Emissions Trading	Cement Australia (March 2007)	Comments on the Issues Paper released by the Prime Minister's Task Group on Emissions Trading
A Sulphur Concrete Retaining Wall	University of Alberta (2002)	An evaluation of the technical feasibility of constructing sizer walls using sulphur concrete.
Corrosion and Chemical Resistant Masonry Materials Handbook, Walter Lee Sheppard	Noyes Publications (1986)	
National Pollution Inventory, Hydrogen Sulfide: Environmental Effects	Australian Government	See http://www.npi.gov.au/substances/hydrogen-sulfide/environmental.html for further information.
A blueprint for a climate friendly cement industry	WWF International	
CO2 emissions from cement production	ICF Incorporated / USEPA	Good Practice Guidance and Uncertainty Management in national GHG inventories
Sulfurcrete Sulfur Concrete Technology	Cominco	
Concrete Technology – Third Edition, M L Gambhir	Tata McGraw-Hill (2004)	
Sulphur concrete – a new construction material	PCI Journal/January-February 1974	
Cement Sector greenhouse gas emissions reduction	The Loreti Group (2009)	
Shell, Life cycle assessment of sulphur concrete	2009 (Confidential; some relevant results of the study have been presented to the Technical Working Group)	Dutch consulting firm INTRON examined a number of pathways to market for sulphur concrete products, and estimated the net GHG and other environmental benefits.
Shell – product information on Shell Thiocrete	See www.shell.com for further information.	Shell Thiocrete is a modified sulphur binder specifically designed to replace Portland cement in the production of concrete

Document Title	Publishing Body / Date	Description
		products, such as paving stones and curbs.
General Chemistry, 9th Edition, Ebbing & Gammon	Brooks Cole; 9 edition, January 16, 2008	General chemistry background reference
Cement Industry Energy and CO2 Performance "Getting the Numbers Right"	World Business Council for Sustainable Development	This report provides carbon dioxide and energy performance information based on emissions data from individual cement plants, and it was used as a reference for the information in Appendix A and description of Emission Factor for the production of Portland cement.

APPENDIX A: EMISSIONS FACTORS FOR THE PRODUCTION OF PORTLAND CEMENT

This section discusses the emissions factors for the parameter $EF_{Portland\ Cement\ Production}$.

Specific Displacement

The mass of sulphur cement produced by the project may displace Portland cement from a specific Portland cement production facility. Provided the project proponent can demonstrate and justify specific displacement, site specific factors for kiln emission intensity and clinker to cement ratio must be used based on facility feedstock and fuel records.

In general, the equation for determining an emission factor based on site specific information is provided below:

$$EF_{Clinker} = \frac{\sum_k \left(Vol\ Fuel_k\ \times EF\ Fuel_{k,x}\ \times GWP_x\right)}{Mass_{Clinker}} + 540\ kg_{CO2}\ tonnes^{-1}$$

Where:

$EF_{clinker}$	=	Emission factor per tonne of clinker for the baseline scenario (kg CO_2e/t clinker)
$Vol\ Fuel_k$	=	Volume of each type of fuel combusted for clinker production (L, m^3 or other)
$EF\ Fuel_{k,x}$	=	Emissions factor for fuel combustion for each GHG listed (kg GHG/L, m^3 or other).
GWP_x	=	Global warming potential for each GHG (CO_2, CH_4, N_2O)
$Mass_{Clinker}$	=	Mass of total clinker production in the quantification period (t)
540 kg_{CO2} $tonnes^{-1}$	=	Mass of CO_2 attributable to the calcination of one tonne of clinker.

The amount of CO_2 released due to the calcination of one tonne of clinker has been described as nearly constant by the authors of the World Business Council for Sustainable Development in the report "Cement Industry Energy and CO_2 Performance: Getting the numbers right." This value is considered nearly constant. However, proponents may propose an alternative method to calculate the amount of CO_2 released due to the calcination of one tonne of clinker with justification.

The clinker to cement ratio (as described in Equation 3) is based on actual measurements of mass of cement produced and mass of clinker produced in the quantification period. It is expressed as a unit-less value (or percent) and applied as described in Equation 3.

Uncertainty related to the source of displaced Portland cement must be low and must be characterized by reviewing regional cement supply. Proponents must demonstrate that the distance/economics/logistics/etc. of secondary supplies of Portland cement would have not been viable.

Regional Displacement

The mass of sulphur cement produced by the project may displace Portland cement on a regional basis, meaning multiple Portland cement production facilities would contribute to the general cement supply in a region. In the absence of evidence for a specific displacement, the project proponent must demonstrate and justify regional estimates for kiln emission intensities and clinker to cement ratios. The project proponent must demonstrate that the factors used are conservative.

Regional factors may be determined by the project proponent and must be justified by citing records / studies / etc. specific to the region relevant to the project. In the absence of actual regional factors, an international report is cited below with reference to international regional kiln emission intensities and clinker to cement ratios.

The emission factor for clinker production and the ratio of clinker in Portland cement are listed below in Tables A1 and A2, respectively and were derived from the World Business Council for Sustainable Development's the Cement Sustainability Initiative report, *Cement Industry Energy and* CO_2 *Performance "Getting the Numbers Right"*.

The factors in Table A1 include emissions from the chemical process of calcination and emissions from fuel combustion, and consider those facilities that combust a wide range of carbon intensive and biogenic fuel sources.

Table A1: CO_2 emissions per tonne of clinker per kiln type (global average)

Kiln Type	kg CO_2/tonne clinker ($EF_{Clinker}$)
Dry with preheater and precalciner	842
Dry with preheater and without precalciner	861
Dry without preheater	955
Semi wet/Semi dry	896
Wet	1043

Table A2: Ratio of Clinker to Cement on a Regional Basis

Region	Clinker to Cement Ratio (%)
Africa and Middle East	79
Asia excluding China, India, CIS and Japan	84
China and India	74
CIS	80
Europe	76
Japan, Australia and New Zealand	83

Latin America	74
North America	84
World	78

The project proponent must justify the above factors are conservative to determine the emission factor for production of Portland cement in the absence of justification of site specific or region specific factors. This ensures uncertainty in the estimates is accounted conservatively.

DOCUMENT HISTORY

Version	Date	Comment
v1.0	15 May 2015	Initial version

VCS Methodology

VM0032

Methodology for the Adoption of Sustainable Grasslands through Adjustment of Fire and Grazing

Version 1.0

16 July 2015

Sectoral Scope 14

Methodology developed by:

Soils for the Future

In partnership with:

The Nature Conservancy

Fauna and Flora International

TABLE OF CONTENTS

1 SOURCES

The following have informed the development of the methodology:

- The R Project for Statistical Computing
- IPCC, 2000. *Emissions: energy and transport*. Pages 55-70 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. IPCC National Greenhouse Gas Inventories Programme
- IPCC, 2006. *Emissions from livestock and dung management*. Pages 1-85 Guidelines for National Greenhouse Gas Inventories. IPCC
- IPCC, 2006. *Grasslands*. Pages 1-49 Guidelines for Greenhouse Gas Inventories. IPCC
- IPCC, 2006. *Quantifying uncertainties in practice*. Chapter 6.*in* R. Odingo, editor. IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories IPCC
- Microsoft, 2006. *Monte Carlo Simulation for Excel*

This methodology uses the latest versions of the following tools:

- CDM A/R methodological tool *Calculation of the number of sample plots for measurements within A/R CDM project activities*
- VMD0016 *Methods for stratification of the project area (X-STR)*
- VT0001 *Tool for the Demonstration and Assessment of Additionality in VCS AFOLU Project Activities*
- VMD0040 *Leakage from Displacement of Grazing Activities*
- VCS *AFOLU Non-Permanence Risk Tool*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

2.1 Project Activities

The project activities eligible to apply this methodology include any that manipulate number and type of domestic livestock grazing animals (e,g cattle, sheep, horses, goats, camels, llamas, alpacas, guanacos, or buffalo) and/or grouping, timing and season of grazing (eg, continuous unrestricted, planned rotational, bunched herd rotational or other means of restricting livestock access to forage in order to allow vegetation response) in ways that sequester soil carbon and/or reduce methane emissions. Altering fire frequency and/or intensity, (eg, shifting from late season to early season burning or changing prescribed burn schedules from one every other year to one every five years) in ways that increase carbon inputs to soil, is also an included activity. Increased fire may be used to shift plant species composition such that net carbon sequestration in soil increases (eg, conducting a single burn to shift vegetation from shrubs to grasses), but the net increase in SOC must compensate for any losses in woody biomass and increases in methane (CH_4) and nitrous oxide (N_2O) emissions. Grassland restoration activities to improve livestock forage density (eg seeding of legumes or perennial grasses) that do not involve mechanical tillage of soil are allowed.

It is expected that such project activities will occur on grasslands that have historically experienced SOC loss. As these areas would continue to maintain low levels or further loss of SOC in the absence of the project, it is therefore expected that other carbon pools, such as aboveground carbon pools or biomass, will have relatively little change. The loss of SOC in the baseline prior to the project start date may be caused by fires that occur frequently enough to reduce SOC, or overgrazing that is expected to continue in the absence of the project.

Some grasslands (eg, savannas and open woodlands) may feature significant aboveground woody plant biomass that exceeds five percent of the soil carbon pool. Some woody biomass, largely in the form of shrubs or small trees, can reduce grass density and soil carbon. Management fires to reduce this woody cover might therefore reduce carbon in the aboveground woody biomass pool but compensate by increasing grass production and total carbon sequestration in soil.[1] Such scenarios are allowable under this methodology.

2.2 Quantification Approach

Projects may rely on measured or modeled approaches (see Table 1 below):

Measured approach: Emission reductions are quantified following a period in which enhanced soil sequestration and/or reduced methane emissions can be demonstrated. Such projects have a reduced uncertainty compared to those following a modeled approach, but projects that include soil sequestration activities may claim and verify emission reductions only after increases in soil carbon can be detected (likely every five or more years, depending on the productivity of the site).

Modeled approach: Emission reductions are quantified using a validated model after demonstrating management activities, which are known to sequester carbon and/or reduce methane emissions, have been implemented. Reduced emissions from sequestration and reduced methane emissions associated with these activities are then estimated by models with acceptable precision which have been validated for the project and re-calibrated at regular intervals thereafter (5-10 years, depending on the productivity of the site).

Modeled approaches have higher uncertainty due to the uncertainty in the parameters used to calculate emissions and removals and the uncertainty in whether model calculations actually describe changes in sequestration and reduced emissions. Consequently, verified modeled emission reductions will likely be reduced due to uncertainty deductions. However, because activities may be demonstrated annually, emission reductions may be verified annually, if desired.

This modeling approach requires the use of soil carbon models that have been published in peer-reviewed journal articles. Models must have been validated with independent data. Data used to validate the model must have been published in a peer-reviewed journal article and independent from data used to build the model. Soil carbon models describe how the density of soil organic carbon (SOC) changes as a result of biogeochemical processes and soil characteristics (eg, soil texture and type, pH, temperature, and moisture) and modifications in the capture of CO_2 and production of carbon-containing root and shoot biomass by plants. This aboveground and belowground biomass may undergo one of several fates:

1) Conversion back to CO_2 by combustion during fire,
2) Consumption and respiration by grazing animals,
3) Decomposition and respiration by microbes in soil and/or in the guts of invertebrate decomposers, or
4) Remaining as SOC from decomposed plant material or grazing animal dung.

As would be expected for such a complicated process, such models usually require the input of many parameters that need to be measured or obtained from the literature. When choosing which approach to take, the project proponent must consider carefully its ability to obtain necessary parameter measurements and to validate the chosen model for their project area.

Table 1: Summary of Measured vs Modeled Approaches

Measured Approach	Frequency	Modeled Approach	Frequency
Baseline			
Demonstration of SOC impoverishing activities		**Demonstration of SOC impoverishing activities**	
Measurements		**Measurements**	
* Initial SOC		* Initial SOC	
* Past grazing animal numbers		* Past grazing animal numbers	
* Forage quality		* Forage quality	
* Uncertainty analysis		* Past fire frequency	
		Build Model	
		* Choose model	
		* Measure/find parameters	
		* Accuracy assessment of prediction	
		* Predict initial SOC	
		* Monte Carlo analysis for uncertainty	
Project Scenario			
* Conduct activities * Measure ΔSOC * Animal numbers during crediting period * Forage quality during crediting period * Uncertainty analysis	Every 5-10 years	* Conduct activities * Measure/find parameters * Measure project fire frequency * Measure grazing animal numbers * Calculate methane emissions * Uncertainty analysis	Every 1-2 years
Verified Carbon Unit Calculation at Verification			
* Methane * Uncertainty analysis and deduction ***Claim VCU's**	Every 5-10 years	* Calculate ΔSOC from model * Methane * Uncertainty analysis *** Claim VCU's**	Every 1-2 years
Model Re-calibration			
		* Measure/find parameters * Measure ΔSOC * Assessment of prediction * Model adjustment	Every 5-10 years

Table 1 summarizes the procedures for applying either the measured approach or the modeled approach. While there are additional steps to using the modeled approach compared to the measured approach, the project proponent may monitor activities and calculate emission reductions more frequently (eg every 1-2 years as opposed to every 5-10 years) with the measured approach.

2.3 Baseline and Project Emissions and Reductions

The project proponent must demonstrate baseline conditions for the 10 years prior to the project start date, including:

1) land uses,

2) fire histories such as the number of times, sections or strata of the project area burned and when these fires occurred, and

3) grazing livestock animal numbers from detailed records such as surveys of livestock owners, past aerial surveys or ground censuses of livestock animals. These data are necessary to assess baseline methane emissions from enteric fermentation.

Baseline conditions may be determined from analysis of past satellite images, such as MODIS Burned Area Product maps to assess fire histories or with other satellite imagery such as Landsat, with demonstrated suitability from peer-reviewed scientific papers and/or from data from the project area to detect vegetation types and trends. Interpretation of satellite images during the project crediting period coupled with ground assessments of the occurrence of fire at multiple sampling stations is needed for verification of fire-abatement activities.

For the project scenario, both the modeled and measured approaches require sampling of soils and measurement of bulk density and SOC. If using the modeled approach, the soil sample depth is determined by the model (eg, 20 – 100 cm). This sampling will occur at the start of the project and be used to establish the baseline scenario. Likewise, for both approaches, ground censuses, household surveys, and/or aerial surveys of grazing animal numbers broken out by species, sex, and age are needed to determine baseline methane emissions and project reductions (or increases).

The measured approach simply calculates the difference in SOC at each verification event since the project start date or previous verification event. Note that sufficient time must pass between verification events to detect changes in SOC (eg, five or more years, depending on productivity in the project area). The initial and subsequent measurements of SOC occur at each of many permanent sampling stations located in different subareas (strata) within the project area that differ strongly in current or past vegetation, soil types or management activities. The sum of the differences in SOC, called ΔSOC, at each sampling station across the project area reflects net GHG emission reductions and removals from the soil carbon pool.

If a modeled approach is used, measurements of parameters, or information used to obtain parameter values, must be available to be input into a peer-reviewed, published, and accuracy-tested (at least once) model of soil carbon dynamics (eg, SNAP[2] CENTURY[3, 4]], EPIC[4], or the Hurley Pasture[5] models). The model must include parameters impacted by project activities (eg, grazing intensity and fire frequency) as well as critical factors affecting carbon inputs and outputs to soil (eg, soil texture, climate, and plant characteristics that affect decomposition). The specific factors needed will depend on the model used, as some models, such as CENTURY, require more than 20 factors, while others, like SNAP, require only five factors. To ensure that a model predicts changes in emissions or removals accurately and precisely enough to achieve a sufficiently low uncertainty in estimated changes in carbon stocks from project activities, the chosen model must be tested to demonstrate it is appropriate for use in the project area. Such a test uses site condition and management history data to predict carbon stocks that reflect the consequence of past management actions and conditions, such as rainfall, plant species composition, grazing intensity and fire history. This predicted carbon stock is compared to current, measured carbon stocks and the accuracy and precision of the predictions must be demonstrated within subareas (strata) of the project area that differ strongly in past conditions or in management activities. The details of the model test are presented in section 8.1.3.3.

Following the model test, soil carbon dynamics are modeled for the project area to estimate the maximum SOC that would likely have occurred for the 10 years prior to the project start date, as the baseline SOC. The same model is then used to calculate an expected future equilibrium SOC under proposed project activities, the time in years to reach this equilibrium, and the average annual increment in SOC sequestration expected under the proposed project activities. The statistics of variation needed to calculate uncertainties for each parameter in the model are also required in order to determine an overall uncertainty in the model calculations of SOC through a Monte Carlo simulation analysis. Uncertainty in the difference between maximum SOC in the past 10 years and an expected future equilibrium SOC will be used to determine any potential uncertainty deduction (section 8.4.4).

2.4 Leakage

Emissions from leakage primarily occur from the displacement of current activities inside the project area to areas outside the project area. For this proposed methodology, leakage would occur primarily by displacement of livestock to other grazing lands in which grazing would result in loss of soil carbon and/or increased methane emissions. Such displacement is limited by the applicability conditions for the methodology, but where displacement does occur leakage emissions must be quantified according to the procedures within the methodology.

3 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions and acronyms apply to this methodology:

3.1 Defined Terms

Baseline Period
A historical reference period over which the project's baseline emissions are calculated, and that consists of the ten consecutive years occurring immediately before the project start date

Calibration
Process by which predictive models use local measurements to determine the values of their parameters, and which will make the models more representative of the project area.

Calibration Period
Under a modeled approach, the time in years following the project start date or most recent re-calibration when soil carbon is to be measured again in order to re-calibrate the chosen soil carbon model. This period may be much longer than the verification period for modeled approach projects in order to allow sufficient time for measureable changes in soil carbon to occur

Cellulose
Carbon-rich plant material that, to decompose requires special enzymes (cellulases) typically found only in certain fungi, bacteria or other microorganisms

Enteric Fermentation
Process of microbial digestion of plant material in the digestive tract of grazing animals that, in the absence of oxygen, yields methane (CH_4) as a byproduct

Equilibrium
State of a carbon pool when inputs to the pool are balanced by outputs, such as when inputs to soil organic matter are balanced by losses from respiration by microorganisms

Exclosure
Fence or other device that excludes grazing animals from an area, sufficient to allow measurement of aboveground biomass inside in order to compare with biomass outside; used in estimating grazing intensity

Fire management
Set of practices that either inhibit fire or burn vegetation on purpose to achieve desired goals for vegetation and soil carbon.

Grasslands
Lands with more than 250 mm mean annual precipitation covered by natural and managed herbaceous cover that lack trees over 5m in height with greater than 50% canopy cover (forests)[1]

Grazing animal
Mammals that eat primarily herbaceous plants or the leaves of shrubs; in this methodology, applies to livestock species subject to control by the project proponent

Legumes
Plants in the pea family, either woody or non-woody, that harbor bacteria in their roots that perform nitrogen fixation, or the conversion of nitrogen gas in the atmosphere into chemical forms that can be used by plants

Lignin
Carbon-rich plant material that is generally impervious to decomposition by microorganisms

Neutral Detergent Fiber
Plant material resistant to rapid digestion or decomposition, which includes cellulose and lignin

[1] http://www.fao.org/agriculture/crops/thematic-sitemap/theme/spi/gcwg/definitions/en/

Overgrazing

Grazing that has resulted in permanent vegetation species changes from mostly palatable to unpalatable species, reduction in vegetation cover that expose more than 80 percent bare ground, and/or consumption of more than 75 percent of production

Prescribed Fires

Fires that are set on purpose by landholders as part of a specific strategy to manage vegetation in the project area

Rotational Grazing

Various practices of planned grazing in which animals are restricted, by herding or fencing, to small portions (< 25%) of available grazing lands for relatively short periods of time, followed by movement to new portions of available grazing land. The restricted access and time is designed for livestock grazing animals to eventually visit all or most of available grazing lands but still allow forage plant species sufficient time and resources (water, nutrients) to regrow and set seed following grazing or to complete growth and seed set before grazing.

Soil Organic Carbon Density

Amount of carbon in the soil, expressed as a mass per unit area rather than as a percent

Soil Carbon Dynamic Model

A model published in the peer-reviewed scientific literature that predicts changes in soil organic carbon as a function of various input variables, which may include aboveground production, belowground production, precipitation, temperature, initial soil organic carbon, soil texture, and grazing intensity and possibly other factors detailed in the peer-reviewed article(s) describing the model

Soil Organic Carbon (SOC)

See VCS document *Program Definitions*.

Tier 1, 2, or 3

The level of precision and use of local measurements in calculating various emissions and removals of greenhouse gases, as assigned by the IPCC

3.2 Acronyms

A/R	Afforestation / Reforestation
AFOLU	Agriculture, Forestry and Other Land Use
AIC	Akaike Information Criterion
ALM	Agricultural Land Management
CDM	Clean Development Mechanism
CI	Confidence Interval

IPCC	Intergovernmental Panel on Climate Change
NDVI	Normalized Difference Vegetation Index
SAVI	Soil-Adjusted Vegetation Index
SGMAFG	Sustainable grassland management though adjustment of fire and grazing
UNFCCC	United Nations Framework Convention on Climate Change
VCS	Verified Carbon Standard
VCU	Verified Carbon Unit

4 APPLICABILITY CONDITIONS

This methodology applies to project activities that adjust the number, type and husbandry of grazing animals, adjust the frequency and intensity of planned or unplanned fires, and/or introduce herbaceous grassland species as potential forage for grazing animals or to restore degraded soils.

The methodology is applicable under the following conditions:

1) The project area must be grasslands in the baseline and project scenarios.
2) Lands are grazed and/or subject to fires in the baseline and/or project scenarios. Lands may be used for different purposes, such as livestock production, conservation, hunting or tourism.
3) The project must be structured to keep livestock within the project area, and the project proponent must be able to enforce the boundaries of the project area.
4) The project must result in no net increase in the density of, or time spent by animals in confined corrals where dung can pile up and begin to decompose anaerobically[5] and result in CH_4 and N_2O emissions, such as an increase in the number of livestock aggregated (eg, kept in corrals or pens) that would result in more than 50 percent of the ground area covered by dung.[2]
5) Baseline emissions derived from livelihood-driven human impacts on aboveground woody biomass (eg, cutting for fuel wood, charcoal or timber sales) must be deemed de minimis (ie, not included in the cumulative 95 percent of total baseline emissions) and project activities cannot significantly alter such livelihood-driven activities.
6) For projects that propose to modify grazing, the maximum individual project size[3] is 3 million ha or 5 percent of a country's land area currently or potentially used to graze livestock, as judged by national government land use inventories or other documentation.

[2] This criterion is conservative relative to the conditions of dung accumulation that would result in significant anaerobic decomposition

[3] These constraints are designed to avoid market leakage, such as if a reduction in livestock created a meat or milk shortage that would encourage overstocking of livestock elsewhere in a country

The methodology is not applicable under the following conditions:

- Project activities that involve mechanical vegetation removal or soil tillage
- The project area receives a net import of inorganic or organically-derived fertilizer

5 PROJECT BOUNDARY

The spatial extent of the project boundary must be established following the guidelines in the latest version of the VCS document *AFOLU Requirements*.

Table and 3 below identify the carbon pools and GHG sources included or excluded from the project boundary.

Table 2: Selected Carbon Pools under Baseline and Project Activity

Carbon Pools	Included?	Justification/ Explanation
Aboveground woody biomass	Optional	Where the project activities involve changes in fire management, the project proponent must monitor changes in aboveground woody plant biomass. Where the project activity is to reduce fire frequency, there may be increases in removals from woody biomass which must be quantified and monitored. Where the project plans to burn woody biomass to promote soil sequestration, aboveground woody biomass must be included, because woody plants in some savanna grasslands can account for 10-30 percent of carbon stocks[6] and can be dramatically reduced by fire. Where the project activities do not involve changes in fire management, quantification and monitoring of changes in removals from woody plant biomass is optional.
Aboveground non-woody biomass	No	Aboveground non-woody biomass is typically burned or decomposed within the same year of its production and therefore is not a major sink and is considered in balance with CO_2 uptake, respiration by plants, and annual decomposition[7]
Belowground biomass	No	Belowground non-woody biomass is typically burned or decomposed within the same year of its production and therefore is not considered a major sink in grasslands because it is considered in balance with CO_2 uptake, respiration by plants, and annual decomposition [7]. As tillage is not allowed according to applicability conditions, any increase from project activities may be conservatively excluded.
Dead wood	No	Negligible in grasslands, particularly those with fire.
Litter	No	In grasslands, litter exhibits high turnover which further reflects balance with CO_2 uptake, respiration by plants, and annual decomposition[7].
Soil organic carbon (SOC)	Yes	Major carbon pool covered by SGMAFG
Wood products	No	An optional pool for VCS ALM projects, it is considered negligible for untilled grasslands

This methodology has applicability conditions for no tillage and activities that do not include avoided conversion of grasslands. Consequently, aboveground non-woody biomass, litter, and belowground biomass are considered negligible sinks because they turnover considerably throughout the year, sometimes by as much as 100 percent [7]. These carbon pools may later be used as potential parameters for soil carbon models because they influence the input of carbon to the soil, but they do not represent significant, permanent sinks or reservoirs of carbon.

Table 3: GHG Sources Included In or Excluded From the Project Boundary

Source		Gas	Included?	Justification/Explanation
Baseline	Grazing animals	CO_2	No	Balanced with CO_2 uptake, respiration by plants, and annual decomposition [7]
		CH_4	Yes	Target removal for methodology
		N_2O	No	No increase in concentration of dung and forage if not fertilized (see applicability conditions)
	Burning biomass	CO_2	No	Balanced with CO_2 uptake by plants
		CH_4	Optional	If reducing or maintaining fire is a project activity, CH_4 may be conservatively excluded. Otherwise CH_4 emissions must be calculated to determine net change in carbon stocks from increasing fire to induce an increase in SOC
		N_2O	No	Negligible under applicability conditions
	Soil emissions	CO_2	No	Assumed to be in balance with C inputs to SOC (SOC at equilibrium)
		CH_4	No	Negligible since project is not in wetland
		N_2O	No	Negligible under applicability conditions
Project	Grazing animals	CO_2	No	Balanced with CO_2 uptake by plants
		CH_4	Yes	Target removal for methodology
		N_2O	No	No increase in concentration of dung (applicability conditions) and forage is low in N
	Burning biomass	CO_2	No	Balanced with CO_2 uptake by plants[7]
		CH_4	Optional	If reducing or maintaining fire is a project activity, may be conservatively excluded. Otherwise CH_4 emissions must be calculated to determine net change in carbon stocks from increasing fire to induce an increase in SOC
		N_2O	No	Negligible under applicability conditions
	Soil emissions	CO_2	No	Accounted for in measured ΔSOC
		CH_4	No	Negligible since project not in wetland
		N_2O	No	Negligible under applicability conditions

Unless specifically planted at high density to achieve aboveground biomass greater than 120 g/m^2 on average, leguminous plants, either woody (eg, *Acacia* or *Prosopis* species) or herbaceous, are not likely to produce soil N_2O emissions to levels that approach 5 percent of total CO_2 emissions from soil [8, 9]. Consequently, N_2O emissions from soil or biomass burning are negligible.

As per applicability condition 4, this methodology does not apply to projects that result in a net increase in the density of, or time spent by, animals in confined corrals where dung can pile up and begin to decompose anaerobically[5] and result in CH_4 and N_2O emissions. Dung in pastures or open rangelands typically decompose aerobically [10, 11], which releases negligible CH_4 and N_2O emissions.

Increase in the use of fossil fuels due to management, harvesting, and fighting fires is likely to be negligible because the same general activities (eg, livestock grazing, wildlife conservation and tourism) will be occurring in the project area during the project lifetime as under baseline conditions.

6 BASELINE SCENARIO

The baseline scenario is identified as the existing or historical land management practices, under the assumption that these would continue in the absence of the project. The baseline land management activities, such as plans (or lack thereof) for fire management, number of grazing animals and the duration and timing of grazing particular areas of land, must have been in place during the baseline period. In the case that management activities have changed during the baseline period, such changes must be documented and the activities leading to the lowest net emissions or greatest removals during the baseline period must be chosen as the most plausible baseline scenario.

To develop the baseline scenario, the project proponent must document, using published or gathered project-specific data and/or models, historic grazing plans or use of grazing areas by livestock and fire histories in the project area. The method to determine the most plausible baseline condition is provided in Section 8 (Baseline Emissions) with additional information provided in Section 9.3 (Description of the Monitoring Plan). The method includes:

1) Where adjustments in fire frequency and/or intensity are a project activity, the project proponent must demonstrate a fire history, as a map of areas that burned and the number of times they burned over the previous ten years. This may be obtained by using satellite products, such as MODIS Burned Area Product[4] as detailed in Section 9.3.5) that provide polygons of burned areas for 15 day periods throughout the dry or burning season. A GIS program like Quantum GIS (2.6)[5], and other programs like IDRISI [6] or ArcGIS, may perform similar functions. Project proponents may also use dated aerial

[4] http://modis.gsfc.nasa.gov/)
[5] Quantum GIS 2.4 can be downloaded for free at https://www.qgis.org
[6] http://www.clarklabs.org

photographs or accurate hand-drawn maps accompanied by records of where and when land parcels burned.

2) As evidence of past grazing practices and impacts, the project proponent must demonstrate a grazing history, as determined from past livestock grazing animal counts, ground measurements of grazing impacts, and/or ground-validated interpretations of satellite imagery (such as the Normalized Difference Vegetation Index (NDVI), Soil-Adjusted Vegetation Index (SAVI), or other similar index[12, 13]) from a minimum of four intervals across the 10 years, with at least one image from 8-10 years prior to the project start date.

3) Baseline methane emissions require as detailed as possible livestock grazing animal censuses through any combination of professional aerial surveys, ground counts with appropriate spatial extrapolation to the project area[14, 15], or household surveys of livestock held by each household over the previous 10 years. Censuses must categorize, to the extent possible, the species, sex, and age of each animal, and an average body weight for each category[7].

4) Aboveground woody biomass must be sampled at the project start from many locations in the project area (see Section 8.1.3.5) and if necessary for inclusion as a parameter in soil carbon models, analyzed for neutral detergent fiber, cellulose, and lignin in a professional laboratory.

5) Initial soil carbon stocks must be measured to the desired depth following Section 8.1.3.3. The chosen depth must match that applicable to the chosen soil carbon model if the modeled approach is used.

6) Where the modeled approach is used, predictions of soil carbon stocks or stock changes from the chosen model of soil carbon dynamics, such as Century[3, 4, 16], must be tested to demonstrate it is appropriate for use in the project area with measured soil carbon stocks or stock changes from the project area. Correlations between predicted and observed stocks must have $R^2 \geq 0.80$ within strata and an uncertainty based on a 95 percent confidence interval of $\leq$ 20 percent for predicted values applicable to the project area. The use of less accurate model predictions imply larger confidence limits in estimated carbon stocks or stock change after 10 years and thus larger uncertainty deductions in claimed emission reductions. If a model cannot be found to provide sufficient accuracy, the measured approach must be used.

7) The selected model is used to model the soil carbon dynamics and to estimate the maximum SOC that would have occurred in the 10 years prior to the project start date. This provides an uncertainty deduction for activity-based emission reduction calculations.

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[5] IPCC, *Emissions from livestock and dung management*, in *Guidelines for Nartional Greenhouse Gas Inventories*. 2006, IPCC. p. 1-85.

[7] Such data are necessary to use Tier II methods of calculating methane emissions per IPCC 2006 guidelines

8) Where the measured approach is used, estimates of initial soil carbon stocks within different strata must also calculate an uncertainty based on a 95 percent confidence interval, with uncertainty deductions imposed if uncertainty exceeds + 15 percent**.**

9) Uncertainty propagated by all estimated emissions and reductions must be calculated for baseline emissions, project emissions and reductions. Uncertainty deductions will occur if the total uncertainty + 15% percent of estimated net emissions and removals under the project scenario. The deducted removals must be directly proportional to the uncertainty.

7 ADDITIONALITY

Additionality must be demonstrated using the latest version of the VCS tool VT0001 *Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities*. In this tool, the project proponent must (1) identify alternative land use scenarios to the proposed project activity, (2) perform an investment analysis to determine that the proposed project activity is not the most economically or financially attractive of the identified land use scenarios or (3) identify key barriers, and (4) demonstrate how the proposed project activity deviates from common practice.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

8.1.1 Baseline Management Activities

The project proponent must document the management activities that occurred during the baseline period, in order to quantify baseline emissions and/or removals. Management activities must include:

1) The number of livestock grazing animals of different categories (eg, weight, sex, age and species) in one or more areas within or in the entire project area.

2) The average forage removal, or grazing intensity (%) by all animals, as measured by comparison of forage biomass inside and outside fenced exclosures[2, 17], or inside and outside unfenced areas otherwise avoided by livestock, such as conservation areas, with similar soil and climate, or before and after planned grazing events. Estimates of grazing intensity over large areas may be made by using satellite-based indices, such as NDVI[12, 13] , as long as such indices are correlated with ground measurements with a R^2 > 0.35.

3) The pattern of time and timing of animal use of the project area.

4) Prescribed burns at some desired frequency.

Management activities may also be considered to mean a lack of management in the form of unplanned livestock grazing, lack of grazing, or unplanned fires. The project proponent must also provide evidence of the baseline vegetation conditions and their association with management activities in the project area during the baseline period. Such evidence must take the form of any one or combination of the following, in no particular order of preference:

5) Field data on vegetation composition (biomass, percent cover, incidence). Dominant vegetation types that are associated with lower soil carbon (eg, annual plants) or with grasses with high lignin and cellulose content such as various *Pennisetum* spp. (in Africa), *Spinifex* spp., (Australia), switchgrass *Panicum virgatum* or Johnson grass *Sorghum halepense* (North America), or *Paspalum* spp. (South America)) following consumption by livestock. These data may be presented as visually estimated percent cover of different vegetation types and average percent cover of annual and perennial grasses, bare ground and shrubs, must be provided if applicable.

6) Measurements of grazing intensity from exclosure (fence) experiments, visual estimates calibrated from exclosure experiments or ungrazed areas within the project area with similar soils and rainfall to areas where soil carbon is expected to be increased.

7) GPS-referenced, dated photographs of a representative sample of the project area, with sufficient evidence to judge a shift to project scenario vegetation from similar photographs taken of the same view at the same GPS point.

8) Interpreted satellite images, such as indices of NDVI[12, 13] or maps of burned areas[18, 19] across multiple years, coupled with ground vegetation data to support the conclusion that these images are correctly interpreted with reasonable accuracy (ie, R^2 > 0.35 between index and vegetation measure from 1).

8.1.2 Design and Establishment of Permanent Sampling Stations

This methodology depends greatly on the success at measuring changes in SOC, the results of project activities, and/or key inputs into soil carbon models such as grazing intensity and/or the intensity and frequency of fires. Because these measurements in grasslands often vary by a large amount over distances of a few meters, the project proponent must establish permanent sampling stations, marked with permanent materials, like PVC, metal or stone, with recorded GPS locations to 10 meter accuracy, or close enough to find the permanent markers of the station. Measurements of carbon stocks in soil and wood (if relevant) at the same place may then be compared over time and control for initial differences in SOC, grazing and fire history, vegetation, topography, and other factors. Project impacts on carbon stocks are therefore best detected by measuring the change in carbon stocks between years at each sampling station and then summed over all sampling stations rather than the difference between mean stocks across all sampling stations in different years. This sampling approach will greatly reduce the variance, and therefore, uncertainty, in changes in stocks between baseline and project activities. Further details about measurements at these permanent stations are discussed in Section 0.

8.1.2.1 Number of Sampling Stations

The total number of sampling stations, n, for the project area must be determined by using the CDM A/R methodological tool *Calculation of the number of sample plots for measurements within*

A/R CDM project activities.[20] As soil is typically sampled from three or more pooled 5-10 cm diameter cores at a station and therefore from a small total area (< 0.05 m^2), there are potentially a large number of potential sampling sites in even the smallest project area (< 1 km^2). Consequently, the total number of sampling stations, according to the CDM tool, is largely insensitive to the total area of the project for a measured approach as shown in see Figure .

Figure 1: Estimate Number of Sampling Stations

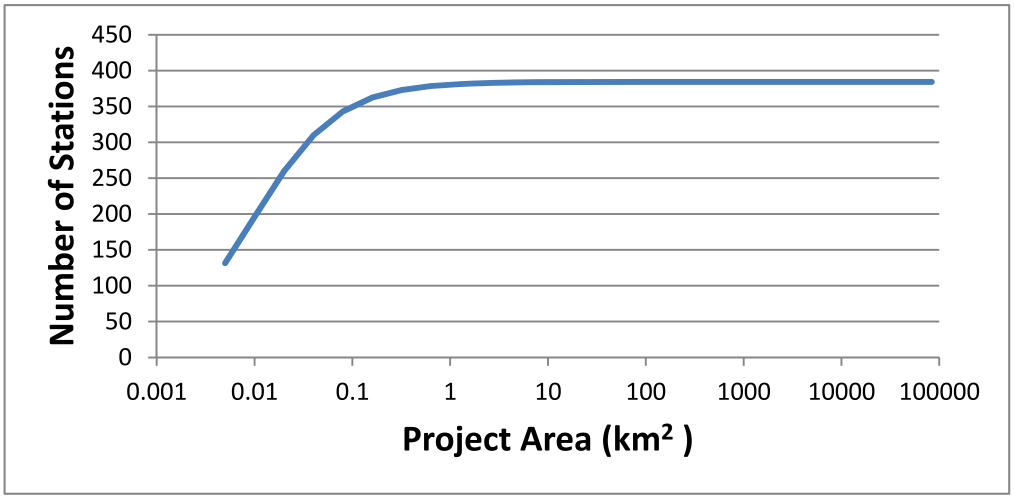


Figure 1 shows the estimated number of sampling stations needed to detect an increase in mean SOC of 0.3 percent for samples with a typically observed standard deviation of 0.3 percent (100 percent of mean) and target standard error of less than 10 percent.

8.1.2.2 Stratification

<u>Measured Approach</u>

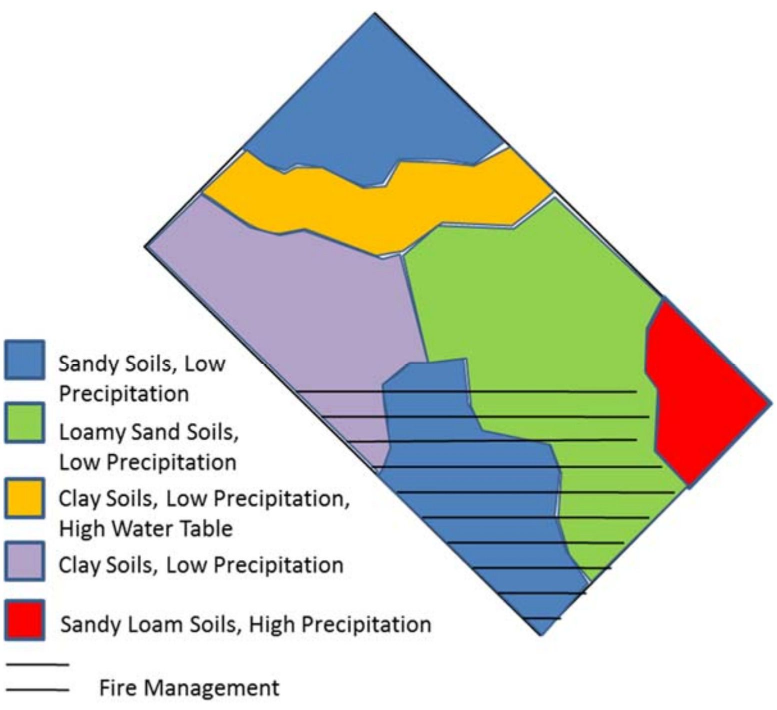
Obtaining precise estimates of soil organic carbon requires careful stratification[21, 22]. Stratification on the basis of vegetation and management practices must provide a good initial scope of stratification for soil, but additional factors, such as topography (top, middle and bottom of slopes), and texture (proportion of sand, silt and clay) may also be important for defining strata. A cluster, regression tree or other similar analysis of SOC from the permanent sampling stations, which is required to establish baseline SOC stocks, must be used to decide a final stratification. These types of analyses examine a set of different measurements from different locations to find groups of locations with similar values, and may be conducted in many ways depending on the extent of variability in soils, climate, and management in a project area[22]. For a detailed discussion and recommended approaches, see references [23, 24].

Rather than limit uncertainty in absolute measurement of SOC stocks, a modeled approach has the goal to reduce the 95 percent confidence interval of a regression line of predicted change in SOC relative to observed change in SOC. This imposes an additional emphasis for the distribution of sampling stations to include the largest possible variation in SOC, both in terms of the strata chosen and in sampling variation within strata.

Using cluster analysis, regression tree analysis or any other means, such as the latest version of the VCS module VMD0016 *Methods for stratification of the project area (X-STR), v1.0* [25], the project proponent must classify the area by past management practices and preliminary information about soils (such as from a soils map) and climatic conditions (such as from areas that are similar in aboveground productivity, or from rainfall maps). This step is equivalent to stratification in an afforestation / reforestation project[20] but focused on factors related to soil carbon sequestration[7], fire frequency, and animal distribution and management, and reduces the uncertainty in estimates of project removals of GHG. This will produce *s* strata within which baseline and project emissions are calculated, soil carbon changes and methane emissions will be monitored, and past (baseline) and proposed project management activities have been (are) implemented.

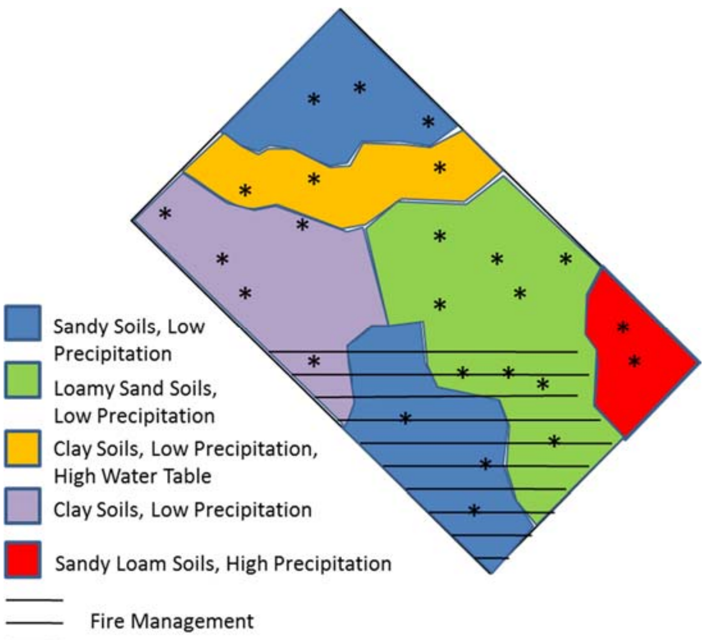
As an example, a project might be subdivided into five areas of different soil type and/or precipitation as seen in Figure . The sampling design would then feature eight strata, one for each combination of management activity, soil type, and precipitation or water availability.

Figure 2: Hypothetical Landscape among Eight Strata Subject to Different Management Practices



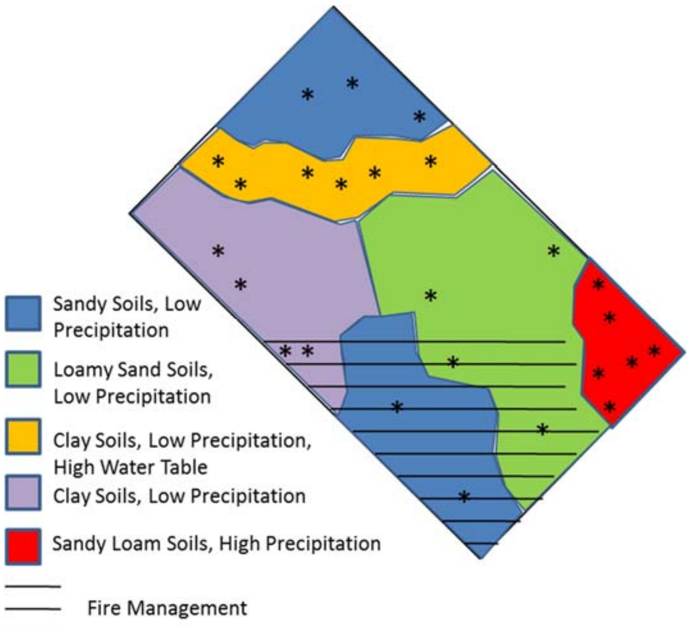
Once each stratum is defined and mapped and the total number of sampling stations determined, then a representative number of sample points, z_m, are chosen within each stratum. The number of points per stratum will depend on which stratified sampling method is used. Where SOC exhibits similar variability among strata (ie, coefficients of variation (standard deviation/mean) differ by less than 40% in areas with different soil, vegetation, or management practices), the number of stations per stratum must be proportional to the proportional area of each stratum in the project area. This is the most likely scenario under the expectation that strata for a project are selected to ensure a low variance (10 percent standard error) within each stratum. For example, in a project with three strata, A, B, and C that represent 50 percent, 40 percent and 10 percent respectively of the total project area and the project area requires 100 sampling stations, then 50, 40, and 10 stations must be placed randomly within each of strata A, B, and C as shown in **Error! Reference source not found.**3 below. This is the case of proportional allocation, which the number of stations is allocated to each stratum on the basis of its proportion of the total project area.

Figure 3: Proportional Allocation of Sampling Stations (Stars) Among the Eight Strata in the Hypothetical Project Area in Figure 2



Alternatively, the best possible stratification of the project area, resulting in the least uncertainty, may still feature certain strata that exhibit much higher variability (> 40% difference in coefficient of variation) in SOC than others. In this case, “optimum” or disproportionate allocation of stations may be most appropriate. Where a disproportionate application is applied, strata receive a number of sampling stations proportional to their coefficient of variation rather than their proportional area. In the example, hypothetical strata A, B, C might receive 20, 20, and 60 percent of stations, respectively if SOC in stratum C is three times more variable (three times higher coefficient of variation), regardless of their proportional areas. As an example, Figure 4 shows the disproportionate allocation of 25 sampling stations in the hypothetical project area shown below. In this case the high precipitation stratum and the clay soils with a high water table are three times more variable than other strata, and thus receive 6 stations, as opposed to two.

Figure 4: Optimal or Disproportional Allocation of Sampling Stations (Stars) Among the Eight Strata of the Hypothetical Project Area in Figure



The primary goal of the distribution of stations must be to reduce variability and increase representation of different SOC values in the project area.

Modeled Approach

For projects using a modeled approach, the objective is to demonstrate that the chosen soil carbon model can predict SOC stocks or changes in SOC stocks at each of a large number of sampling stations that differ in key factors, such as climate soil type, past management, and vegetation. Sampling stations must be selected to encompass as much of the variability in these factors as possible in order to test that the model is appropriate for use in the project area (see Section 8.1.3.3. The sample size must be determined using an online calculator[8] or a power analysis in any standard statistics program. As an example, to achieve the desired model accuracy of R^2 > 0.80 (see Section 8.1.3.3) and an uncertainty of less than 0.08, a total of 120 samples would be needed from across the full variation in SOC within the project area.

8.1.3 Calculation of Baseline Emissions

[8] One resource for online calculators is http://www.danielsoper.com/statcalc3

8.1.3.1 Baseline Emissions from Grazing Animals (BEM)

Baseline methane emissions from grazing animals must be estimated from data on total numbers for different livestock categories that reflect species, age, sex and their respective weights, in the project area. The methodology applies to Tier 2 approaches, as outlined in the *IPCC 2006 Guidelines for National Greenhouse Gas Inventories* Chapter 10, Emissions From Livestock and Dung Management[5] but with local input data. Calculations are based on estimating daily methane emissions as a function of the body weight (kg) of each major animal category [26] (Figure 5: Daily Methane Emissions Data), and then multiplied by the number of animals in each animal category and 365 days in a year. Emissions from all categories may then be summed to provide the total annual methane emissions for the project area. Domestic livestock grazing animals of category c must be classified as one of three animal types: ruminants (sheep, goats, cattle, buffalo, and camelids (ie, camels, alpacas, guanacos, llamas), equids (donkeys, horses) or pigs.

$$BEM = \sum_{c=1}^{K}\left(BN_C \times \ DMEF(W_c)\right) \times GWP_{CH_4} \times 365 \times 6.26x10^{-7} \quad (1)$$

Where:

BEM	= Baseline annual emissions from grazing animals (tCO_2e)
BN_c	= Baseline number of animals of category *c* (head)
$DMEF(W_c)$	= Daily emission factor as a function of animal weight for category *c* (L CH_4 / day)
$W_{C,}$	= Average body weight during the baseline period for animals of category *c* (kg)
GWP_{CH4}	= Global warming potential for methane (tCO_2e / tCH_4)
c	= category of grazing animals
K	= number of categories of grazing animals, eg species, gender, age combinations
365	= Conversion factor for days to years
6.26×10^{-7}	= Conversion factor for L CH_4 / day to t CH_4 / day

Further, $DMEF(W_c)$ is the daily emission factor (liters CH_4 / day) as a function of animal weight for animal category c. These values must be determined using the relevant allometric equations in **Error! Reference source not found.**.

Table 4: Allometric Equations, with Uncertainty, for Daily Methane Emissions for Three Animal Types: Ruminants, Equids, And Pigs

Animal Type	Equation	n	R^2	Uncertainty Percent
Ruminants	$0.66 \times W_C^{0.97}$	62	0.88	9.5%
Equids	$0.18 \times W_C^{0.97}$	23	0.76	28.2%
Pigs	$0.07 \times W_C^{0.99}$	12	0.93	18.6%

BN_c, is the harmonic mean number of animals of each category during the 10 years prior to the project start date, calculated as below. The harmonic mean conservatively weights lower values of methane emissions in a sample[27]. This must be calculated using equation (2). The harmonic mean BN_c for n censuses[27] of $N_{c,i}$ animals in each category c during census i is given by:

$$BN_c = \left(\frac{1}{n}\right) \times \left(\frac{1}{\sum_{i=1}^{n} \frac{1}{N_{c,i}}}\right) \quad (2)$$

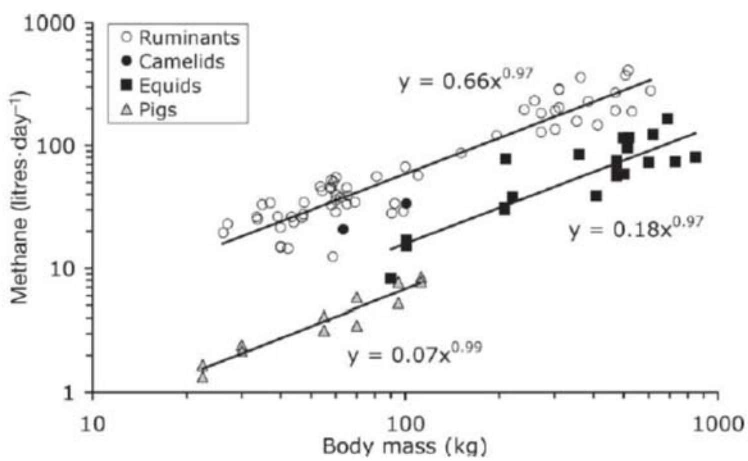
Where:

BN_c	= Baseline number of animals of category *c* (head)
n	= Number of counts
$N_{c,i}$	= Animals in category *c* during count *i* (head)

Calculations of uncertainty are given in Section 8.4.2.1.

Figure 5 shows the daily methane emissions data compiled from the Franz *et al.* (2010) review of 62 measurements for ruminants (sheep, goats, cattle and buffalo), 23 measurements for equids (donkeys and horses) and 12 measurements for pigs, showing how methane emissions scale with body weight W (kg). All animals were fed roughage forage similar in quality (40-50 percent neutral detergent fiber) to plants consumed in unfertilized grasslands that likely apply in this methodology. These relationships are summarized in **Error! Reference source not found.** above.

Figure 5: Daily Methane Emissions Data



Forage quality, and specifically the fiber content of forage, is known to affect methane emissions[28]. However, forage quality is not included because it introduces additional error into the calculation, since dry matter intake would also have to be estimated to yield methane emissions. Furthermore, the forage quality actually consumed, as opposed to that available, by free-living animals on grasslands can probably never be measured accurately across a large-scale project. So instead, it is expected that the uncertainties in the allometric equations in **Error!**

Reference source not found. are irreducible without impractical and prohibitively expensive direct methane measurements on individual animals[28] Depending on the relative abundance of equids in the composition of animals, this uncertainty in methane emissions may induce an uncertainty deduction in the calculation of removed methane emissions.

8.1.3.2 Baseline Emissions of Methane from Burning of Biomass (BEBB)

Biomass burning results in annual emissions of methane. These emissions may be conservatively excluded if project activities do not change or lead to decreased annual emissions, in which case BEBB = 0. If project activities decrease fire, proponents can choose to include biomass burning in baseline emission calculations and show the net decrease in such emissions under the project scenario. If project activities increase fire frequency, such as to remove shrubs and lead to a net increase in total carbon stocks from the increase in SOC associated with establishment of perennial grasses, project proponents must calculate the net change in emissions from biomass burning under the project scenario, BEBB, must be calculated with the following equation:

$$BEBB = \frac{\sum_{m}^{M}\left(FFREQ_{m,b} \times APB_{m,b} \times PA_{m,b}\right) \times BC_G \times EF_{BG} \times GWP_{CH_4}}{1{,}000{,}000} \quad (3)$$

Where,

BEBB	= Baseline annual emissions of methane from burning of biomass (tCO_2e)
$FFREQ_{m,}$	= Proportion of area of stratum *m* burned annually (percent)
$APB_{m,}$	= Mean total aboveground biomass at the end of the growing season in stratum *m* (kg biomass/ha)
$PA_{m,}$	= Baseline area in stratum *m* (ha)
BC_G	= Baseline combustion factor for savanna/grassland (kg biomass burned/kg biomass)
EF_{BG}	= Emission factor for the burning of grassland (g CH_4/kg biomass burned)
GWP_{CH4}	= Global warming potential of CH_4 (tCO_2e / tCH_4)
1,000,000	= Converts g CH_4 into Mg (tons)

8.1.3.3 Baseline Changes in SOC Density

The determination of a change in baseline equilibrium carbon density depends on the type of project approach used.

Measured Approach**.** Where the measured approach is applied, initial $SOC_{m,j,0}$ at each sampling station is the baseline. Initial $SOC_{m,j,0}$ may be calculated from multiple pooled soil cores from each station as:

$$SOC_{m,j,0} = DEPTH_{m,j,0} \times SOC\%_{m,j,0} \times BULK_{m,j,0} \quad (4)$$

Where:

$SOC_{m,j,0}$ = SOC density in station *j* in stratum *m* at time *t =0* (tC/ha)

$DEPTH_{m,j,0}$ = Depth of SOC sampling at the project start (cm)

$SOC\%_{m,j,0}$ = Percent SOC in dry soil from the entire soil profile to the chosen depth at station *j* in stratum *m* at time *t =0* (percent)

$BULK_{m,j,0}$ = Bulk density at station *j* in stratum *m* at time *t =0* (Mg dry soil / m^3) (Note Mg/m^3 are equivalent to g/cm^3, the unit most commonly reported by laboratory analyses)

Note that $SOC\%_{m,j,0}$ is a percent and allows the equation to correctly calculate SOC density (tons/ha).

$DEPTH_{m,j,0}$ must be selected by the project proponent to account for the vast majority (> 80 percent) of SOC in the soil column, reflect depth to hardpans or bedrock, or to match calculations from soil carbon models. $SOC\%_{m,j,0}$ and $BULK_{m,j,0}$ must be measured in a professional laboratory through either combustion methods[29] or multi-spectral diffraction with an infra-red spectrometer following project area-specific calibrations[30]. Bulk density accounts for whether soil is loosely or densely packed and must not include volume occupied by rock fragments or pebbles.

Modeled approach. Baseline management activities and environmental conditions driven by possible project activities, such as grazing intensity and fire frequency, as well as critical factors affecting carbon inputs and outputs to soil, such as soil texture, climate and plant characteristics that affect decomposition must be imported into a peer-reviewed, published soil carbon dynamics model that has been assessed for accuracy at least once with an independent set of data other than that used to construct the model. For example, SNAP[3] CENTURY[4, 16, 31], EPIC[32, 33], Hurley Pasture[34, 35] models are four models that incorporate grazing and/or fire, among others, as factors determining soil carbon.

One or more of these or other candidate models must be assessed for accuracy independently, (ie, with data other than that used to construct the model), and also tested to demonstrate it is appropriate for use in the project area by showing its ability to predict initial carbon stocks in different subareas (strata) within the project area (see below). This analysis assumes that past practices have been in place long enough for SOC to approach equilibrium. Thus the soil carbon model must be able to predict this equilibrium for strata in the project that have experienced similar management activities for 20 years or more. A regression line is fitted to a scatter-plot of model-predicted SOC (x-axis) vs. measured SOC from a large number permanent sampling stations[36] (see section 8.1.2.2). Variation in conditions and management activities across strata may be used as the source of different soil carbon model parameter inputs. The model must generate a coefficient of determination $R^2 > 0.80$ across all strata. The slope of the regression line must have a 95 percent confidence interval that overlaps 1 and the 95 percent confidence interval of the intercept must overlap zero. If these criteria cannot be met with any available models, then the project proponents must use the measured approach.

Bias must be determined by evaluating the percent bias of a simulation (carbon model) relative to observed data[37].

$$MBIAS = \frac{\sum_{i=1}^{n}({Y^{obs}}_i - {Y^{pred}}_i)}{\sum_{i=1}^{n} {Y^{obs}}_i} \quad (5)$$

Where:

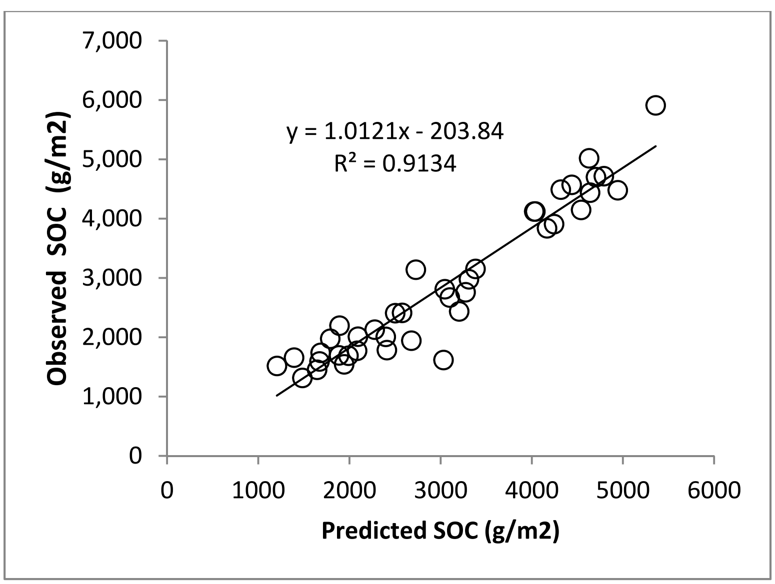
MBIAS	= Percent bias of carbon model predictions relative to observed data
n	= number of sampling stations tested
${Y^{obs}}_i$	= observed SOC density at station i
${Y^{pred}}_i$	= SOC density predicted at station i

Bias of the model chosen for this methodology must be between -20% and +20%.The criteria of $R^2 > 0.80$, slope = 1 and intercept = 0 should ensure that -20% ≤ MBIAS ≤ 20% [37]. In the case that significant bias is found and emission reductions are over-predicted— a subset of observed data may be used to adjust model parameters and fit the model to data, and then the model may be re-tested with the remaining data.

In addition the 95 percent confidence interval for predicted mean SOC, derived from Monte Carlo simulations, must overlap with that of SOC measured at sampling stations in the same stratum. If, for certain strata, the 95 percent confidence intervals do not overlap, then the soil carbon model must be calibrated for that stratum by adjusting one or more parameters until 95 percent confidence intervals do overlap.

Figure provides an example test of predicted SOC (g/m^2) of a soil carbon model with observed measured SOC, showing the regression line, coefficient of determination R^2 and the degree of variation around the regression line expected for an accurate, precise model for calculating baseline SOC and changes in SOC.

Figure 6: Example Test of Predicted SOC (G/M^2) of a Soil Carbon Model with Observed Measured SOC



The statistics of variation needed to calculate uncertainties for each parameter in the model are also necessary to determine an overall uncertainty in the model calculations of SOC. Total uncertainty of model predictions of baseline SOC, changes in SOC or eventual equilibrium SOC may be determined by an analysis called Monte Carlo simulation[3, 38]. In such a simulation, parameter values are randomly chosen from hypothetical normal distributions with mean equal to the parameter value and the measured standard error around that mean. Once all the different parameter values for the model are generated from the hypothetical distributions, a model prediction is made. This process is repeated 100 or more times to produce a mean model prediction with a 95 percent confidence interval. For baseline SOC, the Monte Carlo simulation would generate an expected value of SOC and a 95 percent confidence interval.

In some cases, alternative soil carbon models, and/or the same modeling framework with different sets of input parameters, may be appropriate for the same project area and activity[39]. If so, the project proponent must match predictions of different models to observed SOC and choose the model that best predicts current $SOC_{m,j,0}$ at each station in stratum m with the lowest Akaike Information Criterion (AIC) value, as per standard model selection procedures[40] Different models may use different numbers of parameters, so AIC is a statistic that measures the amount of variation in observation that is not predicted by a model, corrected for the number of parameters K used in the model to make the prediction:

$$AIC = n \times ln\left(\frac{\sum_{i=1}^{n} e_i^2}{n}\right) + 2K + 2K\left(\frac{K+1}{n-K-1}\right) \quad (6)$$

Where:

AIC	= Akaike Information Criterion value
n	= Number of observations tested, and
e_i	= Deviation of an observation from its model prediction
K	= Number of parameters used

Note that models, such as CENTURY[4, 16, 31], with large numbers of parameters (> 80) require a large number of observations n > K to even generate AIC, and such models would have to generate vastly greater fits (higher R^2, lower $\sum_{i=1}^{n} e_i^2$) to observations than much simpler models with fewer parameters, such as the Hurley Pasture model[2, 34, 35].

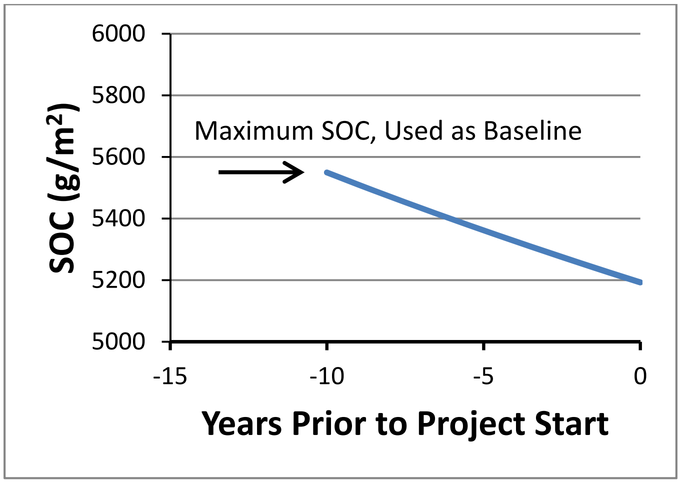
The chosen model must be re-calibrated as soon as changes in SOC may be measured (typically 5 or more years but up to a maximum of 10 years) since the project start date or most recent re-calibration (calibration period). In this case, the model should be used to detect the change in soil carbon during the previous calibration period rather than to predict carbon stocks. Necessary model parameters must be measured as discussed previously in this section and predictions of change in soil carbon stocks must be compared against measured changes at each of the permanent sampling sites using the regression approaches outlined previously in this section. Again, the model should predict observed change in soil carbon with $R^2 > 0.80$ and RMSR < 0.7. If the selected model fails to successfully predict soil carbon changes according to these criteria, then the project proponent may modify the model, or re-calibrate it. Re-calibration may occur by adjusting parameter inputs or coefficients in the model's functions in a reasonable way (justified by peer-reviewed scientific literature) to achieve successful prediction of changes in SOC during the calibration period.

8.1.3.4 Generating Baseline SOC with a Soil Carbon Model

Projects applying a modeled approach, must apply the maximum SOC in the previous 10 years as the baseline SOC stocks. For most projects, this will not have been measured, so the soil carbon model of choice must be used to "back cast," that is estimate SOC that would have occurred during the baseline period**.**

Figure **7**7 provides an example of back casting SOC change from current SOC, based on knowledge of past management activities and environmental conditions. The blue line is predicted SOC of previous years (x-axis). This example shows what baseline SOC would be 10 years prior (5549 g/m^2 at year 10) rather than current (5192 g/m^2 at year 1), thus increasing conservatism in the estimate of baseline SOC.

Figure 7: Example of Back-Casting SOC Change from Current SOC



Maximum baseline $MSOC_{m,j,0}$ for each station in each stratum must be estimated by back casting the chosen model (Figure 7: Example of Back-Casting SOC Change from Current SOC) with model input parameters associated with the soil type, plant species, climate and management activity of that stratum.

Overall, the soil carbon model may be used to estimate a modeled baseline SOC density, $MSOC_{m,j,0}$ = maximum SOC density (tons/ha) at sampling station *j* in stratum *m* during the baseline period.

$$MSOC_{m,j,0} = max(MSOC_{m,j,b}) \quad (7)$$

Where:

$MSOC_{m,j,0}$ = Modeled SOC in station *j* in stratum *m* at *time t =0* (tC / ha)

$MSOC_{m,j,b}$ = Modeled SOC in station *j* in stratum *m* for year *b* during the baseline period (tC / ha)

8.1.3.5 Baseline Emission Removals from Existing Woody Perennials (BRWP)

Under the applicability condition that baseline emissions derived from livelihood-driven human impacts on aboveground woody biomass must be negligible and project activities cannot significantly alter such livelihood-driven activities, it is likely that fire and grazing are the main drivers of change in aboveground woody vegetation. Where a reduction in fire frequency is a project activity, woody plant carbon stocks will increase as a consequence, and reversals of past and ongoing losses of woody plant biomass may be conservatively excluded (ie, BRWP = 0).

If past grazing pressure has been high enough to reduce fuel loads, past fire frequency may have been very low and woody plants, particularly shrubs, may have become abundant. If so, activities to sequester carbon may entail an increase in fire frequency that will reduce aboveground woody biomass but lead to an increase in soil carbon sequestration sufficient to increase total carbon stocks[1]. If fire is employed to change vegetation, aboveground woody biomass, must be accounted for in calculating project emissions and removals.

8.2 Project Emissions

Project emissions and removals depend on the principal set of project activities. Projects that reduce fire events need to account only for changes in methane emissions by grazing animals and changes in SOC. Projects that increase fire events to remove unpalatable woody plants—usually shrubs—in order to stimulate grass and root production can increase total carbon stocks. These projects must account for increased methane emission from biomass burning and emissions from decreased aboveground woody biomass carbon.

8.2.1 Project Methane Emissions from Grazing Animals (PEM_t)

If project activities will include reduction in livestock numbers, then accompanying removals from reduced methane emissions must be conservatively excluded from project removals. This avoids potential leakage from shifting of animals to adjacent grasslands or from market leakage whereby other producers increase livestock numbers to replace project livestock reductions and meet market demand. However, whether or not methane emissions from livestock are reduced, calculations must be based on project data from animal counts or censuses and emission factor data based on project area-applicable body weight of each category from the equations in **Error! Reference source not found.** and Equation (1) (Section 8.1.3.1).

$$PEM_t = \sum_{c=1}^{K} \left(PN_{C,t} \times DMEf\left(W_{C,t}\right)\right) \times GWP_{CH_4} \times 365 \times 6.26x10^{-7} \tag{8}$$

Where:

PEM_t = Project emissions of CH_4 from grazing animals at year t (tCO_2e)

$PN_{C,t}$	= Number of animals of each category *c* in year *t* (head)
$DMEf(W_{C,t})$	= Daily emission factor as a function of animal weight for category *c* (L CH_4 / day)
$W_{C,t}$	= Average body weight during year t for animals of category *c* (kg)
GWP_{CH4}	= Global warming potential for methane (tCO_2e / tCH_4)
365	= Conversion factor for days to years
6.26×10^{-7}	= Conversion factor for L CH_4 / day to tCH_4 / day

The parameters are similar to those used for calculating baseline methane emissions. The number of grazing animal must be measured, because new animal categories may result due to project activities (eg, there is a shift to using different breeds or species of livestock).

8.2.2 Project Emissions from Burning of Biomass ($PEBB_t$)

Where project activities reduce the frequency of fire, this emission may be conservatively excluded, in which case $PEBB_t = 0$. Where project activities increase fire frequency (eg, to remove shrubs) and lead to a net increase in total carbon stocks, the baseline emissions of methane due to burning of biomass, $PEBB_t$, t CO_2e, are calculated using the following equation:

$$PEBB_t = \frac{\sum_m^s \left(PFFREQ_{m,t} \times \left(\sum_{j=1}^{z_m} APB_{j,m,t}\right) \Big/ z_m \right) \times PA_{m,t} \times PC_G \times EF_{BG} \times GWP_{CH_4}}{1{,}000{,}000} \quad (9)$$

Where:

$PEBB_t$	= Project emissions of CH_4 due to biomass burning in stratum m in year t (tCO_2e)
$PFFREQ_{m,t}$	= Proportion of area of stratum *m* burned in year t (percent)
$APB_{j,m,t}$	= Aboveground plant biomass at sampling station *j* in stratum *m* in year *t* at the beginning of the dry/cold/ or burning season (kg biomass/ha)
z_m	= Number of sampling stations in stratum *m* at time *t*
$PA_{m,t}$	= Project area in stratum *m* at time *t* (ha)
PC_G	= Project combustion factor for savanna/grassland (kg biomass burned / kg biomass
EF_{BG}	= Emission factor for the burning of grassland (g CH_4 / kg biomass burned)
GWP_{CH4}	= Global warming potential of CH_4 (t CO_2e / t CH_4)
1,000,000	= factor for converting g CH_4 into tons

The project combustion factor (PC_G) may be estimated in two ways. The project proponent may apply the most applicable IPCC default value [9] or may measure the mean proportion of aboveground biomass after fire ($APB_{m,j,f}$) at the sampling stations in the project area that burned compared with the pre-fire aboveground biomass ($APB_{m,j,t}$) at each station *j* within each stratum *m*[42] :

[9] Table 2.6 in 41. IPCC, *Guidelines for National Greenhouse Gas Inventories* 2006. **4**(Chapter 2).

$$PC_G = 1 - \frac{\sum_{j=1}^{F}\left(\frac{APB_{j,m,f}}{APB_{j,m,t}}\right)}{F} \tag{10}$$

Where:

PC_G	= Project combustion factor for savanna/grassland (kg biomass burned/kg biomass
$APB_{j,m,f}$	= Aboveground plant biomass in stratum *m* in year *t* immediately following fire (kg biomass /ha)
$APB_{j,m,t}$	= Aboveground plant biomass at station *j* in stratum *m* in year *t* at the beginning of the dry/cold or burning season (kg biomass/ha)
F	= Number of sampling stations that burned

8.2.3 Project Changes in SOC Density

The determination of change from baseline equilibrium SOC density depends on the type of project approach used.

Measured Approach:

Where the measured approach is applied, the project sequestration of SOC (in t CO_2e/ha) is calculated using the following equation:

$$PRS_t = {}^{44}/_{12} \times \sum_{m=1}^{s} \frac{PA_m}{z_m} \times \sum_{j=1}^{z_m} \frac{SOC_{m,j,t} - SOC_{m,j,v}}{Y} \tag{11}$$

Where:

PRS_t	= Project removals due to changes in SOC stocks in year *t* (tCO_2e)
PA_m	= Project area of stratum *m* (ha)
s	= Number of strata in the project area
z_m	= Number of sampling stations in stratum *m*
$SOC_{m,j,,v}$	= Baseline SOC in station *j* in stratum *m* in year v, If this is the first monitoring period, v= 0, for subsequent monitoring periods, v represents the year of last verification (tC)
$SOC_{m,j,t}$	= Project SOC measured at station *j* in stratum *m* in year *t* (tC/ha)
Y	= Length of the monitoring period (years)
44/12	= Conversion factor from tC to tCO_2e

$$SOC_{m,j,t} = DEPTH_{m,j,t} \times SOC\%_{m,j,t} \times BULK_{m,j,t} \tag{12}$$

Where:

$SOC_{m,j,t}$	= Project SOC measured at station *j* in stratum *m* in year *t* (tC/ha)

$DEPTH_{m,j,t}$ = Soil core depth (cm)

$SOC\%_{m,j,t}$ = Percent soil carbon at time t (percent)

$BULK_{m,j,t}$ = Bulk density at station j in stratum m in year t (Mg dry soil/m^3; or equivalently, g dry soil/cm^3)

Note that this formula assumes that SOC in year Y and in year 0 (baseline or since last verification) will be measured at a large number (100-1000) of sampling stations j in a stratified project area, including z_m stations in each stratum m (see Section 0).

Modeled Approach:

The selected project area-validated soil carbon model (see Section 8.1.3.3) must be used to simulate a projected equilibrium SOC density, called the project modeled SOC, $PSOC^{eq}_{m,j}$ for sampling station in each stratum under expected project activities. Expected grazing intensities and/or fire frequencies under project activities will combine in the model with other parameters as needed for the chosen soil carbon model to generate $PSOC^{eq}_{m,j}$ for each sampling station The input parameters for the soil carbon model must be chosen to such that conservative estimates of carbon removals are generated. Uncertainties for each parameter in the model must be available to determine an overall uncertainty for $PSOC^{eq}_{m,j}$ with a Monte Carlo simulation[3, 43, 44], as discussed in detail in Section 8.1.3.3. The model must also calculate the number of years D to reach this equilibrium.

Carbon typically accrues in response to management changes with decreasing increments over time as equilibrium is approached[4, 33, 35]. Thus conservatively, the annual increment in SOC is determined by the difference in SOC between the conservative baseline maximum from 10 years prior to the project start ($MSOC_{m,j,0}$) and project modeled equilibrium ($PSOC^{eq}_{m,j,t}$) divided by the time necessary to achieve project equilibrium (D). The project equilibrium must be determined assuming that project activities will be implemented. Thus, multiplying the annual increment in SOC (tons/ha), by the conversion of C to CO_2 44/12 yields CO_2e at that station.

$$PRS_{m,t} = {}^{44}/_{12} \times \frac{PSOC^{eq}_{m} - MSOC_{m,0}}{D} \tag{13}$$

Where:

$PRS_{m,t}$ = Annual project removals due to changes in SOC stocks in stratum m in year t (tCO_2e /ha)

$PSOC^{eq}_{m,}$ = Project modeled equilibrium SOC at station j in stratum m (tC/ha) based on parameter values from z_m sampling stations in stratum m

$MSOC_{m,0}$ = Modeled SOC for stratum m at time $t=0$ (tC/ha) (see section 8.1.3.3)

D = Years required to achieve equilibrium

44/12 = Conversion factor from tC to tCO_2e

$$PRS_t = \sum_{m}^{s} (PA_{m,t} \times PRS_{m,t}) \quad (14)$$

Where:

PRS_t = Project removals due to changes in SOC stocks in year t (tCO_2e)
$PA_{m,t}$ = Project area of stratum m in year t (ha)
s = Number of strata in the project area
z_m = Number of sampling stations in stratum m
$PRS_{m,j,t}$ = Annual project removals due to changes in SOC stocks at station j in stratum m in year t (tCO_2e / ha)

8.2.4 Project Emissions and Removals from Existing Woody Plants ($PERWP_t$)

Where project activities involve changes in fire management, the project proponent must monitor changes in aboveground woody plant biomass (AWPB) to quantify sequestration of GHG in aboveground woody plant carbon from reductions in fire or to ensure that losses of woody biomass from increased fire do not outweigh potential gains from soil carbon sequestration. Where the project activities do not involve changes in fire management, the project proponent may exclude the aboveground and belowground woody biomass pool by assuming PERWP = 0.

$$PERWP_t = \frac{{}^{44}/_{12} \times C \times \sum_{m=1}^{s} \frac{PA_{m,Y}}{z_m} \times \sum_{j=1}^{z_m} AWPB_{m,j,0} - AWPB_{m,j,Y}}{1000 \times Y} \quad (15)$$

Where:

$PERWP_t$ = Project emissions from changes in aboveground woody biomass in year t (tCO_2e)
44/12 = Conversion factor from C to CO_2e
C = Proportion of wood composed of carbon[45, 46] (kg C/kg biomass)
$PA_{m,Y}$ = Project area of stratum m in year Y (ha)
z_m = Number of sampling stations in stratum m
s = Number of strata in the project area
$AWPB_{m,j,0}$ = Aboveground woody biomass at the project start date or beginning of the monitoring period at station j in stratum m; (kg biomass/ha)
$AWPB_{m,j,Y}$ = Aboveground woody biomass at station j in stratum m in year Y (kg biomass/ha)
Y = Length of the monitoring period (years)
1000 = Conversion factor from kg to t

8.3 Leakage

8.3.1 Estimation of Leakage

This methodology considers two forms of leakage: displacement leakage from the movement of livestock off the project area where they may reduce soil carbon, and market leakage, where reductions in livestock numbers as a project activity would create market incentives to replace the lost livestock.

$$LE_t = LD_t + LM_t \quad (16)$$

Where:

LE_t = total leakage emissions in year t (tCO_2e)

LD_t = leakage emissions from displaced livestock in year t (tCO_2e)

LM_t = emissions from market leakage in year t (tCO_2e)

8.3.1.1 Leakage Emissions From Displaced Livestock

Increased GHG emissions from the displacement of livestock outside the project area is limited by the applicability condition that the project must be structured to keep livestock within the project area, and the project proponent must be able to enforce the boundaries of the project area. The project proponent must prevent incursion of livestock from outside the project area or excursion of livestock from inside the project area through fencing, patrolling by game scouts, or other such enforcement of project area boundaries.

The project proponent is expected to control grazing animal numbers inside the project area and account for the number of animals involved and duration of any movement of livestock to outside the project area. Mechanisms must be in place to prevent incursion of livestock onto project lands and to monitor and prevent migration or transport of livestock out of project lands. Such mechanisms may include fencing of private lands, governance structures that penalize lack of cooperation and participation, education, and monitoring on communal grazing lands. Nevertheless, monitoring of project activities may reveal that livestock excursions outside the project area have occurred and any impacts of such excursions on GHG emissions or reductions outside the project area must be accounted for as leakage. Where the project area is not fenced, such as in pastoralist systems, the movement and excursion of livestock to more than two kilometers from the project area boundary is considered leakage.[10]

Leakage methane emissions are deemed as zero because movement of project livestock off the project area does not result in a net increase in the number of livestock emitting methane. However, movement of livestock could result in losses of carbon from higher levels of overgrazing off the project area. Leakage may be accounted in two possible ways: monitored approach or penalty approach.

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[10] This distance allows for possible uncertainty of herders as to the position of herds in or out of the project area and is a typical allowable buffer between ethnic group communal grazing lands [48]

A monitored approach allows livestock to graze on either planned (identified) or unplanned (unidentified) land parcels outside the project area, such land parcels must be classified as grassland, forest, or cropland. In this approach, potential vegetation impacts and baseline SOC in these outside areas must be measured/monitored, following VMD0040 *Leakage from Displacement of Grazing Activities*.

The penalty approach is a more conservative option (leakage calculations will likely be larger) but no monitoring of soils and/or vegetation outside the project area is required and off-project area use of grasslands, croplands, and forests is not differentiated. In this case, displacement leakage (LD_t) must be calculated as a proportion of net removals from increased soil carbon in year t (PRS_t), based on the proportion of total project livestock-days in project year t, 365 x $PN_{c,t}$, that occurred outside the project area.

$$LD_t = \frac{\sum_{x=1}^{d}\sum_{c=1}^{k} DN_{c,x}}{365 \times \sum_{c=1}^{k} PN_{c,t}} \times PRS_t \tag{17}$$

Where:

LD_t	= Leakage emissions from displaced livestock (tCO_2e)
$DN_{C,x}$	= Number of livestock of each category c that were off the project area on day x (head)
d	= Total number of days livestock were off the project area
k	= Total number of livestock categories
$PN_{C,t}$	= Number of animals of each category c in year t (head)
PRS_t	= Project removals due to changes in SOC stocks in year t (tCO_2e)

Alternatively, where using the monitored approach to calculating leakage, the methods for accounting for losses of SOC in VCS module VMD0040 (in Sections 5.2.4 through 5.2.6) must be followed for unidentified grasslands, croplands, and forests. Because this approach explicitly estimates actual losses of SOC from livestock grazing, it is more accurate in its calculation of leakage, and requires the measurement of many additional parameters, as defined in the module. The project proponent, for example, whose livestock were displaced only onto additional grasslands, would be required to measure a number of parameters including, the area of parcels affected, aboveground net primary production, and the number of livestock using the area prior to livestock displacement and following displacement. The monitored approach to calculating displacement leakage does not need to account for CH_4 or N_2O emissions. Methane emissions from project livestock will not change even if livestock are displaced off the project area, and the applicability conditions limit any net increase in dung deposition. Other impacts, such as deforestation or degradation associated with livestock use of forests, or removal of crop residues by livestock must be included in leakage calculations using the monitored approach, if they cannot be shown to be negligible (ie, greater than 0.05 x PER_t, equation 18)

8.3.1.2 Market Leakage Emissions

These result from an increase in activity by other producers of a commodity outside the project area to compensate for the reduced supply of a commodity from within the project area, such as increased timber harvesting elsewhere in a country to compensate for reduced harvesting in a project area). Market leakage is generally considered to be minimal in ALM projects[47] because the projects still allow the same livelihood choices and production of grassland commodities (eg, livestock). The applicability condition that limits project size, and thus potential impact of the project on national and international markets, reduces the chance that project activities will result in declining supply of livestock. Nevertheless, market leakage for any reductions in livestock must be made by using the VCS module VMD0033 "Estimation of emissions from market leakage"[11] to estimate LM_t emissions from market leakage.

Fire alterations are not expected to dramatically alter livelihood choices, (eg, would not prevent use of land for livestock, wildlife conservation, tourism). Projects that manage fire or otherwise do not reduce livestock need not account for market leakage.

Total leakage is negligible where:

$$LE_t < 0.05 \times PNR_t \tag{18}$$

Where:

LE_t	= Total leakage emissions (tCO_2e)
PNR_t	= Project emissions plus removals in year t (tCO_2e)

8.4 Net GHG Emission Reduction and Removals

The estimation of net project emission reductions, PER_t, and net change in carbon stocks, $NCCS_t$, each year of the monitoring period is calculated using the following equation:

$$PER_t = PEM_t + PEBB_t - BEM - BEBB \tag{19}$$

Where:

PER_t	= Net project emission reductions in year t (tCO_2e)
PEM_t	= Project methane emissions from livestock in year t (tCO_2e)
$PEBB_t$	= Project emissions from biomass burning in year t (tCO_2e)
BEM	= Baseline methane emissions from livestock (tCO_2e)
$BEBB$	= Baseline emissions from biomass burning (tCO_2e)

Note that if project methane emissions decrease relative to the baseline from removal of livestock from the project area (note, not from forage improvement), ie $PEM_t - BEM < 0$, this GHG removal must be conservatively excluded to avoid market leakage, and proponents must set $PEM_t - BEM = 0$.

[11] http://www.v-c-s.org/sites/v-c-s.org/files/VMD0033%20Estimation%20of%20Emission%20from%20Market%20Leakage%2C%20v1.0.pdf

$$NCCS_t = PRS_t \pm PERWP_t \qquad (20)$$

Where:

$NCCS_t$	= Net change in carbon stocks in year t (tCO_2e)
PRS_t	= Project removals due to sequestration of soil carbon in year t (tCO_2e)
$PERWP_t$	= Project removals due to loss or gain of carbon stocks in woody biomass in year t (tCO_2e)

The net GHG benefit is calculated using the following equation:

$$R_t = PER_t + NCCS_t - LE_t \qquad (21)$$

Where:

R_t	= Net GHG emission reductions and removals in year t (tCO_2e)
PER_t	= Net project emission reductions in year t (tCO_2e)
$NCCS_t$	= Net change in carbon stocks in year t (tCO_2e)
LE_t	= Total leakage changes in soil carbon in year t (tCO_2e)

8.4.1 Ex-Ante Calculations of Net Emissions and Removals

The project must perform an ex-ante (before project) calculation of expected or estimated net emissions and removals. The key to making such a calculation is to define project quantitative management objectives for fire frequency and/or grazing management compared to baseline activities. The project proponent must do the following:

1) Show a table of baseline and proposed project scenario management activities.
2) Show a table of expected parameters and emissions and removals, and their uncertainties, associated with those management objectives; use data from the peer-reviewed literature, measure activities in the project area, or calculate with a model the resulting changes in emissions and removals associated with the management.
3) Calculate expected project scenario emissions and removals, and their uncertainties, based on these management targets.
4) Show a table of baseline emissions, project emissions and removals, leakage (if any), and total net greenhouse gas emissions and removals for each year of the project crediting period.

8.4.2 Estimation of Uncertainty

The *VCS Standard*[49] requires that uncertainty be calculated on the basis of the full width of the 95 percent CI expressed as a percentage of the estimate of each emission or removal. IPCC Guidelines[43] recommend using a Tier 2 approach to determine uncertainty where emission reductions are determined by a combination of measurements, published emission factors, and process models, such as a soil carbon model. A Tier 2 approach involves conducting Monte Carlo simulations[3, 38], which must calculate R_t from equation (21) (see section 8.4) more than 100 times, with each calculation drawing randomly from hypothetical normal distributions of expected values of each parameter in the calculation, as defined by the mean and standard errors of each parameter. This simulation gives a mean and standard deviation of net emissions and removals R_t that are used to calculate uncertainty (equation (22)). Such Monte Carlo simulations may be done in online computing environments, such as the R Project for Statistical Computing[48], or even with macros developed for spreadsheets[44].

$$UNR_t = \frac{3.84 \times 100 \times SD(MCR_{t,n})}{MCR_t \times (n-1)^{1/2}} \quad (22)$$

Where:

UNR_t = total uncertainty in net emission reductions and removals, not including leakage (%)

n = number of Monte Carlo simulation runs performed (must be > 100)

MCR_t = mean net emissions reductions and removals at time *t*, from *n* Monte Carlo calculations of R_t, (tCO_2e)

$SD(MCR_{t,n})$ = standard deviation of R_t from *n* Monte Carlo simulations

Alternatively, total uncertainty may be calculated by weighting uncertainties according to the magnitude of emission or removal. In this case, uncertainty in net reductions and removals UNR_t is driven by uncertainty in baseline emissions, project emissions and project net changes in carbon stocks.

$$UNR_t = \frac{((\mathrm{UPE}_t \text{ x } (\mathrm{PEM}_t + \mathrm{PEBB}_t))^2 + (\mathrm{UNCCS}_t \text{ x } \mathrm{NCCS}_t)^2 + (\mathrm{UBE} \text{ x } (\mathrm{BEM} + BEBB))^2)^{1/2}}{PEM_t + PEBB_t + NCCS_t + BEM + BEBB} \quad (23)$$

Where:

UNR_t = uncertainty in net emission reductions and removals, not including leakage, at time *t* (%)

UPE_t = uncertainty in project emissions at time *t* (%)

$UNCCS_t$ = uncertainty in net change in carbon stocks at time *t* (%)

UBE = uncertainty in baseline emissions (%)

BEM = baseline animal methane emissions (tCO_2e)

PEM_t = project animal methane emissions at time *t* (tCO_2e)

BEBB = baseline emissions from biomass burning (tCO_2e)

$PEBB_t$ = project emissions from biomass burning (tCO_2e)

$NCCS_t$ = net project changes in carbon stocks (tCO_2e)

Each of the three component uncertainties are derived in detail below

8.4.2.1 Uncertainty in the Baseline

For the calculation of baseline emissions and reductions, BER, uncertainty arises in the calculation of methane emissions only, because all other net emissions are conservatively assumed to be zero, unless increasing fire frequency is a proposed management activity.

In this case:

$$UBE = UBEM \tag{24}$$

Where:

UBE = Uncertainty in baseline emissions (%)

UBEM = Uncertainty in baseline methane emissions from grazing animals (go to section 8.4.2.1.1) (%)

In the case of proposed activities to increase fire frequency:

$$UBE = \frac{((BEM \times UBEM)^2 + \sum_{m=1}^{s}(UBEBB_m \times BEBB_m)^2)^{1/2}}{BEM + \sum_{m=1}^{s} BEBB_m} \tag{25}$$

Where:

$UBEBB_m$ = Uncertainty in baseline methane emissions from burning of biomass (%)

BEM = baseline methane emissions from animals (tCO_2e)

BEBB = baseline emissions from burning of biomass (tCO_2e)

8.4.2.1.1 Uncertainty in baseline methane emissions from grazing animals (UBEM)

$$UBEM = \frac{(\sum_{c=1}^{k}(BEM_c \times UBEM_c)^2)^{\frac{1}{2}}}{\sum_{c=1}^{k} BEM_c} \tag{26}$$

Where:

UBEM = Uncertainty in baseline methane emissions from grazing animals (%)

$UBEM_c$ = Uncertainty in baseline methane emissions from animals in category *c* (%)

BEM_c = Baseline emissions from animals in category *c* (tCO_2e)

$UBEM_c$ is the uncertainty in methane emissions from animals in category c, as dictated by whether the animals are ruminants, equids, or pigs (see Section 8.1.3.1),. $UBEM_c$ is calculated from the uncertainty, for each animal category, in the regression equations predicting per animal daily methane emission (DME_c) based on the mean body weight ($UDME_c$, **Error! Reference source not found.**) and the uncertainty in the harmonic mean of animal counts (UBN_c) during the baseline period.

To obtain UBN_c , first find $SEBN_c$, the standard error[50] of the harmonic mean BN_c of the series' $N_{c,i}$ of animals in category *c* in count *i* of *n* counts or censuses.

$$SEBN_c = (BNc)^2 \times \frac{SD\left(\frac{1}{N_{c,i}}\right)}{(n-1)^{1/2}} \quad (27)$$

Where:

$SEBN_c$	= Standard error of the harmonic mean of animal counts in category *c*
$SD(1/N_{c,i})$	= Standard deviation of the inverses of the count *I* of animals in category *c*
$N_{c,i}$	= Animals in category *c* in census *i* (head)
BN_c	= Harmonic mean number of animals in category *c* (head) during the baseline period (head)
n	= Number of censuses

The 95 percent confidence interval-based uncertainty in the estimated number of animals in category *c* is:

$$UBN_c = 3.84 \times 100 \times \frac{SEBN_c}{BN_c} \quad (28)$$

Where:

UBN_c	= Uncertainty in the harmonic mean of animal counts (%)
$SEBN_c$	= Standard error of the harmonic mean of animal counts
BN_c	= Baseline number of animals of category *c* (head)
3.84	= Multiplier converts expression into a 95% confidence interval
100	= Multiplier converts expression into percent

$$UBEM_c = \left(UBN_c{}^2 + UDME_c{}^2\right)^{1/2} \quad (29)$$

Where:

$UBEM_c$	= Uncertainty in baseline methane emissions from animals in category *c* (%)
UBN_c	= Uncertainty in the baseline harmonic mean of animals of category *c* (%)
$UDME_c$	= Uncertainty in the regression for predicting daily methane emissions for animals of category *c* (%)

8.4.2.1.2 Baseline methane emissions from burning of biomass (BEBB)

In the case of project activities that increase fire frequency, uncertainty in BEBB (UBEBB) is driven by uncertainty in fire frequency ($UFFREQ_m$) in stratum *m* (or mean proportion of area burned), and uncertainty in mean within-stratum aboveground plant biomass at the end of the growing season, $UAPB_m$. $UFFREQ_m$ arises from either the 95 percent confidence interval in annual variation in proportion of area burned over a period of 10 or more years prior to the start date or from uncertainty in the interpretation of satellite images in burned area mapping in stratum *m* resulting from mis-identification or classification errors of burned versus unburned areas[19].

$$UFFREQ_m = 3.84 \times \frac{SD(FFREQ_{m,BY})}{FFREQ_m \times (BY-1)^{1/2}} \times 100 \quad (30)$$

Where:

$UFFREQ_m$	= uncertainty (%) in fire frequency within stratum *m*
$SD(FFREQ_{m,t})$	= standard deviation in fire frequency in stratum *m* over *BY* years in the baseline period.
BY	= number of years in baseline period for which burned area is measured
$FFREQ_m$	= mean proportion of area burned during the baseline period
100	= converts the expression into percent
3.84	= converts the numerator into a 95% confidence interval

$UAPB_m$ arises from the 95 percent confidence interval among permanent sampling stations in clipped, dried, and weighed biomass.

$$UAPB_m = 3.84 \times 100 \times \frac{SD(APB_{z_m})}{APB_m \times (z_m - 1)^{1/2}} \qquad (31)$$

Where:

$UAPB_m$	= uncertainty in aboveground plant biomass within stratum *m*
$SD(APB_{zm})$	= standard deviation in aboveground plant biomass among z_m permanent sampling stations in stratum *m*
z_m	= number of sampling stations in stratum *m*
APB_m	= mean aboveground plant biomass in stratum *m* (kg/m^2)

Therefore these two sources of uncertainty combine as

$$UBEBB = \frac{\left(\sum_m^s \left(BA_m \times \left(UFFREQ_m{}^2 + UAPB_m^2\right)^{1/2}\right)^2\right)^{1/2}}{PA} \qquad (32)$$

Where:

UBEBB	= Uncertainty in baseline methane emissions from burning of biomass
$UFFREQ_m$	= Uncertainty in the fire frequency in stratum *m*
$UAPB_m$	= Uncertainty in mean within-stratum aboveground plant biomass at the end of the growing season in stratum *m*
BA_m	= Baseline area of stratum *m* (ha)
PA	= size of the project area (ha)
s	= number of strata

8.4.2.2 Uncertainty under the project scenario

Uncertainty under the project scenario using a weighted uncertainty approach is determined by uncertainty in project emissions or in carbon stocks, weighted by the magnitude of each, for each year of the monitoring period.

$$UPE_t = \frac{\left((PEM \times UPEM)^2 + \sum_{m=1}^{s}\left(PEBB_{m,t} \times UPEBB_{m,t}\right)^2\right)^{\frac{1}{2}}}{PEM + \sum_{m=1}^{s} PEBB_{m,t}}$$

(33)

Where:

UPE_t = Uncertainty in project emissions (%)

UPEM_t = Uncertainty in project methane emissions from grazing animals (%)

UPEBB_m,t = Uncertainty in project methane emissions from burning of biomass (%)

PEM = project methane emissions by animals during the monitoring period (tCO_2e)

PEBB_m,t = project emissions from biomass burning in stratum *m* at time *t* (tCO_2e)

$$UNCCS_t = \frac{\left(\sum_{m=1}^{s}\left(PRS_{m,t} \times UPRS_{m,t}\right)^2 + \sum_{m=1}^{s}\left(PERWP_{m,t} \times UPERWP_{m,t}\right)^2\right)^{1/2}}{\sum_{m=1}^{s} PRS_{m,t} + \sum_{m=1}^{s} PERWP_{m,t}}$$

(34)

UNCCS_t = Uncertainty in net changes in carbon stocks (%)

UPRS_m,t = Uncertainty in project reductions from soil sequestration (%)

UPERWP_m,t = Uncertainty in project emissions or removals from woody plants (%)

PRS_m,t = Removals from changes in soil carbon stocks in stratum *m* at time *t* (tCO_2e)

PERWP_m,t = Removals from changes in woody plant carbon stocks in stratum *m* at time *t* (tCO_2e)

8.4.2.2.1 Uncertainty in Project Methane Emissions

$$UPEM = \frac{\left(\sum_{c=1}^{k}(PEM_c \times UPEM_c)^2\right)^{1/2}}{\sum_{c=1}^{k} PEM_c} \quad (35)$$

Where:

UPEM = Uncertainty in project methane emissions from grazing animals during the monitoring period (%)

UPEM_c, = Uncertainty in project methane emissions from animals in category *c* (%)

PEM_c = project methane emissions from animals in category *c* (tCO_2e)

$UPEM_{c,}$ is the uncertainty in methane emissions calculated from the uncertainty, for each animal category, in the regression equations for per animal daily methane production (**Error! Reference source not found.**) and the uncertainty in the arithmetic mean of animal censuses for category *c*, PN_c, during the monitoring period.

$$UPEM_{c,} = \left(UPN_c{}^2 + UDME_c{}^2\right)^{1/2} \quad (36)$$

Where:

UPN_c = Uncertainty in the project mean of animals of category *c*

$$UPN_c = 3.84 \times 100 \times \frac{SD(PN_{c,Y})}{PN_c \times (Y\text{-}1)^{1/2}} \quad (37)$$

Where:

$SD(PN_{c,Y})$ = Standard deviation of animal counts in category *c* across Y years of the monitoring period

PN_c = Arithmetic mean of animal numbers in category *c* (head)

Y = Years in the monitoring period

3.84 = Multiplier that converts the numerator into a 95% confidence interval

100 = Multiplier that converts the expression into percent

$UPME_c$ = Uncertainty in the regression, taken from the literature (Table 4) for predicting daily methane emissions for animals of category *c*

8.4.2.2.2 Uncertainty in Project Emissions From Burning Of Biomass

In the case of project activities that increase fire frequency, uncertainty in PEBB, or UPEBB, is driven by uncertainty in fire frequency ($UFFREQ_m$) in stratum *m* (or mean proportion of area burned), and uncertainty in mean within-stratum aboveground plant biomass at the end of the growing season, $UAPB_m$. $UFFREQ_m$ arises from either the 95 percent confidence interval in annual variation in proportion of area burned over the period since last validation or from uncertainty in the interpretation of satellite images in burned area mapping in stratum m resulting from misidentification or classification errors of burned versus unburned areas[19]. $UAPB_m$ arises from the 95 percent confidence interval among permanent sampling stations in clipped, dried, and weighed biomass. Consequently:

$$UPEBB_{m,t} = \left(UPFFREQ_{m,t}{}^2 + UAPB_{m,t}{}^2\right)^{1/2} \quad (38)$$

Where:

$UPEBB$ = Uncertainty in project methane emissions from burning of biomass (%)

$$UPFFREQ_m = 3.84 \times 100 \times \frac{SD(PFFREQ_{m,Y})}{PFFREQ_m \times (Y\text{-}1)^{1/2}} \quad (39)$$

Where:

$UPFFREQ_m$ = Uncertainty in the project fire frequency in stratum *m* (%)

$PFFREQ_m$ = Mean proportion of area of stratum *m* burned during the Y years of the monitoring period

$SD(PFFREQ_{m,Y})$ = Standard deviation in project area of stratum *m* burned during the *Y* years of the monitoring period

$$UAPB_m = 3.84 \times 100 \times \frac{SD(APB_{m,Y})}{APB_m \times (Y-1)^{1/2}} \quad (40)$$

Where:

$UAPB_m$	= Uncertainty in mean within-stratum aboveground plant biomass at the end of the growing season in stratum *m* (%)
APB_m	= mean aboveground plant biomass at the end of the growing season (kg/m^2)
Y	= number of years in the monitoring period
3.84	= multiplier that converts the numerator into a 95% confidence interval
100	= multiplier that converts the expression into percent

8.4.2.2.3 Uncertainty In Project Soil Removals

Under a measured approach, uncertainty in soil sequestration, $UPRS_{m,t}$ in stratum *m* in year *t* is obtained from the 95 percent confidence interval, as required by the VCS rules[47, 49] of measured change in SOC across z_m sampling stations in stratum *m*.

$$UPRS_{m,t} = \frac{SD\Delta SOC_m \times 100 \times 3.84}{\Delta SOC_m \times (z_m - 1)^{1/2}} \quad (41)$$

Where:

$UPRS_{m,t}$	= uncertainty in project soil removals in stratum *m* at time *t* (%)

$$\Delta SOC_m = \sum_{j=1}^{z_m} \frac{SOC_{m,j,t} - SOC_{m,j,v}}{Y} \quad (42)$$

Where:

ΔSOC_m	= Mean of the difference in SOC between the beginning of the project or monitoring period, time *v*, and the year of monitoring *t*, across z_m sampling stations in stratum *m* (tC/ha)

$$SD\Delta SOC_m = \frac{SD(\Delta SOC_{m,z_m})}{(z_m - 1)^{1/2}} \quad (43)$$

Where:

$SD\Delta SOC_m$	= Standard deviation of ΔSOC in stratum *m* during the monitoring period across z_m sampling stations in stratum *m*
Y	= Number of years in the monitoring period
z_m	= Number of sampling stations in stratum *m*
3.84	= Multiplier that converts the numerator into a 95% confidence interval
100	= Multiplier that converts the expression into percent

Under a modeled approach, $UPRS_{m,t}$ is obtained from the calculated 95 percent confidence interval, as required by the VCS[47, 49] from a Monte Carlo simulation of modeled changes in soil carbon (see Sections 8.4.2 and 8.1.3.3) averaged across *n model runs* in stratum *m*.

$$UPRS_{m,t} = 3.84 \times 100 \times \frac{SDMOD\Delta SOC}{MOD\Delta SOC \times (n-1)^{1/2}} \quad (44)$$

Where:

$UPRS_{m,t}$	= Uncertainty in project removals through increased soil carbon in stratum *m* at time *t* (%)
$SDMOD\Delta SOC_m$	= Standard deviation of more than 100 modeled SOC estimates for stratum *m* from Monte Carlo simulation.
$MOD\Delta SOC_m$	= Mean modeled project equilibrium SOC for stratum *m* from more than 100 simulations of project equilibrium SOC, (tC/ha)
n	= Number of times simulation is run (must be greater than 100)
3.84	= Multiplier to convert standard error into a 95% confidence interval
100	= Multiplier to convert to percent

8.4.2.2.4 Uncertainty In Project Emissions And Removals From Woody Plant Biomass

Uncertainty in emissions from loss or gain of aboveground woody plants $UPERWP_{m,t}$ arises from three sources: Consequently, uncertainty in removals or emissions from changes in aboveground woody plant biomass, $UPERWP_{m,t}$, must be calculated as follows:

$$UPERWP_{m,t} = \left(UAWPB_{m,t-1}{}^2 + UAWPB_{m,t}{}^2 + UWD_m{}^2\right)^{1/2} \quad (45)$$

Where:

$UPERWP_{m,t}$	= Uncertainty in project emissions and removals from woody plants in stratum *m* in year *t*
$UAWPB_{m,t-1}$	= Uncertainty in project emissions and removals from woody plant biomass in stratum *m* at the project start date or the previous (year = t-1)
$UAWPB_{m,t}$	= Uncertainty in project emissions and removals from woody plant biomass in stratum *m* in year *t-1*
UWD_m	= Uncertainty in wood density in stratum *m*

(1) Among plot variation in initial (baseline) aboveground woody plant biomass in stratum m, $UAWPB_{m,0}$

$$UAWPB_{m.0} = \frac{SD(AWPB_{m.z_m}) \times 100 \times 3.84}{AWPB_m \times (z_m - 1)^{1/2}} \quad (46)$$

Where:

SD($AWPB_{m,zm}$) = Standard deviation of aboveground woody plant biomass across z_m sampling stations in stratum *m*.

$AWPB_m$ = Mean woody plant biomass across z_m sampling stations in stratum *m* (kg/m^2)

3.84 = Multiplier to convert expression to 95% confidence interval

100 = Multiplier to convert expression to percent

(2) Among plot variation in initial (baseline) aboveground woody plant biomass in year t of verification in stratum m: $UAWPB_{m,t}$,

$$UAWPB_{m,t} = \frac{SD(AWPB_{m,t,.z_m}) \times 100 \times 3.84}{AWPB_{m,t} \times (z_m - 1)^{1/2}} \quad (47)$$

SD($AWPB_{m,t,zm}$) = standard deviation of aboveground woody plant biomass across z_m sampling stations in stratum *m* at time *t* since the project start or last verification.

$AWPB_{m,t}$ = mean woody plant biomass across z_m sampling stations in stratum *m* at time *t* since the project start or last verification (kg/m^2).

3.84 = multiplier to convert numerator to 95% confidence interval

100 =multiplier to convert expression to percent

and

(3) Among plot variation in wood density: *UWD_m*

$$UWD_m = \frac{SD(WD_{m.z_m}) \times 100 \times 3.84}{WD_m \times (z_m - 1)^{1/2}} \quad (48)$$

Where:

SD($WD_{m,zm}$) = standard deviation of wood density across z_m sampling stations in stratum *m* at time *t* since the project start or last verification.

$WD_{m,}$ = mean wood density across z_m sampling stations in stratum *m* (g/cm^3)

3.84 = multiplier to convert expression to 95% confidence interval

100 = multiplier to convert expression to percent

8.4.2.2.5 Uncertainty in Leakage Emissions and Removals

If leakage is not negligible, uncertainty in leakage must be calculated as

$$ULE_t = \left(ULD_t^{\,2} + ULM_t^{\,2}\right)^{1/2} \quad (49)$$

Where

ULE_t = uncertainty in total leakage (%)

ULD_t = uncertainty in displacement leakage (%)

ULM_t = uncertainty in market leakage (%)

$$ULD_t = UPRS_t \quad (50)$$

Where:

$UPRS_t$ = Uncertainty in project removals due to changes in soil carbon stocks in year *t* (%).

This assumes that displacement leakage affects only soil carbon removals, and thus is subject to uncertainty associated with predicting impacts project activities on soil carbon removals

Uncertainty in market leakage, ULM_t, will be determined by using VCS module VMD0033 "Estimating emissions from market leakage."

8.4.2.3 Total Project Uncertainty

The total project uncertainty UT_t is calculated at the time of reporting through propagating the uncertainty in the baseline emissions and that in the project emissions and removals to year t:

Under a Monte Carlo calculation

$$UT_t = (UNR_t^2 + ULE_t^2)^{1/2} \quad (51)$$

Where

UT_t = total project uncertainty (%)

UNR_t = uncertainty in net emissions and removals as calculated with Monte Carlo simulation (%)

ULE_t = uncertainty in leakage emissions and removals (%)

$$UT_t = \frac{((NR_t \times UNR_t)^2 + (LE_t \times ULE_t)^2)^{1/2}}{NR_t + LE_t} \quad (52)$$

Where:

UT_t = Total project uncertainty (%)

UNR_t = Uncertainty in net emissions and removals, not including leakage (%)

ULE_t = Uncertainty in leakage emissions and losses from soil carbon stocks at time *t* (%)

NR_t = Net emissions reductions and removals at time *t*, not including leakage (tCO_2e)

LE_t = Leakage emissions and losses from soil carbon stocks at time *t* (tCO_2e)

8.4.3 Conservative Approach

Calculations of emissions reductions and removals are conservative because:

1) Baseline methane emissions use the harmonic mean for baseline emissions and an arithmetic mean for the project scenario leading to a conservative estimate for reductions in methane emissions (Section 8.1.3.1).
2) Initial baseline SOC level for modelled (activity-based) emission reductions must be the maximum of the previous 10 years, as required by the VCS rules[47, 49] . In the case of modeled approach, the baseline equilibrium SOC is set to this maximum and then compared to the modeled future equilibrium SOC (Section 8.1.3.3).
3) Because models used in the modeled approach must be validated for the project with data from the project area, no model correction is necessary. However, model predictions must meet the requirements for R^2, slope and intercept in a regression versus observed values (see section 8.1.3.3) to assure that the model does not overestimate removals. All parameter choices are to be conservative.
4) Emissions reductions are subject to reductions for uncertainty, as required by the VCS rules[47, 49] in the modeled approach, with uncertainty determined from 95 percent confidence intervals from standard errors calculated during Monte Carlo simulations (Section 8.4.2).

8.4.4 Uncertainty Deduction

If total project uncertainty in year *t*, based on 95 percent confidence intervals, $UT_t \leq$ 30 percent then no deduction must result for uncertainty.

If UT_t > 30 percent then the modified discounted value, $R_t = R_t^{disc}$ for net anthropogenic GHG removal by sinks to account for uncertainty must be:

$$R_t^{disc} = \frac{(100 - UT_t) \times R_t}{100} \tag{53}$$

Where:

R_t^{disc}	= Discounted net GHG emission reductions and removals by year *t* (tCO_2e)
UT_t	= Total project uncertainty
R_t	= Net GHG emission reductions and removals by year *t* (tCO_2e)

For *Y* years of the monitoring period,

$$R_Y = \sum_{t=1}^{d} R_t^{disc} + \sum_{t=1}^{u} R_t \tag{54}$$

Where:

d	= Number of years in which net removal must be discounted
u	= Number of years in which removals are not discounted
Y	= Number of years in the monitoring period *(d + u)*
R_t^{disc}	= Discounted net GHG emission reductions and removals by year *t* (tCO_2e)

R_t = Net GHG emission reductions and removals by year t (tCO_2e)

9 MONITORING

Given applicability conditions and allowable conservative exclusions, monitoring focuses on measuring the key parameters for calculating emissions and removals, demonstrating project management activities and measuring changes in SOC. The project activities key to changing methane emissions are altering the number and species composition of livestock grazing animals and/or species composition of forage plants , altering duration, timing, and intensity of grazing, and/or changing fire frequency, intensity and any accompanying vegetation change (such as in woody biomass). Changes in SOC density under the project scenario will also be monitored, and stratified according to management practices or soil and climatic conditions. Monitoring of soil, vegetation, grazing intensity and occurrence and intensity of fires will fully employ the permanent sampling stations discussed in Section 8.1.2.

9.1 Data and Parameters Available at Validation

9.1.1 Project Design

Data / Parameter	$PA_{m,g}$
Data unit	ha
Description	Project area in stratum m
Equations	3, 9, 11, 14 and 15
Source of data	Measured in project area
Justification of choice of data or description of measurement methods and procedures applied	Using shape files in a GIS or from known coordinates of stratum boundaries or from legal descriptions of the property included in the project area.

Comments	Project proponents must ensure that the following information in regards to the project area of each stratum is provided in the project description: 1) Map(s) of the locations of the permanent sampling plots overlaid on a map of project strata. 2) Results of cluster analysis to determine project strata. 3) Table of all project strata, their description, and area, PA_m 4) Results of analysis to determine the number of sampling units and their allocation among strata

Data Unit / Parameter	GWP_{CH4}
Data unit	t CO_2e/t CH_4
Description	Global-warming potential for CH_4
Equations	6, 8, 12, 30 and 32
Source of data	GWP_{CH4} must be obtained from the IPCC Second Assessment Report
Value applied	21
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comment	

9.1.2 Baseline Methane Emissions

Data / Parameter	$W_{c,t}$
Data unit	kg
Description	Average body weight for animals of category c in year t
Equations	1
Source of data	Measured in project area
Justification of choice of data or description of measurement methods and procedures applied	Necessary to estimate emission factor for grazing animals using allometric equations in **Error! Reference source not found.**. Measurements must be taken in accordance with the procedures described in Section 9.1.2.
Purpose of data	Calculation of baseline emissions

Comments	

Data / Parameter	$N_{c,i}$
Data unit	number
Description	Baseline number of animals of category *c* in census *i*
Equations	1
Source of data	Measured in project area
Justification of choice of data or description of measurement methods and procedures applied	The number of animals in each census *i* must be measured to calculate the harmonic mean of the multiple counts i of n censuses of animals in category c. At least four measurements within the baseline period, with at least two during the period 5-10 years prior to the project start, must be available. Measurements must be taken in accordance with the procedures described in Section 9.1.2.
Purpose of data	Calculation of baseline emissions
Comments	The project description must provide a table of historical censuses or estimates of numbers of grazing animals, BN_c, for each year in which counts or estimates are available, sorted by the k categories of animals in the project area: species, breed (if applicable), sex, and age, plus the respective live body weights (W_c) of each category, with 95% percent CI and uncertainties). The project description must also provide a data table showing calculations of methane emissions based on the equations in **Error! Reference source not found.** for each animal category for each year that data are available. The table must include calculated total emissions for that year and a cell containing the harmonic mean of total annual calculated methane emissions. This will be the baseline BEM. The harmonic mean appropriately and conservatively weights the average methane emissions towards the lower values of a time series of measurements[27]. The table must also contain the uncertainty in daily methane emissions (from the regression equations in **Error! Reference source not found.**) and the harmonic mean and its' uncertainty. Table 5 below may be used as a template.

Table 5: Table for Calculating Baseline Methane Emissions from Animal Censuses.

Grazing Animal Category					Animal Counts (Head)						Methane Emissions	
Species	Sex/Age	Weight (kg)	Annual Methane Emissions/ Animal	Per Animal Uncertainty[1]	Year 1	Year 2	Year 3	Year 4	Harmonic Mean	Uncertainty in Animal Counts	Methane Emissions for Category (tCO2e)	Uncertainty in Methane Emissions
Species 1												
Species 2												
Species 3												
Species 4												
										Total Emissions		

[1] Based on uncertainty in regression models that calculate methane emissions from body mass (see Table 3)

Species-specific weights on the left-hand side are used to calculate annual methane emissions per animal using equation 1 (section 8.1.3.1). Methane emissions per animal are then multiplied by the harmonic mean number of animals (equation 2) to estimate annual methane emissions for the animal category. Uncertainty per animal (from Table 3 in section 8.1.3.1) and uncertainty in the harmonic mean (equation 25 in section 8.4.2) combine in equation 27 to calculate overall uncertainty in methane emissions. This table must be included in the project description.

9.1.3 Parameters for Baseline Calculation of Emissions from Burning of Biomass

For projects that intend to increase fire frequency, the project description must show the equation (Equation 3) used to calculate BEBB and display a table showing estimated fire frequency $FFREQ_m$, initial unburned aboveground plant biomass ($APB_{m,b}$), with 95 percent CI and uncertainties (95 percent CI/estimate, expressed as a percentage) for each and calculated BEBB with for each project stratum.

Data / Parameter	$APB_{m,b}$
Data unit	kg dry mass/ha
Description	Mean total aboveground plant biomass in stratum m in year t at the end of the growing season (summer or wet season)
Equations	3
Source of data	Measured
Justification of choice of data or description of measurement methods and procedures applied	Measured at permanent sampling stations within each stratum *m* by clipping, drying (at 25-50 ^{o}C) and weighing aboveground vegetation from one or more small quadrats. Measured at the beginning of the dry season in the tropics or beginning of the cold or burning season in temperate climates. Must be measured in the project area 1-2 years before the project start date, or within the first year of the monitoring period and prior to the first prescribed burn if fire frequency is to be increased to manage vegetation to increase soil carbon.
Purpose of data	Calculation of baseline emissions
Comments	

Data / Parameter	$FFREQ_m$
Data unit	Dimensionless proportion
Description	Average proportion of area burned in stratum *m* in past 10 years
Equations	3
Source of data	Measured
Justification of choice of data or description of measurement methods and procedures applied	Measured by mapping burned areas with aerial photography or in projects with extensive area (> 10,000 ha), interpreting satellite images, such as MODIS, with published algorithms for assessing burned area[19]. Photography or satellite image interpretations must be verified by records of known burned areas or ground assessments of burns in the past year
Purpose of data	Calculation of baseline emissions
Comments	

Data / Parameter	BC_G
Data unit	kg biomass / kg biomass burned
Description	Baseline combustion factor for savanna/grassland
Equations	3

Source of data	Hoffa et. al., 1999 or Reference [41]
Value Applied	0.5 or default from Table 2.6, respectively
Justification of choice of data or description of measurement methods and procedures applied	It is unlikely that all aboveground biomass is combusted in fire, but this fraction is difficult to measure accurately during past years because biomass remaining after fire must be measured immediately following fire[42]. The fraction of biomass combusted usually averages around 0.75 [42] and setting BC_G = 0.5 makes the potential impact of increasing fire under the project scenario conservative in its likelihood to reduce emissions.
Purpose of data	Calculation of baseline emissions
Comments	

Data / Parameter	EF_{BG}
Data unit	g CH_4/kg biomass burned
Description	Emission factor for the burning of grassland
Equations	3, 9
Source of data	Reference [51]
Value Applied	1.9
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comments	

9.1.4 Parameters for Calculation of Baseline SOC

A critical measurement is initial soil organic carbon which is necessary in establishing the baseline SOC in the measured approach and validating the chosen soil carbon dynamic model in a modeled approach. Multiple stations must be sampled within each stratum so as to determine a 95% percent confidence interval. Some models only quantify changes in SOC to specific depths, (eg, CENTURY only predicts SOC to a depth of 20 cm[16, 31]), and if using a modeling approach with a restricted depth, the project proponents must measure depth that matches that of the model. If using a measured approach or a model that allows different soil depths to be used, and appreciable soil carbon stocks occur below 30 cm[52], then proponents are justified in sampling deeper in the soil profile, even to a depth of 1m. Known volumes of soil from the cores must be sieved to remove rocks, pebbles, and coarse fragments, and then the remainder dried (5 days at 45^{o}C or equivalent) and weighed to determine bulk density (Mg/m^3)[53].

If an IR spectrometer is to be used, the project proponent must show all calibration data in a table with spectral emissions and measurements of soils or plants and graphs showing the regressions of spectral data against measurements.

Data / Parameter	$DEPTH_{m,j,0}$
Data unit	cm
Description	Soil core depth at station *j* in stratum *m* at time *t = 0* (ie, at the start of the project or since the last verification)
Equations	4
Source of data	Measured in project area
Justification of choice of data or description of measurement methods and procedures applied	At each sampling station *j*, according to standard methods[52, 54], soil must be taken from at least 3 soil cores (with 10 cores at each site recommended to reduce uncertainty) to a depth that accounts for the vast majority (> 80 percent) of SOC in the soil column, reflects depth to hardpans or bedrock, or matches calculations from soil carbon models. Multiple cores may be well-mixed into a single composite sample for analysis.
Purpose of data	Calculation of baseline emissions
Comments	

Data / Parameter	$SOC\%_{j,m,0}$
Data unit	Dimensionless proportion
Description	Proportion soil organic carbon at station *j* in stratum *m* at time *t = 0* (ie, at the start of the project or since the last verification)
Equations	4
Source of data	Measured in project area
Justification of choice of data or description of measurement methods and procedures applied	The baseline for the measured offset approach is based on increasing SOC. Tracked at the level of j = 1 to z_m individual sampling stations in each stratum because offset will be based on demonstrating changes in SOC at individual stations and then summing increments. At each sampling station *j*, according to standard methods[52, 54], soil must be taken from at least 3 soil cores (with 10 cores at each site recommended to reduce uncertainty) to a depth that accounts for the vast majority (> 80 percent) of SOC in the soil column, reflects depth to hardpans or

	bedrock, or matches calculations from soil carbon models. Multiple cores may be well-mixed into a single composite sample for analysis. Multiple stations must be sampled within each stratum so as to determine a 95 percent confidence interval. Organic carbon concentrations must be measured in appropriate academic or industrial laboratories that use either chemical[55] combustion or appropriately calibrated spectral analysis methods. IR methods must be calibrated by regression, with $R^2 \geq 0.90$, of IR measurement with measurement by chemical or combustion methods. Graphs of regression of IR versus combustion or chemical methods must be shown. There must be no significant bias (ie, slope 95 percent confidence interval must include 1) intercept 95 percent CI must include 0. Bias must be determined by evaluating percent bias (positive or negative) following equation (5) (see detailed description of bias evaluation in Section 8.1.3.3) and cannot exceed ± 10%. If an IR spectrometer is to be used, the project proponent must show all calibration data in a table with spectral emissions and measurements of soils or plants and graphs showing the regressions of spectral data against measurements.
Purpose of data	Calculation of baseline emissions
Comments	

Data / Parameter	$BULK_{m,j,0}$
Data unit	Mg/m^3 or, equivalently, g/cm^3
Description	Bulk density at station *j* in stratum *m* at time *t = 0* (i.e., at the start of the project or since the last verification)
Equations	4
Source of data	Measured in project area
Justification of choice of data or description of measurement methods and procedures applied	At each sampling station *j*, according to standard methods[52, 54], soil must be taken from at least 3 soil cores (with 10 cores at each site recommended to reduce uncertainty) to a depth that accounts for the vast majority (> 80 percent) of SOC in the soil column, reflects depth to hardpans or bedrock, or matches calculations from soil carbon models. Multiple cores may be well-mixed into a single composite sample for analysis.

	Known volumes of soil from the cores must be sieved to remove rocks, pebbles, and coarse fragments, and then the remainder dried (5 days at 45ºC or equivalent) and weighed to determine bulk density.[53]
Purpose of data	Calculation of baseline emissions
Comments	

9.1.5 Parameters for Soil Carbon Models

Soil carbon models may require anywhere from a few to more than 80 parameters, so there is no definitive list of parameters that would apply to all models. However, in evaluating whether a modeled approach is feasible or desirable, the following parameters are likely to be key inputs into soil carbon models. Each parameter may vary among strata, depending on the size of the project area and underlying variation in soil type and plant species composition. Parameters must yield a predicted SOC density.

Data / Parameter	MAP_m
Data unit	mm/yr
Description	Mean annual precipitation in stratum m
Equations	Model input
Source of data	Precipitation maps from government or peer-reviewed published sources, nearby weather stations, or rain gauges
Justification of choice of data or description of measurement methods and procedures applied	A key variable that affects a number of processes driving SOC
Purpose of data	Calculation of baseline emissions
Comments	

Data / Parameter	$ST_{j,m,y}$
Data unit	ºC
Description	Soil temperature at station j in stratum m in month y
Equations	Model input
Source of data	Measured in project area

Justification of choice of data or description of measurement methods and procedures applied	Must be measured monthly or at least seasonally with a digital thermometer with probes inserted to at least ½ the depth at which SOC will be sampled (ie, to 10 cm if soil will be sampled and modeled to 20 cm [16])
Purpose of data	Calculation of baseline emissions
Comments	

Data / Parameter	$SAND\%_{j,m}$ and/or $CLAY\%_{j,m}$ and/or $SILT\%_{j,m}$
Data unit	Dimensionless proportion expressed as percent
Description	Proportion of soil that is sand, silt, and or clay at station j in stratum m
Equations	Model input
Source of data	Measured in project area
Justification of choice of data or description of measurement methods and procedures applied	Soil collected to desired depth at each sampling station must be mixed, and subsample analyzed for clay, silt, and sand fractions in a professional laboratory. Some models require percent sand, some percent clay and some percent of all three particle classes, sand, silt and clay.
Purpose of data	Calculation of baseline emissions
Comments	

Data / Parameter	$GI_{j,m}$
Data unit	Dimensionless proportion
Description	Mean annual grazing intensity at station j in stratum m
Equations	Model input
Source of data	Measured
Justification of choice of data or description of measurement methods and procedures applied	Measured at each sampling station prior to validation by either 1) Comparing clipped biomass at least at the end of the growing season, or more frequently for some models, inside and outside small (1 m^2) fences. $GI_{j,m}$ = 1 – (biomass outside/biomass inside). Biomass is clipped, dried at 25 – 50 ^oC, and weighed. 2) Visually estimating historical grazing intensity from a calibrated observation method (R^2>0.80 correlation between measured GI (from option 1 above and

	observational method)) based on species composition, bare ground, and vegetation height.
Purpose of data	Calculation of baseline emissions
Comments	

Data / Parameter	$MAPLC_{j,m}$
Data unit	Dimensionless proportion
Description	Mean aboveground plant cellulose plus lignin at sampling plot j in stratum m
Equations	Model input
Source of data	Measured in project area
Justification of choice of data or description of measurement methods and procedures applied	SOC is often closely related to inputs of these forms of carbon because they resist microbial decomposition.
Purpose of data	Calculation of baseline emissions
Comments	

In addition, soil carbon models will likely use fire frequency, $FFREQ_m$ introduced in Section 8.1.3.2, and initial $SOC_{m,j,0}$ introduced in Section 8.1.3.4.

Tracking parameters at each sampling station allows the chosen soil carbon model(s) to be tested at many locations and under different conditions. This improves the ability to infer whether data fit model predictions.

These parameters must be input into the chosen soil carbon model(s) to calculate the SOC parameters described below, which are used in the quantification of removals.

Data / Parameter	$MSOC_{m,j,b}$
Data unit	tC/ha
Description	Modeled SOC at station *j* in stratum *m* for each year *b* during the baseline period
Equations	7
Source of data	SOC model

Justification of choice of data or description of measurement methods and procedures applied	SOC models applied must meet with the modeling requirements described in Section 8.1.3.4.
Purpose of data	Calculation of baseline emissions
Comments	

Data / Parameter	$PSOC^{eq}_{m,j,}$
Data unit	tC/ha
Description	Modeled SOC at equilibrium at station *j* in stratum *m*
Equations	13
Source of data	SOC model
Justification of choice of data or description of measurement methods and procedures applied	SOC models applied must meet with the modeling requirements described in Section 8.2.3.3.
Purpose of data	Calculation of project emissions
Comments	

Data / Parameter	D
Data unit	years
Description	Years required to achieve SOC equilibrium
Equations	13
Source of data	SOC model
Justification of choice of data or description of measurement methods and procedures applied	SOC models applied must meet with the modeling requirements described in Section 8.2.3.
Purpose of data	Calculation of project emissions
Comments	

9.1.6 Parameters for Removals from Woody Plant Biomass

Data / Parameter	C
Data unit	kg C/kg biomass
Description	Proportion of wood composed of carbon
Equations	15
Source of data	CDM, *A/R Methodological Tool: Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*, and MacDicken, 1997
Value applied	0.45
Justification of choice of data or description of measurement methods and procedures applied	
Purpose of data	Calculation of project emissions
Comments	

9.2 Data and Parameters Monitored

Parameters monitored are those needed to calculate removals from reduced methane emissions from animals and/or removals from soil carbon sequestration plus any increases in emissions of methane from burning of biomass and leakage.

Data / Parameter	$PA_{m,t}$
Data unit	ha
Description	Project area in stratum m in year t
Equation	12, 14, 18, 19
Source of data	Measured in project area
Description of measurement methods and procedures to be applied	Using shape files in a GIS or from known coordinates of stratum boundaries or from legal descriptions of the property included in the project area.
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	Areas must be determined from accurate GIS layers of classified project area or from legal descriptions of property included in the project area. Verification should be with Global Positioning

	Systems (GPS) with an accuracy of 10 m or less. Ground points may include permanent sampling stations but also may be necessary to include points at defined stratum boundaries or along roads.
Purpose of data	Calculation of project emissions
Comments	Projects must ensure that the following information in regards to the project area of each stratum is provided within the relevant area of the project description: 1) Map(s) of the locations of the permanent sampling plots overlaid on a map of project strata. 2) Results of cluster analysis to determine project strata. 3) Table of all project strata, their description, and area, PA_m 4) Results of analysis to determine the number of sampling units and their allocation among strata

9.2.1 Project Animal Methane Emissions

Unlike when determining the baseline, the arithmetic mean of the counts during the project crediting period must be used to ensure a conservative estimate of reductions in methane emissions relative to baseline emissions, which are calculated with the harmonic mean[27].

For permissible methods of conducting an animal census, see Section 9.3.3.

Data / Parameter	$PN_{c,t}$
Data unit	number
Description	Mean number of animals of category c in the project area during year t
Equation	8, 17, 18
Source of data	Measured in project area
Description of measurement methods and procedures to be applied	Measured as the arithmetic mean of one or more years' animal censuses during the verification period
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	Based on records of livestock numbers, interviews of grazing managers, coordinators, herders or other administrative staff. Records should be kept as paper and electronic copies,

Purpose of data	Calculation of project emissions
Comments	The project description must provide a table, similar to that for calculating baseline methane emissions, of counts or estimates of numbers of grazing animals, PN_c, for each year during the monitoring period, sorted by the k categories in the project area: species, breed (if applicable), sex, and age, plus the respective live body weights (W_c) of each category, with 95% percent CI and uncertainties. The table must also contain the uncertainty in daily methane emissions and the uncertainty in the arithmetic mean count based on the equations in Section 8.4.2.2.1. Table 6 below may be use as a template.

Table 6: Table for Calculating Project Methane Emissions from Animal Censuses.

Grazing Animal Category					Animal Census (Number of Animals)						Methane Emissions	
Species	Sex/Age	Weight (kg)	Annual Methane Emissions/ Animal	Per Animal Uncertainty[1]	Year 1	Year 2	Year 3	Year 4	Arithmetic Mean	Uncertainty in Animal Counts	Methane Emissions for Category (tCO_2e)	Uncertainty in Methane Emissions
Species 1												
Species 2												
Species 3												
Species 4												
										Total Emissions		

[1] Based on uncertainty in regression models that calculate methane emissions from body mass (see Table 3)

Species-specific weights on the left-hand side are used to calculate annual methane emissions per animal using equation 1 (section 8.1.3.1). Methane emissions per animal are then multiplied by the arithmetic mean number of animals to estimate annual methane emissions for the animal category. Uncertainty per animal (from Table 3 in section 8.1.3.1) and uncertainty in the harmonic mean (equation 25 in section 8.4.2) combine in equation 27 to calculate overall uncertainty in methane emissions. This table must be included in the project description.

9.2.2 Project Emissions from Burning of Biomass

For projects that intend to increase fire frequency, the project description must show the equation (Equation (3)) used to calculate $PEBB_{m,t}$ at time *t* for each project stratum. All projects that alter fire frequency must and display a table showing estimated fire frequency $PFFREQ_{m,t}$ in year *t*, pre-fire aboveground plant biomass ($APB_{j,m,t}$), and post-fire aboveground plant biomass at stations where fire occurred ($APB_{j,m,f}$) with 95 percent CI and uncertainties for each and calculated.

Data / Parameter	$PFFREQ_{m,t}$
Data unit	Dimensionless proportion
Description	Average proportion of area burned in stratum *m* during project year t.
Equations	9
Source of data	Measured
Description of measurement methods and procedures to be applied	Measured by mapping burned areas with aerial photography or in projects with extensive area (> 10,000 ha), interpreting satellite images, such as MODIS with published algorithms for assessing burned area[19]. Photography or satellite image interpretations must be confirmed by records of known burned areas or ground assessments of burns in the past year.
Frequency of monitoring/recording	Every 15 days during the burning season
QA/QC procedures to be applied	Follow procedures in references [18, 19]
Purpose of data	Calculation of project emissions
Comments	

Data / Parameter	$APB_{j,m,t}$
Data unit	kg dry mass/ha
Description	Aboveground plant biomass at station *j* in stratum *m* in year *t* at the beginning of the dry/cold or burning season
Equations	9,10
Source of data	Measured
Description of measurement methods and procedures to be applied	Measured at permanent sampling stations within each stratum m by clipping, drying (at 25-50 ºC) and weighing aboveground vegetation from one or more small quadrats. Measurements from all quadrats must be averaged for each sampling station *j*. Measured at the beginning of the dry/cold/burning season in temperate climates[17, 56].

Frequency of monitoring/recording	Annually
QA/QC procedures to be applied	Samples must be dried in a professional drying oven for 3 days at 45-60ºC or be air-dried in sunshine for 4-7 days to a constant mass
Purpose of data	Calculation of project emissions
Comments	

Data / Parameter	$APB_{j,m,f}$
Data unit	kg dry mass/ha
Description	Aboveground plant biomass in stratum *m* in year *t* at immediately after fire
Equations	10
Source of data	Measured
Description of measurement methods and procedures to be applied	Measured at permanent sampling stations within each stratum m by clipping, drying (at 25-50 ºC) and weighing aboveground vegetation from one or more small quadrats. Measurements from all quadrats must be averaged for each sampling station *j*. Measured immediately following the occurrence of fire[17, 56].
Frequency of monitoring/recording	Once in 1-2 years prior to project start or before the first prescribed burn in the first year of the project
QA/QC procedures to be applied	Samples should be dried in a professional drying oven for 3 days at 45-60ºC or be air-dried in sunshine for 4-7 days to a constant mass
Purpose of data	Calculation of project emissions
Comments	

9.2.3 Parameters for Calculating SOC Removals

If a measured approach is taken, then the critical measurement is of SOC density at the end of the monitoring period at each sampling station, according to standard methods[52, 54]. Soil must be taken from three or more pooled soil cores (with 10 cores at each site recommended to reduce uncertainty) at each station to a desired depth (cm) For more details, see section 9.1.4

In a modeled approach, these same procedures must apply when monitoring soil carbon for the purposes of re-calibrating the chosen soil carbon model. In this case there may be a calibration period of Z years (typically 5-7 years) that is long enough to detect changes in SOC and likely longer than the monitoring periods used in a modeled approach.

Data / Parameter	$DEPTH_{m,j,t}$
Data unit	cm
Description	Soil core depth at station *j* in stratum *m* at time *t = 0* (ie, at the start of the project or since the last verification)
Equations	12
Source of data	Measured in project area
Description of measurement methods and procedures to be applied	Soil must be taken from at least three soil cores (with 10 cores at each site recommended to reduce uncertainty) at each station *j* to a depth that accounts for the vast majority (> 80 percent) of SOC in the soil column, reflects depth to hardpans or bedrock, or matches calculations from soil carbon models. Multiple cores may be well-mixed into a single composite sample for analysis.
Frequency of monitoring/recording	At the end of the monitoring period for measured approach projects, or, for modeled approach, after a desired monitoring period for re-calibrating the chosen soil carbon model on the basis of its ability to predict changes in soil carbon during the monitoring period.
QA/QC procedures to be applied	Depth cored must be the same as for baseline soil carbon sampling (see 9.1.5). However, the depth used in calculating SOC after Y years of project activities must be adjusted to account for changes in bulk density such that $DEPTH_{m,j,Y}$ x $BULK_{m,j,Y}$ = $DEPTH_{m,j,0}$ x $BULK_{m,j,0}$. This ensures that equal masses of soil are compared between year 0 and year Y
Purpose of data	Calculation of project emissions
Comments	

Data / Parameter	$SOC\%_{m,j,t}$
Data unit	Dimensionless proportion
Description	Proportion soil organic carbon at station *j* in stratum *m* at time *t*
Equations	12
Source of data	Measured in project area

Description of measurement methods and procedures to be applied	Soil must be taken from at least three soil cores (with 10 cores at each site recommended to reduce uncertainty) at each station *j* to a depth that accounts for the vast majority (> 80 percent) of SOC in the soil column, reflects depth to hardpans or bedrock, or matches calculations from soil carbon models. Multiple cores may be well-mixed into a single composite sample for analysis. The organic carbon concentrations must be measured in appropriate academic or industrial laboratories with chemical[55] automated, calibrated analytical machines or with project-area calibrated infra-red IR spectrometers[30].
Frequency of monitoring/recording	At the end of the monitoring period for measured approach projects, or, for modeled approach, after a desired monitoring period for re-validating the chosen soil carbon model on the basis of its ability to predict changes in soil carbon during the monitoring period.
QA/QC procedures to be applied	The organic carbon concentrations must be measured in appropriate academic or industrial laboratories with chemical[55] automated, calibrated analytical machines or with project-area calibrated infra-red IR spectrometers[30]. IR methods must be calibrated by regression, with $R^2 \geq 0.90$, of IR measurement with measurement by chemical or combustion methods. Graphs of regression of IR versus combustion or chemical methods must be shown. There must be no significant bias (ie, slope 95 percent confidence interval must include 1) intercept 95 percent CI must include 0, which will ensure that MBIAS, following equation (5) [37] is between -10% and +10%. If an IR spectrometer is to be used, the project proponent must show all calibration data in a table with spectral emissions and measurements of soils or plants and graphs showing the regressions of spectral data against measurements.
Purpose of data	Calculation of project emissions
Comments	

Data / Parameter	$BULK_{m,j,t}$
Data unit	Mg/m^3, or, equivalently, g/cm^3
Description	Bulk density in stratum m, station j, year t
Source of data	Measured in project area
Equations	12

Description of measurement methods and procedures to be applied	Soil must be taken from at least three soil cores (with 10 cores at each site recommended to reduce uncertainty) at each station *j* to a depth that accounts for the vast majority (> 80 percent) of SOC in the soil column, reflects depth to hardpans or bedrock, or matches calculations from soil carbon models. Multiple cores may be well-mixed into a single composite sample for analysis. Known volumes of soil from the cores must be sieved to remove rocks, pebbles, and coarse fragments, and then the remainder dried (5 days at 45ºC or equivalent) and weighed to determine bulk density.
Frequency of monitoring/recording	At the end of the monitoring period for measured approach projects, or, for modeled approach, after a desired monitoring period for re-validating the chosen soil carbon model on the basis of its ability to predict changes in soil carbon during the monitoring period.
QA/QC procedures to be applied	However, the depth used in calculating SOC after Y years of project activities must be adjusted to account for changes in bulk density such that $DEPTH_{m,j,Y}$ x $BULK_{m,j,Y}$ = $DEPTH_{m,j,0}$ x $BULK_{m,j,0}$. This ensures that equal masses of soil are compared between year 0 and year Y [53]
Purpose of data	Calculation of project emissions
Comments	

9.2.4 Parameters for Project Soil Carbon Models

If using the modeled approach, the same soil carbon model used to calculate BSOC must be used to calculate SOC expected after Y years of management under the project scenario. Uncertainties again must be calculated with Monte Carlo simulations[3, 38].

It is crucial that model input parameters must be tracked at each sampling station if possible to allow the chosen soil carbon model(s) to be most responsive to variation in major inputs to the model. The model must predict SOC density from the parameters measured and used in the model.

At verification, the project proponent must provide a list of parameters for each station under the project scenario in year t, using the VCS table format for each. These parameters will vary among models, so an exhaustive list cannot be provided. However each parameter in the model must be listed, along with its uncertainty based on a 95 percent confidence interval, so that uncertainty calculations, following the Monte Carlo procedures in 8.4.2 may be verified. For example:

Data / Parameter	$MAP_{m,Y}$

Data unit	mm/yr
Description	Mean annual precipitation in stratum m over the project crediting period Y years.
Equation	Model input
Source of data	Precipitation maps or nearby weather stations
Description of measurement methods and procedures to be applied	A key variable that affects a number of processes driving SOC
Frequency of monitoring/recording	Annually if obtained from government sources or local weather stations, Daily if collected on the project area
QA/QC procedures to be applied	Data should be obtained from government sources or local official weather stations, or, if not available, from weather data collected on the project area.
Purpose of data	Calculation of project emissions
Comments	

Data / Parameter	$ST_{j,m,Z}$
Data unit	ºC
Description	Soil temperature at station j in stratum m in month Z
Equation	Model input
Source of data	Measured in project area
Description of measurement methods and procedures to be applied	Must be measured with a digital thermometer with probes inserted to at least ½ the depth at which SOC will be sampled (ie, to 10 cm if soil will be sampled and modeled to 20 cm[3, 16])
Frequency of monitoring/recording	At least monthly
QA/QC procedures to be applied	Procedures must follow those in references [57, 58]
Purpose of data	Calculation of project emissions
Comments	

Data / Parameter	$GI_{j,m,z}$
Data unit	Dimensionless proportion
Description	Mean annual grazing intensity at station j in stratum m in year t
Equation	Model input
Source of data	Measured in project area
Description of measurement methods and procedures to be applied	Measured at each sampling station at least twice each growing season prior to verification by comparing clipped biomass at least at the end of the growing season, or more frequently for some models, inside and outside small (1 m^2) fences. GI_m = 1 – (biomass outside/biomass inside). Biomass is clipped, dried at 25 – 50 °C, and weighed.
Frequency of monitoring/recording	Must be at least twice per year, but preferably monthly, particularly in tropical project areas where plant growth can occur in any month
QA/QC procedures to be applied	Samples should be dried in a professional drying oven for 3 days at 45-60°C or be air-dried in sunshine for 4-7 days to a constant mass, following references [2, 17, 56]
Purpose of data	Calculation of project emissions
Comments	

In addition, soil carbon models for the project scenario will likely use project fire frequency, $PFFREQ_{m,t}$ or the frequency of fire (proportion area burned) in stratum m during year t (section Section 9.2.2), and initial $SOC_{m,j,0}$ introduced in Section 8.1.3.4.

9.2.5 Parameters for Project Removals from Woody Plant Biomass

The two principal parameters are the initial and verified aboveground woody plant biomasses. Uncertainty is expressed as 95% percent CI/mean for each recorded difference in biomass at each of the permanent sampling stations.

Data / Parameter	$AWPB_{m,j,0}$
Data unit	kg/ha
Description	Aboveground woody plant biomass at the project start or the year of last verification at station j and stratum m in the beginning of the monitoring period
Equations	15
Source of data	Measured in permanent sampling plots

Description of measurement methods and procedures to be applied	Circular quadrats centered at each permanent sampling station *j* must be sampled for number and diameter at breast height (dbh) of each woody stem within a specified diameter. Radius must be 5-50 cm depending on woody stem density, with smaller radii appropriate for more dense woody vegetation[45, 59].
Frequency of monitoring/recording	During the beginning of the monitoring period
QA/QC procedures to be applied	Procedures must follow those detailed in reference [46]
Purpose of data	Calculation of project emissions
Comments	

Data / Parameter	$AWPB_{m,j,Y}$
Data unit	kg/ha
Description	Aboveground woody plant biomass at station j and stratum m in year Y at the end of the monitoring period
Equations	15
Source of data	Measured in project area at permanent sampling stations
Description of measurement methods and procedures to be applied	Circular quadrats centered at each permanent sampling station *j* must be sampled for number and dbh of each woody stem within a specified diameter. Radius must be 5-50 m depending on woody stem density, with smaller radii appropriate for more dense woody vegetation[45, 59].
Frequency of monitoring/recording	Once at the end of the monitoring period
QA/QC procedures to be applied	Procedures must follow those detailed in reference [46]
Purpose of data	Calculation of project emissions
Comments	

9.2.6 Parameters for Leakage

Data / Parameter	$DN_{C,x}$
Data unit	head
Description	Number of livestock of each category *c* that were outside the project area (outside the fence defining the boundary of the

	project area, or, in the case of open grazing lands eg pastoralist areas, beyond 2 km from the mapped project area boundary on day *x*
Equations	17,18
Source of data	Measured
Description of measurement methods and procedures to be applied	Determined from records of livestock distributions, as recorded from interviews with grazing managers, coordinators, herders, or other administrative staff. For additional details see Section 9.3.3
Frequency of monitoring/recording	Monthly
QA/QC procedures to be applied	Records should be kept as paper and electronic copies
Purpose of data	Calculation of leakage
Comments	

Data / Parameter	d
Data unit	days
Description	Total number of days livestock were off the project area
Equations	17,18
Source of data	Measured
Description of measurement methods and procedures to be applied	Based on records of livestock numbers and their distribution on and off the project area, based on interviews of grazing managers, coordinators, herders or other administrative staff. For additional details see Section 9.3.3
Frequency of monitoring/recording	Monthly
QA/QC procedures to be applied	Records should be kept as paper and electronic copies, with at least one electronic copy kept off the project as an online database
Purpose of data	Calculation of leakage
Comments	

9.3 Description of the Monitoring Plan

9.3.1 Sampling Design

The sampling design of the permanent sampling stations and their division among strata is described in detail in Section 8.1.2.

9.3.2 Impact of Project Activities

Additionality of greenhouse gas reductions arises from the implementation of new management activities, and it is important for the project proponent to monitor the effectiveness of these new activities. Activities fall principally into three major categories: (1) manipulating animal numbers and grazing intensity, (2) managing fire, (3) changing plant species composition and/or lignin and cellulose content.

9.3.3 Animal Numbers

The different methods of animal censuses are reviewed by Seber[60]. The preferred methods are:

1) *Ownership records* in cases where individual records exist for each animal owned by the project proponent or participants. This is the most accurate measure of animal numbers, but is likely to only be possible in developed countries where such records can be created and maintained.

2) *Corral counts*, in which all known corrals or "bomas" where animals are kept at night are identified to category c and counted. The advantage of this method is that it allows a total census as long as all corrals can be located and censused. This may be the superior method for censusing animals kept by pastoralists in less developed countries. Care must be taken to census at times when animals are not being herded long distances to find new pasture or water, as the census may significantly underestimate animal counts. 95 percent confidence intervals may be estimated by repeated counts, comparison of counts among different observers, or subsampling methods like bootstrapping[61].

3) *Ground transect counts*, whereby transects are walked or driven and the number of animals of each category c, at distances measured with rangefinders, are counted. The area sampled by transects (length by mean observation distance) must cover at least 20 percent of the project area[60] to avoid unacceptable variance and uncertainty. Counts must be converted to density and multiplied by area to estimate total animal numbers in each category and their 95 percent confidence intervals by using the program DISTANCE[62]. Transects must be sampled in at least four years of the ten prior to the project start and at least twice per year during the project crediting period Y years. The advantage of this method is that it may be applied to wildlife or to livestock censuses in regions where livestock are not sedentary. The disadvantage is that animals are often aggregated across the landscape, which may greatly increase the variance of the

estimate, animals counted must be extrapolated to get totals for the project area, and accurate classifications of animals into categories may be inaccurate.

4) *Human surveys*, in which animal owners are interviewed about animal numbers of each category, kept in their corrals in the past. At least 30 individuals or 10 percent of the total animal holders in the project area, whichever is greater, must be interviewed. The advantage of this method is that more detail about breeds and weights may be incorporated into the determination of categories and estimation of methane emissions. The disadvantage is that the subsample of animals owned by the people interviewed must be extrapolated to encompass the project area, with accompanying uncertainty.

5) *Aerial surveys* in which animals of each category are counted from aerial photographs. This is a popular method among governments who are satisfied with broad surveys, but typically the uncertainty in aerial surveys is too large to be used with daily methane emissions, which are already plagued with relatively large uncertainties. Typically aerial surveys only work for cattle or other similarly large animals (eg, camels and horses), as sheep and goats are usually too small to be differentiated by species, sex or age from the air. Also, uncertainties for aerial surveys may be prohibitive, as they often exceed 50 percent[60].

9.3.4 Grazing Intensity

The project proponent must be prepared to measure aboveground plant biomass at least semi-annually to determine the impacts of grazing on vegetation throughout the project area. The parameter $GI_{m,j,t}$ represents the percent difference in standing crop between grazed and ungrazed (fenced) vegetation. It may be measured at all permanent sampling stations by comparing aboveground plant biomass, $APB_{j,m,t}$ at each station with biomass inside small fences (0.67 – 2 m^2). Herbaceous and shrub biomass must be clipped from three or more small quadrats at each station and from two or more small (0.67 - 2 m^2) temporary fenced quadrats (utilization cages). Grazing intensity (GI) is 1 – (biomass unfenced/biomass fenced)[17]. Cages must be moved after clipping to ensure that the station measures grazer use of plant production over each season or portion of a season. It may also be measured using calibrated satellite imagery (with at least $R^2 > 0.60$ between the satellite index and measured biomass on the ground) by comparing vegetation indices, such as NDVI or EVI[31, 63], between ungrazed and grazed pixels paired to have similar soil types, precipitation, and other variables.

9.3.5 Fire Frequency

Baseline proportion of area burned ($FFREQ_{m,b}$) and project proportion of area burned during the project crediting period Y requires demonstration of the occurrence and area covered by fires over a period of 10 years for the baseline and Y years for the project scenario. Acceptable information sources include aerial photographs or interpreted satellite images with a resolution (pixel length in m) smaller than 0.5 percent of the square root of the total project area (in m^2)[18, 19]. An example method is Dempewolf's et al. (2007)[19] algorithm, now employed as MODIS Burned

Area images dating back to 2000. These images use red and infra-red spectral information from 15 day composite images, which eliminate clouds and shadows, from MODIS satellites[12] to calculate a BAI, or burned area index that provided 85-95 percent accuracy in classifying image pixels as burned or unburned in East African grassland and savanna. Other methods of image interpretation, particularly aerial photographs, may be used. Any method must be tested by comparing pixels in classified images with observations of burned or unburned during the same time window in the permanent sampling stations. Valid interpretation methods must commit less than 12 percent combined omission and commission errors[19].

9.3.6 Plant Species Composition

A key input variable affecting soil carbon dynamics and soil carbon models is species composition, as management practices to restore soil carbon will likely do so in part by changing plant species composition[32, 64, 65]. Replacement of woody shrubs or annual grasses that dominate under baseline conditions with perennial grasses with deep root systems under the project scenario can lead to rapid carbon sequestration. Tracking plant species composition is possible by measuring aerial cover of the four most dominant species each of grasses, herbs (dicotyledonous plants, wildflowers), and woody plants. Such data can show shifts as a consequence of new management activities.

9.3.7 Plant Lignin and Cellulose

Shifts in species composition may be accompanied by shifts in plant chemical composition that greatly affect calculations of some soil carbon models and measureable soil carbon sequestration. SOC is often closely related to inputs of these forms of carbon because they resist microbial decomposition. Plant cellulose and lignin (MAPLC) may be measured by either: 1) the Van Soest method of sequential digestion of ground plant material (clipped during the measurement of aboveground plant biomass (APB)) in acid detergent and sulfuric acid[66] in a professional laboratory, or 2)with infra-red (IR) spectrometers calibrated to project area plants and soils.

9.3.8 Ex Ante Leakage and Other Emission Sources

Leakage is mainly possible from net transfers of livestock out of the project area, which is not allowed by the applicability conditions but nevertheless must be monitored by inventorying livestock shipping depots and from censuses and interviews with inhabitants of the project area. Close monitoring and census efforts are especially needed during dry seasons or other periods when there may be strong motivation to move animals off the project area. Animal censuses must be timed to coincide with the greatest risk of animal movement to have the greatest chance to track any possible leakage.

[12] http://modis.gsfc.nasa.gov/

The possible but unlikely source of new emissions as a result of the project is the increase in the use of fossil fuels during vehicle and airplane use associated with management activities. These may be tracked with mileage logs in all project and associated vehicles and converted with IPCC 2000 emission factors[67] as stratified by the type of vehicle and fuel type (eg, diesel, gasoline, kerosene), to determine whether fossil fuel use approaches being a significant greenhouse gas source associated with project activity.

10 REFERENCES

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DOCUMENT HISTORY

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VCS Methodology

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Silvestrum

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Table of Contents

1 SOURCES

This methodology references certain procedures set out in the following methodologies and tools:

- CDM tool *AR-Tool14 Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*
- VCS methodology *VM0024 Methodology for Coastal Wetland Creation, v1.0*

The following have also informed the development of the methodology:

- VCS module *VMD0005 Estimation of carbon stocks in the long-term wood products pool, v1.0*

This methodology also uses the latest versions of the following modules and tools:

- CDM tool *Combined tool to identify the baseline scenario and demonstrate additionality for A/R CDM project activities*
- CDM tool *Calculation of the number of sample plots for measurements within A/R CDM project activities*
- CDM tool *Tool for testing significance of GHG emissions in A/R CDM project activities*
- CDM tool *Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities*
- VCS module *VMD0016 Methods for stratification of the project area*
- VCS module *VMD0019 Methods to Project Future Conditions*

CDM tools are available at: cdm.unfccc.int/methodologies/ARmethodologies/approved.

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	Projects located within the United States: Activity method Projects located outside the United States: Project method
Crediting Baseline	Project method

Wetland restoration occurs sporadically throughout the world primarily to create wildlife habitat, restore water quality and quantity levels and provide storm protection and food production. However, wetland restoration also provides the additional benefits of greenhouse gas (GHG) emission reductions and climate change mitigation.

This methodology outlines procedures to estimate net greenhouse gas emission reductions and removals resulting from project activities implemented to restore tidal wetlands. Such activities may include creating, restoring, and/or managing hydrological conditions, sediment supply, salinity characteristics, water quality and/or native plant communities. Accordingly, this methodology is applicable to a wide range of project activities aimed at restoring and creating tidal wetlands, and emission reductions and removals are estimated primarily based on the ecological changes that occur as a result of such activities (eg, increased vegetative cover, changes to water table depth).

This methodology also addresses the potential for the establishment of woody vegetation. As such, this methodology is categorized as a Restoring Wetland Ecosystems (RWE) and Afforestation, Reforestation and Revegetation (ARR) methodology.

Project activities are expected to generate GHG emission reductions and removals through:

- Increased biomass
- Increased autochthonous soil organic carbon
- Reduced methane and/or nitrous oxide emissions due to increased salinity or changing land use
- Reduced carbon dioxide emissions due to avoided soil carbon loss

This methodology is applicable to projects located anywhere in the world, and to all tidal wetland systems (ie, tidal forests (such as mangroves), tidal marshes and seagrass meadows). An activity method is used for the additionality assessment of projects located in the United States, and a project method is used for the additionality assessment of projects located outside the United States. A project method is used with respect to the crediting baseline for all projects.

For strata with organic soil, this methodology sets out procedures for the estimation of peat depletion time (PDT). Likewise, for strata with mineral soils and sediments, this methodology provides procedures for the estimation of soil organic carbon depletion time (SDT). This methodology also includes an assessment of the maximum quantity of GHG emission reductions which may be claimed from the soil organic carbon (SOC) pool (either on the basis of the difference between the remaining soil organic carbon stock in the project and baseline scenarios after 100 years (total stock approach), or the difference in cumulative carbon loss in both scenarios since the project start date (stock loss approach)).

In order to estimate carbon stock changes in tree and shrub biomass, this methodology uses procedures from CDM tool *AR-Tool14 Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*. This methodology also provides a method to account for carbon stock changes in herbaceous vegetation.

Since biomass may be lost due to subsidence following sea level rise, restoration projects involving afforestation or reforestation may account for long-term carbon storage in wood products where trees are harvested before dieback.

GHG emissions from the SOC pool are estimated by assessing emissions of CO_2, CH_4 and N_2O, which may be estimated via several methods (eg, proxies, modeling, default factors, local published values). Where allochthonous SOC accumulates in the project scenario, a procedure is provided to deduct such carbon from net emission reductions.

Proxies for emissions from the SOC pool may include water table depth and soil subsidence (for which procedures from other methodologies and modules are used) and carbon stock change. For non-seagrass tidal wetland systems, a default factor may be used in the absence of local data.

CH_4 emissions in the baseline scenario may be conservatively set to zero. Where the project proponent demonstrates that N_2O emissions do not increase in the project scenario compared to the baseline scenario, N_2O emissions need not be accounted for either. In all cases, N_2O emissions may be conservatively excluded in the baseline scenario.

This methodology also addresses anthropogenic peat fires occurring in drained areas, and establishes a conservative default value (*Fire Reduction Premium*) based on fire occurrence and extension in the project area in the baseline scenario. The procedure is based on VCS module *VMD0046 Methods for monitoring soil carbon stock changes and GHG emissions in WRC project activities.* The approach avoids the direct assessment of GHG emissions from fire in the baseline and project scenarios.

This methodology also includes procedures to account for GHG emissions from prescribed burning (using literature-based emission factors for non-CO_2 GHGs) and fossil fuel use (by incorporating procedures from the CDM tool *Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities*).

This methodology includes procedures for the consideration of sea level rise with respect to determining the geographic boundaries of the project area, and the determination of the baseline scenario and baseline emissions.

Activity-shifting leakage and market leakage are deemed not to occur if the applicability conditions of this methodology are met. Furthermore, activity-shifting leakage and market leakage are deemed not to occur if the pre-project land use will continue during the project crediting period.

Under the applicability conditions of this methodology, ecological leakage does not occur by ensuring that the effect of hydrological connectivity with adjacent areas is insignificant (ie, no alteration of mean annual water table depths will occur in such areas). In tidal wetland restoration projects, de-watering downstream wetlands is not expected.

This methodology provides the steps necessary for estimating the project's net GHG benefits, as represented by the equation below:

$$NER_{RWE} = GHG_{BSL} - GHG_{WPS} + FRP - GHG_{LK}$$

Where:

NER_{RWE}	Net CO_2e emission reductions from the RWE project activity
GHG_{BSL}	Net CO_2e emissions in the baseline scenario
GHG_{WPS}	Net CO_2e emissions in the project scenario
FRP	*Fire Reduction Premium* (net CO_2e emission reductions from organic soil combustion due to rewetting and fire management)
GHG_{LK}	Net CO_2e emissions due to leakage

3 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions apply to this methodology:

Allochthonous Soil Organic Carbon
Soil organic carbon originating outside the project area and being deposited in the project area

Autochthonous Soil Organic Carbon
Soil organic carbon originating or forming in the project area (eg, from vegetation)

Degraded wetland
A wetland which has been altered by human or natural impact through the impairment of physical, chemical and/or biological properties, and in which the alteration has resulted in a reduction of the diversity of wetland-associated species, soil carbon or the complexity of other ecosystem functions which previously existed in the wetland

Impounded Water
A pool of water formed by a dam or pit

Marsh
A subset of wetlands characterized by emergent soft-stemmed vegetation adapted to saturated soil conditions[1]

Mineral Soil
Soil that is not organic

Mudflat
A subset of tidal wetlands consisting of soft substrate not supporting emergent vegetation

Open Water
An area in which water levels do not fall to an elevation that exposes the underlying substrate

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[1] There are many different kinds of marshes, ranging from the prairie potholes to the Everglades, coastal to inland, freshwater to saltwater, but the scope of this methodology is limited to tidal marshes. Salt marshes consist of salt-tolerant and dwarf brushwood vegetation overlying mineral or organic soils.

Organic Soil

Soil with a surface layer of material that has a sufficient depth and percentage of organic carbon to meet thresholds set by the IPCC (Wetlands supplement) for organic soil. Where used in this methodology, the term peat is used to refer to organic soil.

Salinity Average

The average water salinity value of a wetland ecosystem used to represent variation in salinity during periods of peak CH_4 emissions (eg, during the growing season in temperate ecosystems)

Salinity Low Point

The minimum water salinity value of a wetland ecosystem used to represent variation in salinity during periods of peak CH_4 emissions (eg, during the growing season in temperate ecosystems)

Seagrass Meadow

An accumulation of seagrass plants over a mappable area[2]

Tidal Wetland

A subset of wetlands under the influence of the wetting and drying cycles of the tides (eg, marshes, seagrass meadows, tidal forested wetlands and mangroves). Sub-tidal seagrass meadows are not subject to drying cycles, but are still included in this definition.

Tidal Wetland Restoration

Restoration of degraded tidal wetlands in which establishment of prior ecological conditions is not expected to occur in the absence of the project activity. For the purpose of this methodology, this definition also includes activities that create wetland ecological conditions on mudflats or within open or impounded water.

Water Table Depth

Depth of sub-soil or above-soil surface of water, relative to the soil surface

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[2] This definition includes both the biotic community and the geographic area where the biotic community occurs. Note that the vast majority of seagrass meadows are sub-tidal, but a percentage are intertidal.

4 APPLICABILITY CONDITIONS

This methodology applies to tidal wetland restoration project activities (*tidal wetland restoration* as defined in Section 3 above).

This methodology is applicable under the following conditions:

1) Project activities which restore tidal wetlands (including seagrass meadows, per this methodology's definition of *tidal wetland*) are eligible.
2) Project activities may include any of the following, or combinations of the following:
    a) Creating, restoring and/or managing hydrological conditions (eg, removing tidal barriers, improving hydrological connectivity, restoring tidal flow to wetlands or lowering water levels on impounded wetlands)
    b) Altering sediment supply (eg, beneficial use of dredge material or diverting river sediments to sediment-starved areas)
    c) Changing salinity characteristics (eg, restoring tidal flow to tidally-restricted areas)
    d) Improving water quality (eg, reducing nutrient loads leading to improved water clarity to expand seagrass meadows, recovering tidal and other hydrologic flushing and exchange, or reducing nutrient residence time)
    e) (Re-)introducing native plant communities (eg, reseeding or replanting)
    f) Improving management practice(s) (eg, removing invasive species, reduced grazing)
3) Prior to the project start date, the project area:
    a) Is free of any land use that could be displaced outside the project area, as demonstrated by at least one of the following, where relevant:
        i) The project area has been abandoned for two or more years prior to the project start date; or
        ii) Use of the project area for commercial purposes (ie, trade) is not profitable as a result of salinity intrusion, market forces or other factors. In addition, timber harvesting in the baseline scenario within the project area does not occur; or
        iii) Degradation of additional wetlands for new agricultural sites within the country will not occur or is prohibited by enforced law.

    OR

    b) Is under a land use that could be displaced outside the project area (eg, timber harvesting), though in such case emissions from this land use shall not be accounted for.

    OR

    c) Is under a land use that will continue at a similar level of service or production during the project crediting period (eg, reed or hay harvesting, collection of fuelwood, subsistence harvesting).

The project proponent must demonstrate (a), (b) or (c) above based on verifiable information such as laws and bylaws, management plans, annual reports, annual accounts, market studies, government studies or land use planning reports and documents.

4) Live tree vegetation may be present in the project area, and may be subject to carbon stock changes (eg, due to harvesting) in both the baseline and project scenarios.

5) The prescribed burning of herbaceous and shrub aboveground biomass (cover burns) as a project activity may occur.

6) Where the project proponent intends to claim emission reductions from reduced frequency of peat fires, project activities must include a combination of rewetting and fire management.

7) Where the project proponent intends to claim emission reductions from reduced frequency of peat fires, it must be demonstrated that a threat of frequent on-site fires exists, and the overwhelming cause of ignition of the organic soil is anthropogenic (eg, drainage of the peat, arson).

8) In strata with organic soil, afforestation, reforestation, and revegetation (ARR) activities must be combined with rewetting.

This methodology is not applicable under the following conditions:

9) Project activities qualify as IFM or REDD.

10) Baseline activities include commercial forestry.

11) Project activities lower the water table, unless the project converts open water to tidal wetlands, or improves the hydrological connection to impounded waters.

12) Hydrological connectivity of the project area with adjacent areas leads to a significant increase in GHG emissions outside the project area.

13) Project activities include the burning of organic soil.

14) Nitrogen fertilizer(s), such as chemical fertilizer or manure, are applied in the project area during the project crediting period.

5 PROJECT BOUNDARY

5.1 Temporal Boundaries

5.1.1 Peat depletion time (PDT)

Projects that do not quantify reductions of baseline emissions (ie, those which limit their accounting to GHG removals in biomass and/or soil) need not estimate PDT.

PDT ($t_{PDT\text{-}BSL,i}$) for a stratum in the baseline scenario equals the period during which the project is eligible to claim emission reductions from rewetting, and is estimated at the project start date for each stratum *i* as:

$$t_{PDT\text{-}BSL,i} = Depth_{peat,i,t0} / Rate_{peatloss\text{-}BSL,i} \quad \textbf{(1)}$$

Where:

$t_{PDT\text{-}BSL,i}$	PDT in the baseline scenario in stratum *i* (in years elapsed since the project start date); yr
$Depth_{peat,i,t0}$	Average organic soil depth above the drainage limit in stratum *i* at the project start date; m
$Rate_{peatloss\text{-}BSL,i}$	Rate of organic soil loss due to subsidence and fire in the baseline scenario in stratum *i*; m yr^{-1}.
i	1, 2, 3 …M_{BSL} strata in the baseline scenario

If $t_{PDT\text{-}BSL,i}$ falls within the crediting period, subsequent organic carbon loss from remaining mineral soil may be estimated as well using the procedure for SDT in Section 5.1.2.

Organic soil depths, depths of burn scars and subsidence rates must be derived from the data sources described in Section 9.1.

5.1.2 Soil organic carbon depletion time (SDT)

Projects that do not quantify reductions of baseline emissions (ie, those which limit their accounting to GHG removals in biomass and/or soil) need not estimate SDT.

SDT ($t_{SDT\text{-}BSL,i}$) for a stratum in the baseline scenario equals the period during which the project is eligible to claim emission reductions from restoration, and is estimated at the project start date for each stratum *i* as:

$$t_{SDT\text{-}BSL,i} = C_{,i,t0} / Rate_{Closs\text{-}BSL,i} \quad \textbf{(2)}$$

Where:

$t_{SDT\text{-}BSL,i}$	SDT in the baseline scenario in stratum *i* (in years elapsed since the project start date); yr
$C_{i,t0}$	Average organic carbon stock in mineral soil in stratum *i* at the project start date; t C ha^{-1} (see Equation 11)
$Rate_{Closs\text{-}BSL,i}$	Rate of organic soil carbon loss due to oxidation in the baseline scenario in stratum *i*; t C ha^{-1} yr^{-1}.
i	1, 2, 3 …M_{BSL} strata in the baseline scenario

The project proponent must determine the depth ($Depth_{soil,i,t0}$ in Equation 11 below) over which $C_{,i,t0}$ is determined. Note that a shallower depth will lead to a shorter, and more conservative, SDT. Where SDT is not determined, no reductions of baseline emissions from mineral soil may be claimed.

Extrapolation of $Rate_{Closs\text{-}BSL,i}$ over the project crediting period must account for the possibility of a non-linear decrease of soil organic carbon over time, including the tendency of organic carbon concentrations to approach steady-state equilibrium. For this reason, a complete loss of soil organic carbon may not occur in mineral soils. This steady-state equilibrium must be determined conservatively.

In case of alternating mineral and organic horizons, $Rate_{Closs\text{-}BSL,i}$ may be determined for all individual horizons. This also applies to cases where an organic surface layer of less than 10 cm exists or in cases where the soil is classified as organic but its organic matter depletion is expected within the project crediting period and oxidation of organic matter in an underlying mineral soil may occur within this period.

SDT is conservatively set to zero for project sites drained more than 20 years prior to the project start date. SDT is also conservatively set to zero where significant soil erosion occurs in the baseline scenario (*significant* defined as >5 percent of $Rate_{Closs\text{-}BSL,i}$).

With respect to the estimation of SDT, the accretion of sediment in the baseline scenario is conservatively excluded.

5.2 Geographic Boundaries

5.2.1 General

The project proponent must define the geographic boundaries of the project area at the beginning of project activities. The project proponent must provide the geographic coordinates of lands (including sub-tidal seagrass areas, where relevant) included in the project area to facilitate accurate delineation of the project area. Remotely-sensed data, published topographic maps and data, land administration and tenure records and/or other official documentation that facilitates clear delineation of the project area must be used.

The project activity may contain more than one discrete area of land. Each discrete area of land must have a unique geographical identification.

When describing physical project boundaries, the following information must be provided for each discrete area:

- Name of the project area (including compartment numbers, local name (if any)).
- Unique identifier for each discrete parcel of land.
- Map(s) of the area (preferably in digital format).
- The project area must be geo-referenced, and provided in digital format in accordance with VCS rules.

- Total area.
- Details of land rights holder and user rights.

5.2.2 Stratification

Where the project area at the project start date is not homogeneous, stratification may be carried out to improve the accuracy and the precision of carbon stock and GHG flux estimates. Where stratification is employed, different stratifications may be required for the baseline and project scenarios in order to achieve optimal accuracy of the estimates of net GHG emission reductions and removals.

Strata may be defined based on soil type and depth (including eligibility as assessed below), water table depth, vegetation cover and/or vegetation composition, salinity, land type (open water, channel, and unvegetated sand or mudflat) or expected changes in these characteristics.

Strata must be spatially discrete and stratum areas must be known. Areas of individual strata must sum to the total project area. Strata must be identified with spatial data (eg, maps, GIS coverage, classified imagery, sampling grids) from which the area can be determined accurately. Land use/land cover maps in particular must be ground-truthed and less than 10 years old, unless it can be demonstrated that the maps are still accurate. Strata must be discernible taking into account good practice with respect to accuracy requirements for the definition of strata limits and boundaries. The type of spatial data must be indicated and justified in the project description.

The project area may be stratified *ex ante*, and this stratification may be revised *ex post* for monitoring purposes. Established strata may be merged if reasons for their separate establishment are no longer meaningful, or have proven irrelevant to key variables for estimating net GHG emission reductions and removals. Baseline stratification must remain fixed until a reassessment of the baseline scenario occurs. Stratification in the project scenario must be reviewed at each monitoring event prior to verification and revised if necessary.

The sub-sections below specify further requirements and guidance with respect to stratification in certain scenarios.

<u>Areas with organic soil</u>

The project proponent must use VCS module *VMD0016 Methods for Stratification of the Project Areas* in order to stratify project areas that include organic soil.

<u>Seagrass meadows</u>

Given the tendency of seagrasses to respond differently under different light and depth regimes, the project proponent may differentiate between seagrass meadow sections that occur at different depths given discrete, or relatively abrupt, bathymetric and substrate changes.

For seagrass meadow restoration projects in areas with existing seagrass meadows, the project proponent must quantify the percentage of meadow expansion that can be attributed to the restoration effort but that is not the result of direct planting or seeding. Existing meadows (unless smaller in area than 5 percent of the total project area) must be excluded from the calculation of project emissions, even in cases where the restored meadow enhances carbon sequestration rates in existing meadows.

New seagrass meadows that result from natural expansion must be contiguous with restored meadow plots in order to be included in project accounting, unless the project proponent demonstrates that non-contiguous meadow patches originated from restored meadow seeds. This may be performed via genetic testing, or estimated as a percentage of new meadow in non-contiguous plots and observed no less than four years after the project start date.[3] This percentage must not exceed the proportion of restored meadow area relative to the total seagrass meadow areal extent, and the project proponent must demonstrate the feasibility of current-borne seed dispersal from the restored meadow. In cases where a restored meadow coalesces with an existing meadow(s), the project proponent must delineate the line at which the two meadows are joined. The project proponent may use either aerial observations showing meadow extent or direct field observations.

Native ecosystems

In order to claim emission removals from ARR or WRC activities, the project proponent must provide evidence in the project description that the project area was not cleared of native ecosystems to create GHG credits. Such proof is not required where such clearing took place prior to the 10-year period prior to the project start date. Areas that do not meet this requirement must be excluded from the project area.

Stratification of vegetation cover for adoption of the default SOC accumulation rate

The default factor for SOC accumulation rate (see Sections 8.1.4.2.3 and 8.2.4.2.1) may only be applied to non-seagrass tidal wetland systems with a crown cover of at least 50 percent. Areas below this threshold must be marked and excluded from the application of the default SOC accumulation rate. For the baseline scenario, crown covers must be based on a time series of vegetation composition. For the project scenario, crown cover mapping must be performed according to established methods in scientific literature.

Stratification of salinity for the accounting of CH_4

Tidal wetlands may be stratified according to salinity for the purpose of estimating CH_4 emissions. Threshold values of salinity for mapping salinity strata are specified in Section 8.1.4.4.4.

Areas with unrestricted tidal exchange will maintain salinity levels similar to the tidal water source, while those with infrequent tidal flooding will not (in which case the use of channel water salinity

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[3] McGlathery *et al.* (2012)

levels is not reliable). For such areas it is therefore recommended to stratify according to the frequency of tidal exchange.

Procedures for the measurement of salinity levels are specified in Section 9.3.8.

Stratification of water bodies lacking tidal exchange

The area of ponds, ditches or similar bodies of water within the project area must be measured and treated as separate strata when they do not have surface tidal water exchange. CH_4 emissions from these features may be excluded from GHG accounting if the area of these features does not increase in the project scenario.

5.2.3 Sea level rise

When defining geographic project boundaries and strata, the project proponent must consider expected relative sea level rise and the potential for expanding the project area landward to account for wetland migration, inundation and erosion.

For both the baseline and project scenarios, the project proponent must provide a projection of relative sea level rise within the project area based on IPCC regional forecasts or peer-reviewed literature applicable to the region. In addition, the project proponent may also utilize expert judgment[4]. Global average sea level rise scenarios are not suitable for determining changes in wetlands boundaries. Therefore, if used, IPCC most-likely global sea level rise scenarios must be appropriately downscaled to regional conditions including vertical land movements, such as subsidence.

Whether degradation occurs in the baseline scenario or restoration occurs in the project scenario, the assessment of potential wetland migration, inundation and erosion with respect to projected sea level rise must account for topographical slope, land use and management, sediment supply and tidal range. The assessment may use literature relevant to the project area, expert judgment or both.

The potential for tidal wetlands to migrate horizontally must consider the topography of the adjacent land and any migration barriers that may exist. In general, and on coastlines where wetland migration is unimpaired by infrastructure, concave-up slopes may cause ‘coastal squeeze’, while straight or convex-up gradients are more likely to provide the space required for lateral movement.

The potential for tidal wetlands to rise vertically with sea level rise is sensitive to suspended sediment loads in the system. A sediment load of >300 mg per liter has been found to balance high-end IPCC scenarios for sea level rise (Orr *et al*. 2003, Stralsburg *et al*. 2011). French (2006) and Morris *et al*. (2012) suggest that the findings of Orr *et al*. 2003 based in the San Francisco

[4] Requirements for expert judgment are provided in Section 9.3.3.

Bay could be used elsewhere. French (2006) indicates that at 250 mg per liter, sea level rise of 15 mm is balanced at a tidal range of 1 m or greater. Therefore, for marshes with a tidal range greater than 1 meter, the project proponent may use >300 mg per liter as a sediment load threshold above which wetlands are not predicted to be submerged. The project proponent may use lower threshold values for tidal range and sediment load where justified. The vulnerability of tidal wetlands to sea level rise and conversion to open water is also related to tidal range. In general, the most vulnerable tidal wetlands are those in areas with a small tidal range, those with elevations low in the tidal frame and those in locations with low suspended sediment loads.

Alternatively, in the project scenario the project proponent may conservatively assume that part of the wetland within the project area erodes, and does not migrate. In the baseline scenario, the project proponent may conservatively assume that part of the project area submerges, with reduced emissions as a consequence.

The projection of wetland boundaries within the project area must be presented in maps delineating these boundaries from the project start date until the end of the project crediting period, at intervals appropriate to the rate of change due to sea level rise, and at t = 100.

Procedures for accounting for project area submergence due to relative sea level rise are provided in Section 8.2.2.

5.2.4 Ineligible wetland areas

For projects quantifying CO_2 emission reductions, project areas which do not achieve a significant difference (≥ 5 percent) in cumulative carbon loss over a period of 100 years beyond the project start date are not eligible for crediting based on the reduction of baseline emissions, and these areas must be mapped.

The maximum quantity of GHG emission reductions which may be claimed from the soil carbon pool is limited to the difference between the remaining soil organic carbon stock in the project and baseline scenarios after 100 years (total stock approach), or the difference in cumulative soil organic carbon loss in both scenarios over a period of 100 years since the project start date (stock loss approach). The project proponent must calculate this maximum quantity *ex ante* using conservative parameters, and following one of the options below.

1. Total stock approach

The difference between soil organic carbon stock in the project scenario and baseline scenario at t = 100 is estimated as:

$$C_{WPS-BSL,t100} = \sum_{i=1}^{M_{WPS}} \left(C_{WPS,i,t100} \times A_{WPS,i} \right) - \sum_{i=1}^{M_{BSL}} \left(C_{BSL,i,t100} \times A_{BSL,i} \right) \quad \textbf{(3)}$$

$C_{WPS,i,t100}$ requires no adjustment for leakage since the applicability conditions of this methodology are structured to ensure leakage emissions do not occur, as explained in Section 8.3.

The difference between organic carbon stock in the project scenario and baseline scenario at t = 100 ($C_{WPS\text{-}BSL,t100}$) is significant if:

$$\sum_{i=1}^{M_{WPS}} \left(C_{WPS,i,t100} \times A_{WPS,i} \right) \geq 1.05 \times \sum_{i=1}^{M_{BSL}} \left(C_{BSL,i,t100} \times A_{BSL,i} \right) \quad (4)$$

For organic soil:

$$C_{WPS,i,t100} = Depth_{peat\text{-}WPS,i,t100} \times VC \times 10 \quad (5)$$

$$C_{BSL,i,t100} = Depth_{peat\text{-}BSL,i,t100} \times VC \times 10 \quad (6)$$

$$Depth_{peat-BSL,i,t100} = Depth_{peat,i,t0} - \sum_{t=1}^{t=100} Rate_{peatloss-BSL,i,t} \quad (7)$$

$$Depth_{peat-WPS,i,t100} = Depth_{peat,i,t0} - \sum_{t=1}^{t=100} Rate_{peatloss-WPS,i,t} \quad (8)$$

For mineral soil:

$$C_{BSL,i,t100} = C_{i,t0} - \sum_{t=1}^{t=100} Rate_{Closs-BSL,i,t} \quad (9)$$

$$C_{WPS,i,t100} = C_{i,t0} - \sum_{t=1}^{t=100} Rate_{Closs-WPS,i,t} \quad (10)$$

$$C_{i,t0} = Depth_{soil,i,t0} \times VC \times 10 \quad (11)$$

Where a conservative constant rate of subsidence or carbon loss is applied, a possible negative outcome must be substituted by zero.

The carbon content of organic or mineral soil may be taken from measurements within the project area, or from literature involving the project area or similar areas.

2. Stock loss approach

The project proponent may also calculate the maximum quantity based on cumulative soil organic carbon loss up to t = 100 as follows:

$$C_{WPS-BSL,t100} = \sum_{i=1}^{M_{BSL}} \left(C_{loss-BSL,i,t100} \times A_{BSL,i} \right) - \sum_{i=1}^{M_{WPS}} \left(C_{loss-WPS,i,t100} \times A_{WPS,i} \right) \quad \textbf{(12)}$$

For organic soil:

$$C_{loss-BSL,i,t100} = 10 \times \sum_{t=1}^{100} \left(Rate_{peatloss-BSL,i,t} \times VC \right) \quad \textbf{(13)}$$

$$C_{loss-WPS,i,t100} = 10 \times \sum_{t=1}^{100} \left(Rate_{peatloss-WPS,i,t} \times VC \right) \quad \textbf{(14)}$$

For mineral soil:

$$C_{loss-BSL,i,t100} = 10 \times \sum_{t=1}^{100} \left(Rate_{Closs-BSL,i,t} \times VC \right) \quad \textbf{(15)}$$

$$C_{loss-WPS,i,t100} = 10 \times \sum_{t=1}^{100} \left(Rate_{Closs-WPS,i,t} \times VC \right) \quad \textbf{(16)}$$

Where:

$C_{WPS-BSL,i,t100}$	Difference between soil organic carbon stock in the project scenario and baseline scenario in subsidence stratum *i* at *t* = 100; t C ha^{-1}
$C_{WPS,i,t100}$	Soil organic carbon stock in the project scenario in stratum *i* at *t* = 100 ; t C ha^{-1}
$C_{BSL,i,t100}$	Soil organic carbon stock in the baseline scenario in stratum *i* at *t* = 100; t C ha^{-1}
$A_{WPS,i}$	Area of project stratum *i*; ha
$A_{BSL,i}$	Area of baseline stratum *i*; ha
$Depth_{peat-WPS,i,t100}$	Average organic soil depth in the project scenario in stratum *i* at *t* = 100; m
$Depth_{peat-BSL,i,t100}$	Average organic soil depth in the baseline scenario in stratum *i* at *t* = 100; m
VC	Volumetric organic carbon content in organic or mineral soil; kg C m^{-3}
$Depth_{peat,i,t0}$	Average organic soil depth above the drainage limit in stratum *i* at the project start date; m
$Rate_{peatloss-BSL,i,t}$	Rate of organic soil loss due to subsidence and fire in the baseline scenario in stratum *i* in year *t*; m yr^{-1}.
$Rate_{peatloss,WPS,i,t}$	Rate of organic soil loss due to subsidence in the project scenario in stratum *i* in year *t*; m yr^{-1}.
$C_{i,t0}$	Soil organic carbon stock in mineral soil in stratum *i* at the project start date; t C ha^{-1}

$Rate_{Closs\text{-}BSL,i,t}$	Rate of organic carbon loss in mineral soil due to oxidation in the baseline scenario in stratum *i* in year *t*; t C ha^{-1} yr^{-1}.
$Rate_{Closs,WPS,i,t}$	Rate of organic carbon loss in mineral soil due to oxidation in the project scenario in stratum *i* in year *t*; t C ha^{-1} yr^{-1}. This value is conservatively set to zero as loss rates are likely to be negative. This parameter must be reassessed when the baseline is reassessed.
$Depth_{soil,i,t0}$	Mineral soil depth in stratum *i* at the project start date (as in Equation 11); m
$C_{loss\text{-}BSL,i,t100}$	Cumulative soil organic carbon loss in the baseline scenario in stratum *i* at *t* = 100; t C ha^{-1}
$C_{loss\text{-}WPS,i,t100}$	Cumulative soil organic carbon loss in the project scenario in stratum *i* at *t* = 100; t C ha^{-1}
i	1, 2, 3 …M_{BSL} strata in the baseline scenario
t_{100}	100 years after the project start date

5.2.5 Buffer zones

Where established, buffer zones must be mapped in accordance with the VCS rules.

5.3 Carbon Pools

The carbon pools included in and excluded from the project boundary are shown in Table 5.1 below.

Carbon pools may be deemed *de minimis* and do not need to be accounted for if together the omitted decrease in carbon stocks or increase in GHG emissions (Table 5.2) amounts to less than 5 percent of the total GHG benefit generated by the project. Peer reviewed literature or the CDM tool *Tool for testing significance of GHG emissions in A/R CDM project activities* may be used to determine whether decreases in carbon pools are *de minimis*.

Table 5.1 Selection and justification of carbon pools

Carbon Pool	Included?	Justification/Explanation
Above-ground tree biomass	Yes	Major carbon pool may significantly increase or decrease in both the baseline and project scenarios, in the case of establishment or presence of tree vegetation. Above-ground tree biomass in the baseline scenario must be included. Above-ground tree biomass in the project scenario may be included or conservatively omitted.
Above-ground non-tree biomass	Yes	Carbon stock in this pool may increase in the baseline scenario and may increase or decrease in the project scenario.

Below-ground biomass	Yes	Major carbon pool may significantly increase in the baseline, or decrease in the project, or both, in case of presence of tree vegetation. Below-ground biomass in the baseline scenario must be included. Below-ground biomass in the project scenario may be included or conservatively omitted.
Litter	No	This pool is optional for WRC methodologies. Litter is only included indirectly in association with the quantification of herbal mass.
Dead wood	No	This pool is optional for WRC methodologies.
Soil	Yes	The soil organic carbon stock may increase due to the implementation of the project activity.
Wood products	Yes	Carbon stock in this pool may increase in the project scenario.

5.4 Sources of Greenhouse Gases

The greenhouse gases included in or excluded from the project boundary are shown in Table 5.2 below.

GHG sources may be deemed *de minimis* and do not have to be accounted for if together the omitted decrease in carbon stocks (Table 5.1) or increase in GHG emissions amounts to less than 5 percent of the total GHG benefit generated by the project. Peer-reviewed literature or the CDM tool *Tool for testing significance of GHG emissions in A/R CDM project activities* may be used to determine whether increases in emissions are *de minimis*.

Table 5.2 GHG Sources Included In or Excluded From the Project Boundary

Source		Gas	Included?	Justification/Explanation
Baseline	The production of methane by microbes	CH_4	Yes	May be conservatively excluded in the baseline scenario.
	Denitrification/nitrification	N_2O	Yes	May be conservatively excluded in the baseline scenario.
	Burning of biomass and organic soil	CO_2	Yes	Implicitly included in the *Fire Reduction Premium* approach.
		CH_4	Yes	Implicitly included in the *Fire Reduction Premium* approach.
		N_2O	Yes	Implicitly included in the *Fire Reduction Premium* approach.
	Fossil fuel use	CO_2	Yes	May be conservatively excluded in the baseline scenario.
		CH_4	No	Conservatively excluded in the baseline scenario.
		N_2O	No	Conservatively excluded in the baseline scenario.
Project	The production of methane by microbes	CH_4	Yes	Potential major source of emissions in the project in low salinity and freshwater areas.
	Denitrification/nitrification	N_2O	Yes	May increase as a result of the project activity.
	Burning of biomass	CO_2	No	CO_2 is addressed in carbon stock change procedures.
		CH_4	Yes	Potential major source of fire emissions.
		N_2O	Yes	Potential major source of fire emissions.
	Fossil fuel use	CO_2	Yes	Potential major source of emissions in project scenario.
		CH_4	No	Not a significant source of emissions in project fuel use.
		N_2O	No	Not a significant source of emissions in project fuel use.

6 BASELINE SCENARIO

6.1 Determination of the Most Plausible Baseline Scenario

At the project start date, the most plausible baseline scenario for tidal wetland restoration projects must be identified as degraded tidal wetlands, or mudflats or shallow open water, in which establishment of wetland ecological conditions is not expected to occur in the absence of the project activity.

For projects not eligible to apply the activity method for demonstrating additionality (see Section 7.1 below), the baseline scenario must be determined using the latest version of CDM tool *Combined tool to identify the baseline scenario and demonstrate additionality for A/R CDM project activities*. This tool has been designed for CDM A/R project activities, and is used in this methodology noting the following:

Where the tool refers to:	It must be understood as referring to:
A/R, afforestation, reforestation, or forestation	WRC or WRC/ARR, or restoration
Net greenhouse gas removals by sinks	Net greenhouse gas emission reductions
CDM	VCS
DOE	VVB
tCERs, lCERs	VCUs

Step 0 and sub-step 2b, paragraph 15 (regarding forested areas since 31 December 1989), must be disregarded. Footnotes 1-3 may also be disregarded[5].

For projects eligible to apply the activity method for demonstrating additionality (see Section 7.1 below), all elements of the tool related to additionality must be disregarded.

6.2 Reassessment of the Baseline Scenario

The project proponent must reassess the baseline scenario in accordance with the VCS rules.

For this reassessment, when applying the *Fire Reduction Premium* approach specified in Section 8.3, the historic reference period must be extended to include the original reference period and all subsequent monitoring periods up to the beginning of the current monitoring period. The fire reference period must not be extended, as this is a fixed 10-year period ending 5 years before the

[5] Sub-step and footnotes as in version 01 of the tool, the prevailing version of the tool as of the writing of this methodology.

project start date.

In addition, the project proponent must, for the duration of the project, re-determine, where applicable, the PDT every 10 years. This reassessment must use the procedure specified in Section 5.1. Data sources must be updated where new information relevant to the project area has become available.

7 ADDITIONALITY

7.1 Projects Located in the United States

This methodology uses an activity method for the demonstration of additionality of tidal wetland restoration projects located in the United States.

Step 1: Regulatory surplus

The project proponent must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the *VCS Standard*.

Step 2: Positive list

The applicability conditions of this methodology represent the positive list. The positive list was established using the activity penetration option (Option A in the *VCS Standard*). Projects located in the United States[6], and which meet all of the applicability conditions of this methodology, are deemed additional.

Justification for the activity method is provided in Appendix 2.

7.2 Projects Located outside the United States

This methodology uses a project method for tidal wetland restoration projects located outside the United States. Such projects must use the latest version of the CDM *Combined tool to identify the baseline scenario and demonstrate additionality for A/R CDM project activities* for the demonstration of additionality, taking into account the additional guidance provided in Section 6.1 above.

[6] Defined as the 35 coastal states, commonwealths or territories of the United States of America.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

8.1.1 General approach

Emissions in the baseline scenario are attributed to carbon stock changes in biomass carbon pools, soil processes, or a combination of these. In addition, where relevant, emissions from fossil fuel use may be quantified.

Emissions in the baseline scenario are estimated as:

$$GHG_{BSL} = GHG_{BSL\text{-}biomass} + GHG_{BSL\text{-}soil} + GHG_{BSL\text{-}fuel} \quad \textbf{(17)}$$

$$GHG_{BSL-biomass} = -\sum_{t=1}^{t^*} \sum_{i=1}^{M_{BSL}} \left(\frac{44}{12} \times \Delta C_{BSL-biomass,i,t} \right) \quad \textbf{(18)}$$

$$GHG_{BSL-soil} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{BSL}} GHG_{BSL-soil,i,t} \quad \textbf{(19)}$$

$$GHG_{BSL-fuel} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{BSL}} GHG_{BSL-fuel,i,t} \quad \textbf{(20)}$$

Where:

GHG_{BSL}	Net CO_2e emissions in the baseline scenario up to year t^*; t CO_2e
$GHG_{BSL\text{-}biomass}$	Net CO_2e emissions from biomass carbon pools in the baseline scenario up to year t^*; t CO_2e
$GHG_{BSL\text{-}soil}$	Net CO_2e emissions from the SOC pool in the baseline scenario up to year t^*; t CO_2e
$GHG_{BSL\text{-}fuel}$	Net CO_2e emissions from fossil fuel use in the baseline scenario up to year t^*; t CO_2e
$\Delta C_{BSL\text{-}biomass,i,t}$	Net carbon stock changes in biomass carbon pools in the baseline scenario in stratum i in year t; t C yr^{-1}
$GHG_{BSL\text{-}soil,i,t}$	GHG emissions from the SOC pool in the baseline scenario in stratum i in year t; t CO_2e yr^{-1}
$GHG_{BSL\text{-}fuel,i,t}$	GHG emissions from fossil fuel use the baseline scenario in stratum i in year t; t CO_2e yr^{-1}
i	1, 2, 3 …M_{BSL} strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the project start date

Estimation of GHG emissions and removals related to the biomass pool is based on carbon stock changes. Estimation of GHG emissions and removals from the SOC pool is based on either various proxies (eg, carbon stock change, water table depth) or through the use of literature, data, default factors or models.

Assessing GHG emissions in the baseline scenario consists of determining GHG emission proxies/parameters and assessing their pre-project spatial distribution, constructing a time series of the chosen proxies/parameters for each stratum for the entire project crediting period and determining annual GHG emissions per stratum for the entire project crediting period.

In order to project the future GHG emissions from soil per unit area in each stratum for each projected verification date within the project crediting period under the baseline scenario, the project proponent must apply the latest version of VCS module *VMD0019 Methods to Project Future Conditions*. When applying Steps 13 and 14 of *VMD0019* (version 1, issued 16 November 2012, the version of the module current as of the writing of this methodology) the project proponent must use the guidance for sea level rise provided in Section 5.2 of this methodology.

Four driving factors are likely to be relevant for GHG accounting in the baseline scenario, and are relevant for use of *VMD0019*. Each factor affects the evolution of the site over a 100-year period. These include:

- Initial land use and development patterns.
- Initial infrastructure that impedes natural tidal hydrology.
- Natural plant succession for the physiographic region of the project.
- Climate variables as likely drivers of changes in tidal hydrology within the 100-year timeframe of the project, influencing sea level rise, precipitation and associated freshwater delivery.

Land use and development patterns – In order to derive trends in land use, assumptions about the likelihood of future development of the project area must be documented and considered in light of current zoning, regulatory constraints to development, proximity to urban areas or transportation infrastructure, and expected population growth, including how land would develop within and surrounding the project site and how such changes would change hydrologic conditions within the project area. Current development patterns and plausible future land use changes must be mapped to a scale sufficient to estimate GHG emissions from the baseline scenario. In the case of abandonment of pre-project land use in the baseline scenario, the project proponent must consider non-human induced hydrologic changes brought about by collapsing dikes or ditches that would have naturally closed over time, and progressive subsidence, leading to rising relative water levels, increasingly thinner aerobic layers and reduced CO_2 emission rates.

Infrastructure impediments to tidal hydrology – In order to derive trends in tidal wetland evolution, the baseline scenario must take into account the current and historic layout of any tidal barriers and drainage systems. The tidal barriers and drainage layout at the start of the project activity must be mapped at scale (1:10,000 or any other scale justified for estimating water table depths throughout the project area). Historic tidal barriers and drainage layout must be mapped using topographic and/or hydrological maps from (if available) the start of the major hydrological impacts but covering at least the 20 years prior to the project start date. Historic drainage structures (collapsed ditches) may (still) have higher hydraulic conductivity than the surrounding areas and function as preferential flow paths. Historic tidal barriers (agricultural dikes and levees) may constrain the tidal flows and prevent natural sedimentation patterns. The effect of historic tidal barriers and drainage structures on current hydrological functioning of the project area must be assessed on the basis of quantitative hydrological modeling and/or expert judgment.

Historic information on the pre-existing channel network as determined by aerial photography may serve to set trends in post-project dendritic channel formation in the field. Derivation of such trends must be performed on the basis of hydrologic modeling using the total tidal volume, soil erodibility and/or expert judgment. With respect to hydrological functioning, the baseline scenario must be restricted by climate variables and quantify any impacts on the hydrological functioning as caused by planned measures outside the project area (eg, dam construction or further changes in hydrology such as culverts), by demonstrating a hydrological connection to the planned measures.

Natural plant succession - Based on the assessment of changes in water table depth, a time series of vegetation composition must be derived *ex ante*, based on vegetation succession schemes in the baseline scenario from scientific literature or expert judgment. For example, diked agricultural land will undergo natural plant succession to forests, freshwater wetlands, tidal wetlands, rank uplands, or open water based on the scenario's land use trajectory, inundation scenario, proximity to native or invasive seed sources, plant succession trajectories of adjacent natural areas or likely maintenance consistent with projected future human land use (eg, pasture, lawn, landscaping).

Climate variables – Consistent with the sea level rise guidance provided in Section 5.2 above, areas of inundation and erosion within the project area must be considered in relation to the above three factors. Expected changes in freshwater delivery associated with changes in rainfall patterns must be considered, including expected human responses to these changes.

The project proponent must, for the duration of the project crediting period, reassess the baseline scenario every 10 years. Based on the reassessment criteria specified in Section 6 above, the revised baseline scenario must be incorporated into revised estimates of baseline emissions. This baseline reassessment must include the evaluation of the validity of proxies for GHG emissions.

8.1.2 Accounting for sea level rise

The consequences of submergence of a given stratum due to sea level rise are:

1) Carbon stocks from aboveground biomass are lost to oxidation, and

2) Depending upon the geomorphic setting, soil carbon stocks may be held intact or be eroded and transported beyond the project area.

Regarding (1) above, where biomass is submerged, it is assumed that this carbon is immediately and entirely returned to the atmosphere. For such strata:

$$\Delta C_{BSL\text{-}biomass,i,t} = 12/44 \times (C_{BSL\text{-}biomass,i,t} - C_{BSL\text{-}biomass,i,(t\text{-}T)}) / T \qquad \textbf{(21)}$$

For the year of submergence:

$$C_{BSL\text{-}biomass,i,t} = 0$$

Where:

$\Delta C_{BSL\text{-}biomass,i,t}$	Net carbon stock change in biomass carbon pools in the baseline scenario in stratum *i* in year *t*; t C yr^{-1}
$C_{BSL\text{-}biomass,i,t}$	Carbon stock in biomass in the baseline scenario in stratum *i* in year *t* (from $C_{TREE\_BSL,t}$ in *AR-Tool14*); t CO_2e
i	1, 2, 3 …M_{WPS} strata in the baseline scenario
t	1, 2, 3, … *t** years elapsed since the project start date
T	Time elapsed between two successive estimations (T=$t_2 - t_1$)

The gradual loss of vegetation in the project area due to submergence may be captured by detailed stratification into areas with and without vegetation.

For strata where conversion to open water is expected before *t* = 100, the long-term average of $C_{TREE\_BSL,t}$ and $C_{SHRUB\_BSL,t}$ in *AR-Tool14* must be calculated as defined in Section 8.2.3.

Regarding (2) above, the project proponent may apply models (see Section 8.1.4.2) to assess the time and rate of submergence of the project area.

For areas that drown out while the area of ponds increases, the loss of SOC may be assumed to be insignificant. It is assumed that, upon submergence, soil carbon is not returned to the atmosphere unless site-specific scientific justification is provided.

In areas with wave action, sediment will erode and carbon will be removed. Assuming that all carbon is re-sedimented and stored (and not oxidized) is conservative. The project proponent may justify a greater oxidation rate for the baseline scenario based on appropriate scientific research.

Restoration projects may be designed in such a way that they have advantages over the baseline scenario in one or more of the following ways, as must be quantified and justified in the project description:

- The point in time when submergence and erosion sets off.

- The amount of carbon that erodes upon submergence.
- The oxidation rate of eroded soil organic matter. In the most conservative approach, the oxidation constant is 0 for the baseline and 1 for the project scenario.

8.1.3 Net carbon stock change in biomass carbon pools in baseline scenario

Net carbon stock change in biomass carbon pools in the baseline scenario are estimated as:

$$\Delta C_{BSL\text{-}biomass,i,t} = \Delta C_{BSL\text{-}tree/shrub,i,t} + \Delta C_{BSL\text{-}herb,i,t} \quad \textbf{(22)}$$

Where:

$\Delta C_{BSL\text{-}biomass,i,t}$	Net carbon stock change in biomass carbon pools in the baseline scenario in stratum *i* in year *t*; t C yr^{-1}
$\Delta C_{BSL\text{-}tree/shrub,i,t}$	Net carbon stock change in tree and shrub carbon pools in the baseline scenario in stratum *i* in year *t*; t C yr^{-1}
$\Delta C_{BSL\text{-}herb,i,t}$	Net carbon stock change in herb carbon pools in the baseline scenario in stratum *i* in year *t*; t C yr^{-1}
i	1, 2, 3 …M_{BSL} strata in the baseline scenario
t	1, 2, 3, … *t** years elapsed since the project start date

Trees and shrubs

Net carbon stock change in trees and shrubs in the baseline scenario are estimated by applying the latest version of CDM tool *AR-Tool14 Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*, noting that:

1) *AR-Tool14* is only used to derive net carbon stock changes in tree and shrub carbon pools ($\Delta C_{BSL\text{-}tree/shrub,i,t}$), and
2) The following equation applies:

$$\Delta C_{BSL\text{-}tree/shrub,i,t} = 12/44 \times (\Delta C_{TREE\_BSL,t} + \Delta C_{SHRUB\_BSL,t}) \quad \textbf{(23)}$$

Where:

$\Delta C_{BSL\text{-}tree/shrub,i,t}$	Net carbon stock changes in tree and shrub carbon pools in the baseline scenario in stratum *i* in year *t*; t C yr^{-1}
$\Delta C_{TREE\_BSL,t}$	Change in carbon stock in baseline tree biomass within the project area in year *t*; t CO_2-e yr^{-1} (derived from application of *AR-Tool14*; calculations are done for each stratum *i*)
$\Delta C_{SHRUB\_BSL,t}$	Change in carbon stock in baseline shrub biomass within the project area in year *t*; t CO_2-e yr^{-1} (derived from application of *AR-Tool14*; calculations are done for each stratum *i*)

For strata where reforestation or revegetation activities in the baseline scenario include harvesting, the long-term average of $C_{TREE\_BSL,t}$ in *AR-Tool14* must be calculated as specified in Section 8.2.3.

Herbaceous vegetation

Net carbon stock change in herbaceous vegetation in the baseline scenario is estimated using a carbon stock change approach as follows:

$$\Delta C_{BSL\text{-}herb,i,t} = (C_{BSL\text{-}herb,i,t} - C_{BSL\text{-}herb,i,,(t-T)}) / T \quad \textbf{(24)}$$

Where:

$\Delta C_{BSL\text{-}herb,i,t}$	Net carbon stock change in herbaceous vegetation carbon pools in the baseline scenario in stratum *i* in year *t*; t C yr^{-1}
$C_{BSL\text{-}herb,i,t}$	Carbon stock in herbaceous vegetation in the baseline scenario in stratum *i* in year *t*; t C
i	1, 2, 3 …M_{BSL} strata in the baseline scenario
t	1, 2, 3 … *t** years elapsed since the project start date
T	Time elapsed between two successive estimations ($T=t_2 - t_1$)

A default factor7 for carbon stock in herbaceous vegetation of 3 t C ha^{-1} may be applied for strata with 100 percent herbaceous cover. For areas with a vegetation cover <100 percent, a 1:1 relationship between vegetation cover and carbon stock must be applied. The default factor may be claimed only for the first year of the project crediting period as herbaceous biomass quickly reaches a steady state. Vegetation cover must be determined by commonly used techniques in field biology. Procedures for measuring carbon stocks in herbaceous vegetation are provided in Section 9.3.6. The above default factor may not be applied in case *AR-Tool14* is used.

Where a carbon stock increase in herbaceous vegetation is quantified in the project scenario, carbon stock changes must also be quantified in the baseline scenario; where a carbon stock decline is quantified in the baseline scenario, carbon stock changes must also be quantified in the project scenario.

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[7] Calculated from peak aboveground biomass data from 20 sites summarized in Mitsch & Gosselink. The median of these studies is 1.3 kg d.m. m^{-2}. This was converted to the default factor value as follows: 1.3 × 0.45 × 0.5. The factor 0.45 converts organic matter mass to carbon mass; the factor 0.5 is a factor that averages annual peak biomass (factor = 1) and annual minimum biomass (factor = 0, assuming ephemeral aboveground biomass and complete litter decomposition).

8.1.4 Net GHG emissions from soil in baseline scenario

8.1.4.1 General

Net GHG emissions from soil in the baseline scenario are estimated as:

$$GHG_{BSL\text{-}soil,i,t} = A_{i,t} \times (GHG_{BSL\text{-}soil\text{-}CO2,i,t} - Deduction_{alloch} + GHG_{BSL\text{-}soil\text{-}CH4,i,t} + GHG_{BSL\text{-}soil\text{-}N2O,i,t}) \quad \textbf{(25)}$$

For organic soils where $t > t_{PDT\text{-}BSL,i}$:

$GHG_{BSL\text{-}soil,i,t} = 0$

For mineral soils where $t > t_{SDT\text{-}BSL,i}$:

$GHG_{BSL\text{-}soil,i,t} = 0$

Where:

$GHG_{BSL\text{-}soil,i,t}$	GHG emissions from the SOC pool in the baseline scenario in stratum i in year t; t CO_2e yr^{-1}
$GHG_{BSL\text{-}soil\text{-}CO2,i,t}$	CO_2 emissions from the SOC pool in the baseline scenario in stratum i in year t; t CO_2e ha^{-1} yr^{-1}
$Deduction_{alloch}$	Deduction from CO_2 emissions from the SOC pool to account for the percentage of the carbon stock that is derived from allochthonous soil organic carbon; t CO_2e ha^{-1} yr^{-1}
$GHG_{BSL\text{-}soil\text{-}CH4,i,t}$	CH_4 emissions from the SOC pool in the baseline scenario in stratum i in year t; t CO_2e ha^{-1} yr^{-1}
$GHG_{BSL\text{-}soil\text{-}N2O,i,t}$	N_2O emissions from the SOC pool in the baseline scenario in stratum i in year t; t CO_2e ha^{-1} yr^{-1}
$A_{i,t}$	Area of stratum i in year t; ha
$t_{PDT\text{-}BSL,i}$	Peat depletion time in the baseline scenario in stratum i in years elapsed since the project start date; yr
$t_{SDT\text{-}BSL,i}$	Soil organic carbon depletion time in the baseline scenario in stratum i in years elapsed since the project start date; yr
i	1, 2, 3 …M_{BSL} strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the project start date

GHG emissions from disturbed carbon stocks in stockpiles (originating from piling, dredging, channelization) exposed to aerobic decomposition must be accounted for in the baseline scenario. Such stockpiles must be identified in the stratification of the project area and accounting procedures provided in this Section 8.1.4 must be used.

The baseline scenario may involve the construction of levees to constrain flow and flooding patterns, the construction of dams to hold water, and/or upstream changes in land surface leading to intensified run-off. In such cases, the project proponent must account for hydrological processes that lead to increased carbon burial and GHG reductions within the project area using procedures provided in this section.

The sub-sections below provide guidance with respect to the methods which may be used to estimate net GHG emissions from soil in the baseline scenario.

Use of proxies

Proxies (as defined in VCS document *Program Definitions*) may be used to derive values of GHG emissions. The project proponent must demonstrate that such proxies are strongly correlated with the value of interest and that they can serve as an equivalent or better method (eg, in terms of reliability, consistency or practicality) to determine the value of interest than direct measurement of the value itself. Such proxies must also have been developed and tested for use in systems that are in the same or similar region as the project area, share similar geomorphic, hydrologic, and biological properties, and are under similar management regimes, unless any differences should not have a substantial effect on GHG emissions.

Use of models

The project proponent may apply deterministic models (models as defined in VCS document *Program Definitions*) to derive values of GHG emissions. In addition to the VCS requirements for selection and use of models, modeled GHG emissions and removals must have been validated with direct measurements from a system with the same or similar water table depth and dynamics, salinity, tidal hydrology, sediment supply and plant community type as the project area.

Use of published data

Peer-reviewed published data may be used to generate values for the average rate of GHG emissions in the same or similar systems as those in the project area. Such data must be limited to systems that are in the same or similar region as the project area, share similar geomorphic, hydrologic, and biological properties, and are under similar management regimes unless any differences should not have a substantial effect on GHG emissions.

Use of default factors

Emission factors must be derived from peer-reviewed literature and must be appropriate to ecosystem type and conditions and the geographic region of the project area.

The default factors in Sections 8.1.4.2.3, 8.1.4.4.4, and 8.1.4.5.4 are subject to periodic re-assessment per the requirements for periodic assessment of default factors set out in VCS document *Methodology Approval Process*.

IPCC default factors[8] may be used as indicated in this methodology. Tier 1 values may be used, but their use must be justified as appropriate for project conditions.

8.1.4.2 CO_2 emissions from soil

CO_2 emissions from soils may be estimated using:

1) Proxies;
2) Published values;
3) Default factors;
4) Models;
5) Field-collected data; or
6) Historical or chronosequence-derived data.

In certain cases allochthonous soil organic carbon may accumulate in the project area. Procedures for the estimation of a compensation factor for allochthonous soil organic carbon are specified in Section 8.1.4.3.

8.1.4.2.1 Proxy-based approach

CO_2 emissions may be estimated using proxies such as water table depth, soil subsidence and carbon stock change (where such proxies meet the guidance set out in Section 8.1.4.1 above). Where the project proponent uses a proxy, such emissions are represented by the following equation:

$$GHG_{BSL\text{-}soil\text{-}CO2,i,t} = f\ (\text{GHG emission proxy}) \qquad \textbf{(26)}$$

<u>Water table depth</u>

Water table depth may be used as a proxy for CO_2 emissions for mineral and organic soils where the project proponent is able to justify their use as described in Section 8.1.4.1.

When using water table depth as a proxy, it must be projected for the 10-year baseline period through hydrologic modeling, taking into consideration the following:

- Long-term average climate variables (over 20+ years prior to the project start date from two climate stations nearest to the project area) influencing water levels and the timing and quantity of water flow;
- Planned water management activities documented in existing land management plans, predating consideration of the proposed project activity; and

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[8] 2013 Supplement to the 2006 Guidelines: Wetlands

- Potential offsite influences (eg, changes in sedimentation rates, upstream water supply, sea level rise).

If the mean annual water table depth in the project area exceeds the depth range for which the emission-water table depth relationship determined for the project is valid, a conservative extrapolation must be used.

Subsidence

Soil subsidence may also be used as a proxy for CO_2 emissions from the SOC pool, using the equation below:

$$GHG_{BSL\text{-}soil\text{-}CO2,i,t} = 44/12 \times C_{peatloss\text{-}BSL,i,t} \quad \textbf{(27)}$$

$$C_{peatloss\text{-}BSL,i,t} = 10 \times Rate_{subs\text{-}BSL,i} \times VC \quad \textbf{(28)}$$

Where:

$GHG_{BSL\text{-}soil\text{-}CO2,i,t}$	CO_2 emissions from the SOC pool in the baseline scenario in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}
$C_{peatloss\text{-}BSL,i,t}$	Organic soil carbon loss due to subsidence in the baseline scenario in subsidence stratum *i* in year *t*; t C ha^{-1}
$Rate_{subs\text{-}BSL,i}$	Rate of organic soil loss due to subsidence in the baseline scenario in stratum *i*; m yr^{-1}
VC	Volumetric organic carbon content of organic soil; kg C m^{-3}
i	1, 2, 3 …M_{BSL} subsidence strata in the baseline scenario
t	1, 2, 3 … *t** years elapsed since the start of the project activity

Carbon stock change

Carbon stock change may also be used as a proxy for CO_2 emissions from the SOC pool, using the equation below:

$$GHG_{BSL\text{-}soil\text{-}CO2,i,t} = 44/12 \times -(C_{BSL\text{-}soil,i,t} - C_{BSL\text{-}soil,i,,(t-T)}) / T \quad \textbf{(29)}$$

Where:

$GHG_{BSL\text{-}soil\text{-}CO2,i,t}$	CO_2 emissions from the SOC pool in the baseline scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
$C_{BSL\text{-}soil,i,t}$	Soil organic carbon stock in the baseline scenario in stratum *i* in year *t*; t C ha^{-1}
i	1, 2, 3 …M_{BSL} strata in the baseline scenario
t	1, 2, 3 … *t** years elapsed since the start of the project activity
T	Time elapsed between two successive estimations ($T=t_2 - t_1$)

8.1.4.2.2 Published values

Peer-reviewed published data may be used to generate a value for $GHG_{BSL\text{-}soil\text{-}CO2,i,t}$ based on the average rate of CO_2 emissions in the same or similar systems as those in the project area, based on the guidelines set out in Section 8.1.4.1 above. Refer also to the instructions in Section 5.1 above for the estimation of the rate of organic soil carbon loss due to oxidation in the baseline scenario from mineral soils ($Rate_{Closs\text{-}BSL}$).

8.1.4.2.3 Default factors

For tidal marsh and mangrove systems, a default factor may be used in the absence of data suitable for using the published value approach, using the value provided below:

$$GHG_{BSL\text{-}soil\text{-}CO2,i,t} = -1.46^{(9)}\ t\ C\ ha^{-1}\ yr^{-1} \times 44/12 \quad \textbf{(30)}$$

The above default factor may only be applied to areas with a crown cover of at least 50 percent. By contrast, for areas with a crown cover of less than 15 percent, this value may be assumed to be insignificant and accounted for as zero.

In the absence of data suitable for using the published value approach, the most recently published IPCC emission factors[10] may be used to estimate CO_2 emissions from the SOC pool, except for tidal marsh and mangrove systems.

8.1.4.2.4 Modeling

A peer-reviewed published model may be used to generate a value of $GHG_{BSL\text{-}soil\text{-}CO2,i,t}$ in the same or similar systems as those in the project area based on the guidelines set out in Section 8.1.4.1 above.

8.1.4.2.5 Field-collected data

Soil coring may be used to generate a value of $C_{BSL\text{-}soil,i,t}$ as outlined in Section 9.3.7. For the baseline scenario, soil cores must be collected within 2 years prior to the project start date. Where the project proponent uses an installed reference plane for the baseline scenario, it must have been installed at least 4 years prior to the baseline measurement, which is good practice to ensure that a reliable average accumulation rate is obtained.

8.1.4.2.6 Historical data or chronosequences

The rate of organic soil carbon loss due to oxidation in the baseline scenario from mineral soils

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[9] (within equation 30) This default factor was derived from the median rate of the literature synthesis of Chmura et al. 2003. The synthesis included studies worldwide, including marshes and mangroves. The median was used as the best estimate of central tendency because the data were not normally distributed.

[10] 2013 Supplement to the 2006 Guidelines: Wetlands

($Rate_{Closs\text{-}BSL}$) may be estimated using either historical data collected from the project area (as described in Section 9.3.7) or chronosequence data collected at similar sites (as described in Section 8.1.4.1). Refer also to the instructions set out in Section 5.1. CO_2 emissions from the SOC pool are calculated as follows:

$$GHG_{BSL\text{-}soil\text{-}CO2,i,t} = Rate_{Closs\text{-}BSL,i,t} \times 44/12 \quad \textbf{(31)}$$

Where:

$GHG_{BSL\text{-}soil\text{-}CO2,i,t}$	CO_2 emissions from the SOC pool in the baseline scenario in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}
$Rate_{Closs\text{-}BSL,i,t}$	Rate of organic carbon loss in mineral soil due to oxidation in the baseline scenario in stratum *i* in year *t*; t C ha^{-1} yr^{-1}.
i	1, 2, 3 …M_{BSL} strata in the baseline scenario
t	1, 2, 3 … *t** years elapsed since the start of the project activity

8.1.4.3 Deduction for allochthonous carbon

A deduction from the estimate of CO_2 emissions from the SOC pool must be applied to account for the percentage of sequestration resulting from allochthonous soil organic carbon accumulation. A deduction must not be used if the approach used above to estimate CO_2 emissions directly estimates autochthonous CO_2 emissions or otherwise accounts for allochthonous carbon.

$$Deduction_{alloch} = GHG_{BSL\text{-}soil\text{-}CO2,i,t} \times (\%C_{alloch} /100) \quad \textbf{(32)}$$ [11]

Where:

$Deduction_{alloch}$	Deduction from CO_2 sequestration in the SOC pool to account for the percentage of the carbon stock that is derived from allochthonous soil organic carbon; t CO_2e ha^{-1} yr^{-1}
$GHG_{BSL\text{-}soil\text{-}CO2,i,t}$	CO_2 emissions from the SOC pool in the baseline scenario in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}
$\%C_{alloch}$	Percentage of the total soil organic carbon that is allochthonous; %
i	1, 2, 3 …M_{BSL} strata in the baseline scenario
t	1, 2, 3 … *t** years elapsed since the start of the project activity

$Deduction_{alloch}$ may be conservatively set to zero in the baseline scenario.

For strata with organic soils or seagrass systems[12], $Deduction_{alloch}$ = 0.

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[11] Estimation may be made for total or recalcitrant allochthonous carbon. This equation only applies if $GHG_{BSL\text{-}soil\text{-}CO2,i,t}$ is negative (sequestration).

$\%C_{alloch}$ may be estimated using either:

1) Published values
2) Field-collected data
3) Modeling

Published values

Peer-reviewed published data may be used to generate a value of the percentage of allochthonous soil organic carbon in the same or similar systems as those in the project area based on the guidelines described in Section 8.1.4.1.

Field-collected data

For this method, the allochthonous carbon percentage is estimated using default values (listed below) and measured through analysis of field-collected soil cores (for soil carbon or organic matter), sediment tiles (for deposited sediment carbon or organic matter), or through collection of suspended sediments in tidal channels or sediments deposits in tidal flats (for sediment carbon or organic matter).

For the following equation, $\%C_{soil}$ may be measured directly or derived from $\%OM_{soil}$ using the equations in Section 9.3.7. $\%C_{autoch}$ is derived from $\%OM_{autoch}$ (defined below) using the equations in Section 9.3.7.

$$\%C_{alloch} = 100 \times (\%C_{soil} - \%C_{autoch}) / \%C_{soil} \quad \textbf{(33)}$$

Where:

$\%C_{alloch}$	Percentage of the total soil organic carbon that is allochthonous; %
$\%C_{soil}$	Percentage of soil that is organic carbon; %
$\%C_{autoch}$	Percentage of soil that is autochthonous organic carbon; %

For the following equation, $\%OM_{soil}$ may be estimated directly using loss-on-ignition (LOI) data or indirectly from $\%C_{soil}$ using the equations below. $\%OM_{depsed}$ may be estimated directly using loss-on-ignition (LOI) data, indirectly from $\%OM_{soil}$ using the equations below, or by using the default value given below.

$$\%OM_{autoch} = (\%OM_{soil} - \%OM_{depsed}) / (1 - (\%OM_{depsed} / 100)) \quad \textbf{(34)}$$

[12] For seagrass systems, this zero deduction may only be used when the 'layer with soil organic carbon indistinguishable from the baseline SOC concentration' method is used with field-collected data on carbon stock changes (Duarte 2013, Greinier *et al*. 2013)

Where:

$\%OM_{autoch}$	Percentage of soil that is autochthonous organic matter; %
$\%OM_{depsed}$	Percentage of deposited sediment that is organic matter; %
$\%OM_{soil}$	Percentage of soil that is soil organic matter; %

The following equations may be used to derive $\%OM_{soil}$ from $\%C_{soil}$ and $\%OM_{depsed}$ from $\%C_{depsed}$, respectively. Alternatively, an equation developed using site-specific data may be used or an equation from peer-reviewed literature may be used if the equation represents soils from the same or similar systems as those in the project area.

For marsh soils[13]*:*

$$\%OM_{soil} = (-0.4 + \sqrt{(0.4^2 + 4 \times 0.0025 \times \%C_{soil}}) \Big/ (2 \times 0.0025) \quad \textbf{(35)}$$

$$\%OM_{depsed} = (-0.4 + \sqrt{(0.4^2 + 4 \times 0.0025 \times \%C_{depsed}})) \Big/ (2 \times 0.0025) \quad \textbf{(36)}$$

For mangrove soils[14]:

$$\%OM_{soil} = \%C_{soil} \times 1.724 \quad \textbf{(37)}$$

$$\%OM_{depsed} = \%C_{depsed} \times 1.724 \quad \textbf{(38)}$$

For seagrass soils with $\%OM$ < 20 percent[15]*:*

$$\%OM_{soil} = (\%C_{soil} + 0.21) / 0.4 \quad \textbf{(39)}$$

$$\%OM_{depsed} = (\%C_{depsed} + 0.21) / 0.4 \quad \textbf{(40)}$$

Where:

$\%C_{soil}$	Percentage of soil that is organic carbon; %
$\%C_{depsed}$	Percentage of deposited sediment that is organic C; %

In all cases, the following default factor may be used for the determination of $\%OM_{depsed}$:

$\%OM_{depsed}$ = 3.0[16]

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[13] Craft *et al.* 1991

[14] Allen 1974

[15] Fourqurean *et al*. 2012 as summarized in Howard *et al.* 2014

[16] Andrews *et al.* 2011

Modeling

A quantitative model may be used to estimate the percent of allochthonous soil organic carbon where such model meets the guidelines set out in Section 8.1.4.1 above. The modeled percentage allochthonous soil organic carbon must be verified with direct measurements from a system with similar water table depth and dynamics, salinity and plant community type as the project area. The model must be accepted by the scientific community as shown by publication in a peer-reviewed journal and repeated application to different wetland systems.

8.1.4.4 CH_4 emissions from soil

CH_4 emissions from soil in the baseline scenario may be conservatively excluded.

CH_4 emissions from soils may be estimated using:

1) Proxies;
2) Field-collected data
3) Published values;
4) Default factors;
5) Models; or
6) IPCC emission factors.

Where the project proponent accounts for CH_4 emissions in the baseline scenario, the options described in the sections below may be applied to estimate such emissions.

8.1.4.4.1 Proxy-based approach

Where relevant, CH_4 emissions from organic soil may be estimated using proxies such as water table depth and vegetation composition (where such proxies meet the requirements set out in Section 8.1.4.1 above). Where the project proponent uses a proxy, such emissions are represented by the following equation:

$$GHG_{BSL\text{-}soil\text{-}CH4,i,t} = f\,(\text{GHG emission proxy}) \times CH_4\text{-}GWP \qquad \textbf{(41)}$$

Where:

$GHG_{BSL\text{-}soil\text{-}CH4,i,t}$	CH_4 emissions from the SOC pool in the baseline scenario; t CO_2e ha^{-1} yr^{-1}
f (GHG emission proxy)	Proxy for CH_4 emissions; t CH_4 ha^{-1} yr^{-1}
$CH_4\text{-}GWP$	Global warming potential of CH_4; dimensionless

8.1.4.4.2 Field-collected data

Field-collected data may also be used to estimate CH_4 emissions (see Section 9.3.8).

8.1.4.4.3 Published values

Peer-reviewed published data may be used to generate a value based on the average CH_4 emissions rate in the same or similar systems as those in the project area based on the guidelines set out in Section 8.1.4.1 above.

8.1.4.4.4 Default factor

For tidal wetland systems, a default factor[17] may be used in the absence of data suitable for using the published value *approach* for the estimation of $GHG_{BSL\text{-}soil\text{-}CH4,i,t}$. Where the salinity average or salinity low point is >18 ppt, the project proponent may apply a default emission factor of:

$$GHG_{BSL\text{-}soil\text{-}CH4,i,t} = 0.011 \text{ t } CH_4 \text{ ha}^{-1} \text{ yr}^{-1} \times CH_4\text{-}GWP \quad \textbf{(42)}$$

Where the salinity average or salinity low point is ≥ 20 ppt, the project proponent may apply a default emission factor of:

$$GHG_{BSL\text{-}soil\text{-}CH4,i,t} = 0.0056 \text{ t } CH_4 \text{ ha}^{-1} \text{ yr}^{-1} \times CH_4\text{-}GWP \quad \textbf{(43)}$$

Procedures for measuring the salinity average or salinity low point are provided in Section 9.3.8.

The project proponent must not use the default value of 0.011 t CH_4 ha^{-1} yr^{-1} for the baseline scenario and 0.0056 t CH_4 ha^{-1} yr^{-1} for the project scenario to create a difference in emissions and claim an emission reduction. The use of the default factor is intended for projects that restore salinity levels from fresh/brackish to much higher levels that inhibit CH_4 emissions.

8.1.4.4.5 Modeling

A quantitative model which meets the guidance set out in Section 8.1.4.1 above may also be used to estimate CH_4 emissions from the SOC pool.

8.1.4.4.6 Emission factors

The most recently published IPCC emission factors may be used to estimate CH_4 emissions from the SOC pool for non-tidal wetland systems. Tier 1 values may also be used, but must be applied conservatively including accounting for local salinity and vegetative cover conditions.

8.1.4.5 N_2O emissions from soil

N_2O emissions may be conservatively excluded in the baseline scenario.

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[17] Taken from Poffenbarger *et al.* 2011

N_2O emissions from soils may be estimated using:

1) Proxies;
2) Field-collected data;
3) Published values;
4) Default factors;
5) Models; or
6) IPCC emission factors.

Where the project proponent accounts for N_2O emissions in the baseline scenario, the options described in the sections below may be applied to estimate such emissions.

8.1.4.5.1 Proxy-based approach

Where relevant, N_2O emissions may be estimated using proxies such as water table depth and vegetation composition (where such proxies meet the guidance set out in Section 8.1.4.1 above). Where the project proponent uses a proxy, such emissions are represented by the following equation (note that the determination of the similarity of systems must include the nitrogen levels of the systems):

$$GHG_{BSL\text{-}soil\text{-}N2O,i,t} = f\ (N_2O \text{ emission proxy}) \times N_2O\text{-}GWP \quad \textbf{(44)}$$

Where:

$GHG_{BSL\text{-}soil\text{-}N2O,i,t}$	N_2O emissions from the SOC pool in the baseline scenario due to denitrification/nitrification; t CO_2e ha^{-1} yr^{-1}
f (N_2O emission proxy)	Proxy for N_2O emissions; t N_2O ha^{-1} yr^{-1}
$N_2O\text{-}GWP$	Global warming potential for N_2O; dimensionless

8.1.4.5.2 Field-collected data

Field-collected data may be used to estimate N_2O emissions (see Section 9.3.8).

8.1.4.5.3 Published values

Peer-reviewed published data may be used to generate a value based on the average N_2O emissions rate in the same or similar systems as those in the project area based on the guidelines described in Section 8.1.4.1. Note that determination of the similarity of systems must include the nitrogen levels of the systems.

8.1.4.5.4 Default factors

The following default factors[18] may be used for the estimation of $GHG_{BSL\text{-}soil\text{-}N2O,i,t}$ in the absence of data suitable for using the published value approach. Use of a default factor is only permitted for the systems listed below, except where the project area receives hydrologically direct inputs from a point or non-point source of nitrogen such as wastewater effluent or an intensively nitrogen-fertilized system.

For open water systems where the salinity average or salinity low point is >18 ppt:

$$GHG_{BSL\text{-}soil\text{-}N2O,i,t} = 0.000157 \text{ t } N_2O \text{ ha}^{-1} \text{ yr}^{-1} \times N_2O\text{-}GWP \quad \textbf{(45)}$$

For open water systems where the salinity average or salinity low point is >5 and ≤18 ppt:

$$GHG_{BSL\text{-}soil\text{-}N2O,i,t} = 0.00033 \text{ t } N_2O \text{ ha}^{-1} \text{ yr}^{-1} \times N_2O\text{-}GWP \quad \textbf{(46)}$$

For other open water systems:

$$GHG_{BSL\text{-}soil\text{-}N2O,i,t} = 0.00053 \text{ t } N_2O \text{ ha}^{-1} \text{ yr}^{-1} \times N_2O\text{-}GWP \quad \textbf{(47)}$$

For non-seagrass wetland systems where the salinity average or salinity low point is >18 ppt:

$$GHG_{BSL\text{-}soil\text{-}N2O,i,t} = 0.000487 \text{ t } N_2O \text{ ha}^{-1} \text{ yr}^{-1} \times N_2O\text{-}GWP \quad \textbf{(48)}$$

For non-seagrass wetland systems where the salinity average or salinity low point is >5 and ≤18 ppt:

$$GHG_{BSL\text{-}soil\text{-}N2O,i,t} = 0.000754 \text{ t } N_2O \text{ ha}^{-1} \text{ yr}^{-1} \times N_2O\text{-}GWP \quad \textbf{(49)}$$

For other non-seagrass wetland systems:

$$GHG_{BSL\text{-}soil\text{-}N2O,i,t} = 0.000864 \text{ t } N_2O \text{ ha}^{-1} \text{ yr}^{-1} \times N_2O\text{-}GWP \quad \textbf{(50)}$$

Procedures for measuring the salinity average and salinity low point are set out in Section 9.3.8 below.

8.1.4.5.5 Modeling

A quantitative model which meets the requirements set out in Section 8.1.4.1 above may also be used to estimate N_2O emissions from the SOC pool.

8.1.4.5.6 Emission factors

The most recently published IPCC emission factors may also be used to estimate N_2O emissions

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[18] Taken from Smith *et al.* 1983.

from the SOC pool. Tier 1 values may also be used, but must be applied conservatively following the guidance set out in Section 8.1.4.1 above.

8.1.5 Emissions from fossil fuel use in baseline scenario

Emissions from the use of vehicles and mechanical equipment in the baseline scenario ($GHG_{BSL\text{-}fuel,i,t}$) may be conservatively excluded. However, these emissions in the baseline scenario may be estimated using the procedures set out in Section 8.2.6 below.

8.2 Project Emissions

8.2.1 General approach

Emissions in the project scenario are attributed to carbon stock changes in biomass carbon pools, soil processes, or a combination of these. In addition, where relevant, emissions from organic soil burns and fossil fuel use may be quantified.

Organic soil combustion due to anthropogenic fires is addressed using a conservative default factor (*Fire Reduction Premium*) that is expressed as a proportion of the CO_2 emissions avoided through rewetting (see Section 8.3).

Emissions in the project scenario are estimated as:

$$GHG_{WPS} = GHG_{WPS\text{-}biomass} + GHG_{WPS\text{-}soil} + GHG_{WPS\text{-}burn} + GHG_{WPS\text{-}fuel} \quad \textbf{(51)}$$

$$GHG_{WPS-biomass} = -\sum_{t=1}^{t^*} \sum_{i=1}^{M_{WPS}} \left(\frac{44}{12} \times \Delta C_{WPS-biomass,i,t} \right) \quad \textbf{(52)}$$

$$GHG_{WPS-soil} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{WPS}} GHG_{WPS-soil,i,t} \quad \textbf{(53)}$$

$$GHG_{WPS-burn} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{WPS}} GHG_{WPS-burn,i,t} \quad \textbf{(54)}$$

$$GHG_{WPS-fuel} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{WPS}} GHG_{WPS-fuel,i,t} \quad \textbf{(55)}$$

Where:

GHG_{WPS}	Net CO_2e emissions in the project scenario up to year t^*; t CO_2e
$GHG_{WPS\text{-}biomass}$	Net CO_2e emissions from biomass carbon pools in the project scenario up to year t^*; t CO_2e
$GHG_{WPS\text{-}soil}$	Net CO_2e emissions from the SOC pool in the project scenario up to year t^*; t

	CO_2e
$GHG_{WPS\text{-}burn}$	Net CO_2e emissions from prescribed burning in the project scenario up to year *t**; t CO_2e
$GHG_{WPS\text{-}fuel}$	Net CO_2e emissions from fossil fuel use in the project scenario up to year *t**; t CO_2e
$\Delta C_{WPS\text{-}biomass,i,t}$	Net carbon stock change in biomass carbon pools in the project scenario in stratum *i* in year *t*; t C yr^{-1}
$GHG_{WPS\text{-}soil,i,t}$	GHG emissions from the SOC pool in the project scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
$GHG_{WPS\text{-}burn,i,t}$	GHG emissions from prescribed burning in the project scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
$GHG_{WPS\text{-}fuel,i,t}$	GHG emissions from fossil fuel use the project scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
i	1, 2, 3 …M_{WPS} strata in the project scenario
t	1, 2, 3, … *t** years elapsed since the project start date

Ex-ante estimates of GHG_{WPS} must be based on a project scenario that is defined *ex ante*, and must be projected using the latest version of VCS module *VMD0019 Methods to Project Future Conditions*.

Ex-post estimates of GHG_{WPS} must be based on monitoring results.

8.2.2 Accounting for sea level rise

See Section 8.1.2 for procedures for accounting for sea level rise, noting that for the project scenario, the project proponent may conservatively assume that all eroded carbon is oxidized, or may justify a smaller oxidation rate based on appropriate scientific research.

8.2.3 Net carbon stock change in biomass carbon pools in project scenario

Net carbon stock change in biomass carbon pools in the project scenario is estimated as:

$$\Delta C_{WPS\text{-}biomass,i,t} = \Delta C_{WPS\text{-}tree/shrub,i,t} + \Delta C_{WPS\text{-}herb,i,t} \quad \textbf{(56)}$$

Where:

$\Delta C_{WPS\text{-}biomass,i,t}$	Net carbon stock change in biomass carbon pools in the project scenario in stratum *i* in year *t*; t C yr^{-1}
$\Delta C_{WPS\text{-}tree/shrub,i,t}$	Net carbon stock change in tree and shrub carbon pools in the project scenario in stratum *i* in year *t*; t C yr^{-1}
$\Delta C_{WPS\text{-}herb,i,t}$	Net carbon stock change in herb carbon pools in the project scenario in stratum *i* in year *t*; t C yr^{-1}
i	1, 2, 3 …M_{WPS} strata in the project scenario

t	1, 2, 3, … t^* years elapsed since the project start date

Trees and shrubs

The net carbon stock change in trees and shrubs in the project scenario are estimated using CDM tool *AR-Tool14 Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*, noting that the following equation applies:

$$\Delta C_{WPS\text{-}tree/shrub,i,t} = 12/44 \times (\Delta C_{TREE\_PROJ,t} + \Delta C_{SHRUB\_PROJ,t}) \quad \textbf{(57)}$$

Where:

$\Delta C_{BSL\text{-}tree/shrub,i,t}$	Net carbon stock change in tree and shrub carbon pools in the project scenario in stratum i in year t; t C yr^{-1}
$\Delta C_{TREE\_PROJ,t}$	Change in carbon stock in tree biomass in the project scenario in year t; t CO_2-e yr^{-1} (derived from application of *AR-Tool14*; calculations are done for each stratum i)
$\Delta C_{SHRUB\_PROJ,t}$	Change in carbon stock in shrub biomass in the project scenario in year t; t CO_2-e yr^{-1} (derived from application of *AR-Tool14*; calculations are done for each stratum i)

For the *ex-ante* estimation of tree biomass, an IPCC default factor[19] may be used.

Where reforestation or revegetation activities in the project scenario include harvesting, the maximum number of GHG credits generated by these activities must not exceed the long-term average GHG benefit from the tree component.

For strata where harvesting occurs, the maximum carbon stock in tree biomass ($C_{TREE,i,t}$) used in *AR-Tool14* is limited to $C_{AVG\text{-}TREE,i}$, calculated as follows:

$$C_{AVG-TREE,i} = \frac{\sum_{t=1}^{n} C_{TREE,i,t}}{n} \quad \textbf{(58)}$$

Where:

$C_{AVG\text{-}TREE,i}$	Long-term average carbon stock in baseline or project tree biomass within the project area (in stratum i) in time period n; t CO_2-e
$C_{TREE,i,t}$	Carbon stock in baseline or project tree biomass within the project area (in stratum i) in year t (derived from application of *AR-Tool14*); t CO_2-e yr^{-1}
i	1, 2, 3 …M_{WPS} strata in the project scenario
t	1, 2, 3 … n years elapsed since the project start date

[19] 2013 Supplement to the 2006 Guidelines: Wetlands (Table 4.4). This value can only be used until biomass stock in Table 4.3 of the guidelines is reached.

n	Total number of years in the established time period

The long-term average carbon stock must be calculated for both the baseline and the project scenario.

For projects undertaking even-aged management, the time period *n* over which the long-term average GHG benefit is calculated includes at minimum one full harvest/cutting cycle, including the last harvest/cut in the cycle. For projects under conservation easements with no intention to harvest after the project crediting period (which must be shown in the project description based on verifiable information), or in case of selective cutting, the time period *n* over which the long-term average is calculated is the length of the project crediting period.

Projects may account for long-term carbon storage in wood products. In this case, the parameter $C_{TREE,t}$ in equation 58 must be read as $C_{TREE,i,t}$ + $C_{WP,i,t}$. Procedures for the calculation of $C_{WP,i,t}$ are provided in Appendix 1.

Examples of how to calculate the long-term average carbon benefit are provided in VCS document *AFOLU Guidance: Example for Calculating the Long-Term Average Carbon Stock for ARR Projects with Harvesting.*

Biomass may be lost due to subsidence following sea level rise. For strata where conversion to open water is expected before t = 100, the maximum stock in tree and shrub biomass ($C_{TREE,i,t}$ *and* $C_{SHRUB,t}$*, respectively) used in AR-Tool14* is limited to $C_{AVG-TREE,i}$, *as calculated in equation 58*.

Restoration projects which include afforestation or reforestation components may account for long-term carbon storage in wood products in case trees are harvested before dieback. In this case, the parameter $C_{TREE,t}$ in equation 58 must be read as $C_{TREE,i,t}$ + $C_{WP,i,t}$.

$C_{AVG-SHRUB,i}$ is calculated as follows:

$$C_{AVG-SHRUB,i} = \frac{\sum_{t=1}^{n} C_{SHRUB,i,t}}{n} \quad \textbf{(59)}$$

Where:

$C_{AVG-SHRUB,i}$	Long-term average carbon stock in baseline or project shrub biomass within the project area (in stratum *i*) in time period *n*; t CO_2-e
$C_{SHRUB,i,t}$	Carbon stock in baseline or project shrub biomass within the project area (in stratum *i*) in year *t* (derived from application of *AR-Tool14*); t CO_2-e yr^{-1}
i	1, 2, 3 …M_{WPS} strata in the project scenario
t	1, 2, 3 … *n* years elapsed since the project start date
n	Total number of years in the established time period

Herbaceous vegetation

The net carbon stock change in herbaceous vegetation biomass in the project scenario is estimated using a carbon stock change approach as follows:

$$\Delta C_{WPS\text{-}herb,i,t} = (C_{WPS\text{-}herb,i,t} - C_{WPS\text{-}herb,i,,(t\text{-}T)}) / T \quad \textbf{(60)}$$

Where:

$\Delta C_{WPS\text{-}herb,i,t}$	Net carbon stock changes in herb carbon pools in the project scenario in stratum *i* in year *t*; t C yr^{-1}
$C_{WPS\text{-}herb,i,t}$	Carbon stock in herbaceous vegetation in the project scenario in stratum *i* in year *t*; t C ha^{-1}
i	1, 2, 3 …M_{WPS} strata in the project scenario
t	1, 2, 3 … *t** years elapsed since the start of the project activity
T	Time elapsed between two successive estimations (T=$t_2 - t_1$)

A default factor for $C_{WPS\text{-}herb,i,t}$ of 3 t C ha^{-1} (see Section 8.1.3) may be applied for strata with 100 percent herbaceous cover. For areas with a vegetation cover <100 percent, a 1:1 relationship between vegetation cover and $C_{WPS\text{-}herb,i,t}$ must be applied. The default factor may be claimed only for the first year of the project crediting period as herbaceous biomass quickly reaches a steady state. Vegetation cover must be determined by commonly used techniques in field biology. Procedures for measuring carbons stocks in herbaceous vegetation are provided in Section 9.3.6. The above default factor may not be applied in case *AR-Tool14* is used.

Where the carbon stock change in herbaceous vegetation is quantified in the project scenario, it must also be quantified in the baseline scenario.

8.2.4 Net GHG emissions and removals from soil in project scenario

8.2.4.1 General

Net GHG emissions from soils in the project scenario are estimated as:

$$GHG_{WPS\text{-}soil,i,t} = A_{i,t} \times (GHG_{WPS\text{-}soil\text{-}CO2,i,t} - Deduction_{alloch} + GHG_{WPS\text{-}soil\text{-}CH4,i,t} + GHG_{WPS\text{-}soil\text{-}N2O,i,t})^{(20)} \quad \textbf{(61)}$$

Where:

$GHG_{WPS\text{-}soil,i,t}$	GHG emissions from the SOC pool in the project scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
$GHG_{WPS\text{-}soil\text{-}CO2,i,t}$	CO_2 emissions from the SOC pool in the project scenario in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}
$Deduction_{alloch}$	Deduction from CO_2 emissions from the SOC pool to account for the

[20] This equation only applies if $GHG_{WPS\text{-}soil\text{-}CO2,i,t}$ is negative (sequestration).

	percentage of the carbon stock that is derived from allochthonous soil organic carbon; t CO_2e ha^{-1} yr^{-1}
$GHG_{WPS-soil-CH4,i,t}$	CH_4 emissions from the SOC pool in the project scenario in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}
$GHG_{WPS-soil-N2O,i,t}$	N_2O emissions from the SOC pool in the project scenario in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}
$A_{i,t}$	Area of stratum *i* in year *t*; ha
i	1, 2, 3 …M_{WPS} strata in the project scenario
t	1, 2, 3, … *t** years elapsed since the project start date

8.2.4.2 CO_2 emissions from soil

CO_2 emissions from soils may be estimated using one of the following approaches:

1) Proxies;
2) Published values;
3) Default factors;
4) Models; or
5) Field-collected data.

In certain cases allochthonous soil organic carbon may accumulate in the project area, and such carbon must be accounted for in the project scenario. Procedures for the estimation of a compensation factor for allochthonous soil organic carbon are specified in Sections 8.1.4.3 and 8.2.4.2.2.

8.2.4.2.1 Approaches for estimating $GHG_{WPS-soil-CO2,i,t}$

$GHG_{WPS-soil-CO2,i,t}$ must be calculated using the same procedures set out in Sections 8.1.4.2.1 – 8.1.4.2.6 above. For all equations in these sections, the subscript *BSL* must be substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario.

8.2.4.2.2 Deduction for allochthonous carbon

A deduction must be applied to account for allochthonous carbon using the procedures set out in Section 8.1.4.3. The project proponent must also follow the additional guidance below.

The determination of the deduction for allochthonous carbon is mandatory for the project scenario unless the project proponent is able to demonstrate that the allochthonous carbon would have been returned to the atmosphere in the form of carbon dioxide in the absence of the project.

The deduction for allochthonous carbon must only be applied to soil layers deposited or accumulated after the project start date (such as materials formed above a feldspar marker horizon).

If the organic surface layer exceeds 10 cm, the soil is deemed organic and no deduction is required. If an organic surface layer of up to 10 cm is present, *deduction_alloch* must be determined only in such cases where the project experiences mineral sedimentation events sufficient to create mineral soil layers. In practice, the project area may show mineral sedimentation in places. If this is observed it is assumed that at some point during the project crediting period mineral sediment can be deposited on top of organic surface layers, unless the project proponent can justify that strata with an organic surface layer of less than 10 cm will not experience mineral sedimentation during the project crediting period.

8.2.4.3 CH_4 emissions from soil

The estimation of CH_4 emissions in project scenario must follow one of the approaches provided in Section 8.1.4.4 above. For all equations in these sections, the subscript *BSL* must be substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario.

8.2.4.4 N_2O emissions from soil

Where the project proponent is able to demonstrate (eg, by referring to peer-reviewed literature based on similar project circumstances[21]) that N_2O emissions do not increase in the project scenario compared to the baseline scenario, N_2O emissions may be excluded.

N_2O emissions must be accounted for in the project scenario in strata where water levels were lowered as a result of project activities[22]. Seagrass restoration projects do not require N_2O emission accounting. The estimation of N_2O emissions in the project scenario may follow one of the approaches provided in Section 8.1.4.5. For all equations in these sections, the subscript *BSL* must be substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario.

In addition, where the project proponent is able to demonstrate (eg, by referring to peer-reviewed literature) that N_2O emissions in the project scenario are *de minimis*, N_2O emissions may be excluded. To demonstrate that N_2O emissions are *de minimis* in the project scenario, the project proponent must use CDM tool *Tool for testing significance of GHG emissions in A/R CDM project activities*, or refer to peer-reviewed literature.

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[21] Project circumstances are defined by pre-project land use (eg, forestry, agriculture, abandonment after such activities) and its intensity (especially related to N-fertilization), climatic zone, water table depths, and soil type.

[22] See applicability conditions.

8.2.5 Net non-CO_2 emissions from prescribed burning in project scenario

Where the project proponent introduces prescribed burning of shrub and herbaceous biomass, the project proponent must a) demonstrate that the project does not decrease carbon sequestration rates if using the default factor approach for carbon dioxide emissions accounting from soil, and b) account for CH_4 and N_2O emissions as follows:

$$GHG_{WPS\text{-}burn,i,t} = CO_2e_{N2O,i,t} + CO_2e_{CH4,i,t} \quad \textbf{(62)}$$

$$CO_2e_{N2O,i,t} = Biomass_{i,t} \times EF_{N2O,burn} \times N_2O\text{-}GWP \times 10^{-6} \times A_{i,t} \quad \textbf{(63)}$$

$$CO_2e_{CH4,i,t} = Biomass_{i,t} \times EF_{CH4,burn} \times CH_4\text{-}GWP \times 10^{-6} \times A_{i,t} \quad \textbf{(64)}$$

Where:

$GHG_{WPS\text{-}burn,i,t}$	GHG emissions from prescribed burning in the project scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
$CO_2e_{N2O,i,t}$	CO_2e emissions resulting from N_2O emissions due to prescribed burning in stratum *i* in year *t*; t CO_2e yr^{-1}.
$CO_2e_{CH4,i,t}$	CO_2e emissions resulting from CH_4 emissions due to prescribed burning in stratum *i* in year *t*; t CO_2e yr^{-1}.
$Biomass_{i,t}$	Aboveground shrub and herbaceous biomass in stratum *i* in year *t* (from Section 8.2.3), kg d.m. ha^{-1}
$EF_{N2O,burn}$	Emission factor for N_2O for vegetation burning; g N_2O / kg dry biomass
$EF_{CH4,burn}$	Emission factor for CH_4 for vegetation burning; g CH_4 / kg dry biomass
$N_2O\text{-}GWP$	Global warming potential of N_2O; dimensionless
$CH_4\text{-}GWP$	Global warming potential of CH_4; dimensionless
$A_{i,t}$	Area of stratum *i* in year *t;* ha
i	1, 2, 3 …M_{WPS} strata in the project scenario
t	1, 2, 3, … *t** years elapsed since the project start date

8.2.6 Emissions from fossil fuel use

Where emissions from the use of vehicles and mechanical equipment for earth moving in WRC project activities are above *de minimis* as compared to the baseline scenario, such emissions must be estimated by applying CDM tool *Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities*, noting that the following equation applies:

$$GHG_{WPS\text{-}fuel,i,t} = ET_{FC,y} \quad \textbf{(65)}$$

Where:

$GHG_{WPS\text{-}fuel,i,t}$	GHG emissions from fossil fuel use in the project scenario in stratum *i* in year *t*; t CO_2e yr^{-1}

$ET_{FC,y}$	CO_2 emissions from fossil fuel combustion during the year *y*; t CO_2 (derived from application of CDM tool *Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities*; calculations are done for each stratum *i*)
i	1, 2, 3 …M_{WPS} strata in the project scenario
t	1, 2, 3, … *t** years elapsed since the project start date

The tool has been designed for A/R CDM project activities, but must be used for the purposes of this methodology, noting the following:

Where the tool refers to:	It must be understood as referring to:
A/R	WRC
CDM	VCS
DOE	VVB

8.3 Emission reductions due to rewetting and fire management (Fire Reduction Premium)

This methodology addresses the emission reductions generated from reduced anthropogenic fires occurring in drained organic soils due to rewetting and fire management. Emission reductions are estimated using a conservative default factor which is based on fire occurrence and extension in the project area in the baseline scenario. This method avoids the need for direct assessment of GHG emissions from fire in the baseline and the project scenarios. The project proponent must apply the latest version of VCS module *VMD0046 Methods for monitoring soil carbon stock changes and GHG emissions in WRC project activities* to estimate of the *Fire Reduction Premium* (*FRP*).

For each stratum with organic soil to which the project proponent applies the approach, the parameters $E_{peatsoil\text{-}WPS,i,t}$ (Greenhouse gas emissions from the peat soil within the project boundary in the project scenario in stratum *i* in year *t* (t CO_2e yr^{-1})) and $E_{peatsoil\text{-}BSL,i,,t}$ (GHG emissions from microbial decomposition of the peat soil within the project boundary in the baseline scenario in stratum *i* in year *t* (t CO_2e yr^{-1})) in the module are obtained from $GHG_{WPS\text{-}soil,i,t}$ and $GHG_{BSL\text{-}soil,i,t}$.

8.4 Leakage

8.4.1 Activity-shifting leakage and market leakage

The applicability conditions of this methodology are structured to ensure that activity-shifting leakage and market leakage do not occur. As such, where the applicability conditions of this methodology are met, activity-shifting leakage and market leakage may be assumed to be zero.

8.4.2 Ecological leakage

It may be assumed that ecological leakage does not occur in projects meeting the applicability conditions of this methodology, because projects must be designed in a manner which ensures that their hydrological connectivity with adjacent areas does not lead to a significant increase in GHG emissions outside the project area. This may be achieved by a project design which causes no alteration of mean annual water table depths or flooding frequency or duration in adjacent areas, or limiting such alteration to levels that do not influence GHG emissions. Where, at the design stage, hydrological changes are expected to impact GHG emissions in areas outside the project area, the project design must be adjusted to include such areas in the project area.

The project proponent must demonstrate that their project design meets these requirements through expert judgment, hydrologic modeling or monitoring of alterations of water table depth at the project area. In tidal wetland restoration projects, de-watering downstream wetlands is not expected if project areas are set sufficiently large to include expected areas of changed hydrology.

Hydrologic models must consider water displacement from project activities and the hydrologic connection or blockage of inlets that would change the wetland boundary. Procedures for monitoring alterations of water table depth at the project area are provided in Section 9.3.4.

The tidal range and sediment delivery experienced by wetlands outside the project area must remain within the system tolerance, which is defined by the high and low tides and regional sediment budget, and assessed using hydrological models (and/or empirical analysis) and expert judgment.

To guide this assessment, Table 8.1 outlines avoidance criteria related to a variety of processes that may occur outside the project area due to an inappropriate project design.

Table 8.1 Processes Associated with Ecological Leakage Outside Project Boundary and Related Criteria for their Avoidance

Ecological leakage process outside project boundary	Avoidance criterion
Lowering water table that causes increased soil carbon oxidation	Maintain wetland conditions (eg, converting from impounded water to a wetland does not cause soil oxidation)
Lowering water table that causes increased N_2O emissions	No conversion of non-seagrass wetland to open water
Raising water table that causes increased CH_4 emissions	No conversion of non-wetland to wetland

Raising water table that causes decreased vegetation production that causes decreased new soil carbon sequestration	No causation of vegetated to non-vegetated (or poorly vegetated) conditions

Projects meeting the requirements of this Section 8.4 may assume that GHG_{LK} = 0.

8.5 Net GHG Emission Reduction and Removals

8.5.1 Calculation of net GHG emissions reductions

The total net GHG emission reductions from the RWE project activity are calculated as follows:

$$NER_{RWE} = GHG_{BSL} - GHG_{WPS} + FRP - GHG_{LK} \quad \textbf{(66)}$$

Where:

NER_{RWE}	Net CO_2e emission reductions from the RWE project activity; t CO_2e
GHG_{BSL}	Net CO_2e emissions in the baseline scenario; t CO_2e
GHG_{WPS}	Net CO_2e emissions in the project scenario; t CO_2e
FRP	*Fire Reduction Premium* (net CO_2e emission reductions from organic soil combustion due to rewetting and fire management); t CO_2e
GHG_{LK}	Net CO_2e emissions due to leakage; t CO_2e

Long-term benefit in WRC projects

For projects claiming reductions of baseline GHG emissions, the maximum quantity of GHG emission reductions that may be claimed from the SOC pool is limited to the difference between the organic soil carbon stock in the project scenario and baseline scenario after a 100-year time frame. Procedures for estimating this difference in stratum *i* at *t* = 100 ($C_{WPS\text{-}BSL,i,t100}$) are provided in Section 5.2.4. The component $GHG_{BSL\text{-}soil\text{-}CO2,i,t}$ - $GHG_{WPS\text{-}soil\text{-}CO2,i,t}$ within equation 61 must be capped as follows:

$$GHG_{BSL-soil-CO2,i,t} - GHG_{WPS-soil-CO2,i,t} \le \frac{44}{12} \times C_{WPS-BSL,t100} \quad \textbf{(67)}$$

Where:

$GHG_{BSL\text{-}soil\text{-}CO2,i,t}$	CO_2 emissions from the SOC pool in the baseline scenario in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}
$GHG_{WPS\text{-}soil\text{-}CO2,i,t}$	CO_2 emissions from the SOC pool in the project scenario in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}
$C_{WPS\text{-}BSL,t100}$	Difference between organic soil carbon stock in the project scenario and baseline scenario at *t*=100; t C ha^{-1}

Note also that NER_{RWE} must be corrected for uncertainty by estimating the total uncertainty for the RWE project activity (NER_{RWE_ERROR}) using the procedures set out in Section 8.5.2 below.

8.5.2 Estimation of uncertainty

The following procedure allows the project proponent to estimate uncertainty in the estimation of emissions and carbon stock changes (ie, for calculating a precision level and any deduction in credits for lack of precision following project implementation and monitoring) by assessing uncertainty in baseline and project estimations.

This procedure focuses on the following sources of uncertainty:

- Uncertainty associated with estimation of stocks in carbon pools and changes in carbon stocks
- Uncertainty in assessment of project emissions

Where an uncertainty value is not known or cannot be calculated, the project proponent must justify that it is using a conservative number and an uncertainty of 0 percent may be used for this component.

Uncertainty guidance

A precision target of a 90 percent or 95 percent confidence interval equal to or less than 20 percent or 30 percent, respectively, of the recorded value must be targeted. This is especially important in terms of project planning for measurement of carbon stocks where sufficient measurement plots should be included to achieve this precision level across the measured stocks.

Levels of uncertainty must be known for all aspects of baseline and project implementation and monitoring. Uncertainty will generally be known as the 90 percent or 95 percent confidence interval expressed as a percentage of the mean. Where uncertainty is not known, it must be demonstrated that the value used is conservative.

Estimated carbon emissions and removals arising from AFOLU activities have uncertainties associated with the measures and estimates of several parameters. These include the project area or other activity data, carbon stocks, biomass growth rates, expansion factors and other coefficients. It is assumed that the uncertainties associated with the estimates of the various input data are available, either as default factors given in IPCC Guidelines (2006), IPCC GPG-LULUCF (2003), expert judgment or estimates based of sound statistical sampling.

Alternatively, conservative estimates may also be used instead of uncertainties, provided that they are based on verifiable literature sources or expert judgment. In this case the uncertainty is assumed to be zero. However, these procedures combine uncertainty information and conservative estimates resulting in an overall *ex-post* project uncertainty.

Planning to diminish uncertainty

It is important that the process of project planning consider uncertainty. Procedures including stratification and the allocation of sufficient measurement plots help ensure that low uncertainty in carbon stocks results and ultimately full crediting can result.

It is good practice to apply this procedure at an early stage to identify the data sources with the highest uncertainty to allow the opportunity to conduct further work to diminish uncertainty.

Note that in Parts 1 – 3 below the denominators of the equations must be expressed in absolute values.

Part 1 – Uncertainty in baseline estimates

$$Uncertain_{BSL,i} = \frac{\sqrt{\left(U_{BSL,SS1,i} * E_{BSL,SS1,i}\right)^2 + \left(U_{BSL,SS2,i} * E_{BSL,SS2,i}\right)^2 ... + ...\left(U_{BSL,SSn,i} * E_{BSL,SSn,i}\right)^2}}{E_{BSL,SS1,i} + E_{BSL,SS2,i} ... + ...E_{BSL,SSn,i}} \quad \textbf{(68)}$$

Where:

$Uncertain_{BSL,i}$	Percentage uncertainty in the combined carbon stocks and GHG sources in the baseline scenario in stratum *i*; %
$U_{BSL,SS,i}$	Percentage uncertainty (expressed as 90 percent confidence interval as a percentage of the mean, where appropriate) for carbon stocks and GHG sources in the baseline scenario in stratum *i* (1,2…n represent different carbon pools and/or GHG sources); %
$E_{BSL,SS,i}$	Carbon stock or GHG sources (eg, trees, down dead wood) in stratum *i* (1,2…n represent different carbon pools and/or GHG sources) in the baseline scenario; t CO_2e
i	1, 2, 3 …M_{BSL} strata in the baseline scenario

To assess uncertainty across combined strata, use the equation below:

$$Uncertain_{BSL} = \frac{\sqrt{\left(U_{BSL,1} * A_1\right)^2 + \left(U_{BSL,2} * A_2\right)^2 ... + ...\left(U_{BSL,M_{BSL}} * A_{M_{BSL}}\right)^2}}{A_1 + A_2 ... + ...A_{M_{BSL}}} \quad \textbf{(69)}$$

Where:

$Uncertain_{BSL}$	Total uncertainty in baseline scenario; %
$U_{BSL,i}$	Uncertainty in baseline scenario in stratum *i*; %
A_i	Area of stratum *i*; ha
i	1, 2, 3 …M_{BSL} strata in the baseline scenario

Part 2 – Uncertainty ex-post in the project scenario

$$Uncertain_{WPS,i} = \frac{\sqrt{\left(U_{WPS,SS1,i} * E_{WPS,SS1,i}\right)^2 + \left(U_{WPS,SS2,i} * E_{WPS,SS2,i}\right)^2 ... + ...\left(U_{WPS,SSn,i} * E_{WPS,SSn,i}\right)^2}}{E_{WPS,SS1,i} + E_{WPS,SS2,i} ... + ... E_{WPS,SSn,i}} \quad \textbf{(70)}$$

Where:

$Uncertain_{WPS,i}$	Percentage uncertainty in the combined carbon stocks and GHG sources in the project scenario in stratum *i*; %
$U_{WPS,SS,i}$	Percentage uncertainty (expressed as 90 percent confidence interval as a percentage of the mean, where appropriate) for carbon stocks and GHG sources in the project scenario in stratum *i* (1,2…n represent different carbon pools and/or GHG sources); %
$E_{WPS,SS,i}$	Carbon stock or GHG sources (eg, trees, down dead wood, etc.) in stratum *i* (1,2…n represent different carbon pools and/or GHG sources) in the project scenario; t CO_2e
i	1, 2, 3 …M_{WPS} strata in the project scenario

To assess uncertainty across combined strata, use the equation below:

$$Uncertain_{WPS} = \frac{\sqrt{\left(U_{WPS,1} * A_1\right)^2 + \left(U_{WPS,2} * A_2\right)^2 ... + ...\left(U_{WPS,M_{BSL}} * A_{M_{BSL}}\right)^2}}{A_1 + A_2 ... + ... A_{M_{BSL}}} \quad \textbf{(71)}$$

Where:

$Uncertain_{WPS}$	Total uncertainty in project scenario; %
$U_{WPS,i}$	Uncertainty in project scenario in stratum *i*; %
A_i	Area of stratum *i*; ha
i	1, 2, 3 …M_{WPS} strata in the project scenario

Part 3 – Total error in project activity

$$NER_{ERROR} = \frac{\sqrt{(Uncertain_{BSL} \times GHG_{BSL})^2 + (Uncertain_{WPS} \times GHG_{WPS})^2}}{GHG_{BSL} + GHG_{WPS}} \quad \textbf{(72)}$$

Where:

NER_{ERROR}	Total uncertainty for project activity; %
$Uncertain_{BSL}$	Total uncertainty in baseline scenario; %
$Uncertain_{WPS}$	Total uncertainty in the project scenario; %
GHG_{BSL}	Net CO_2e emissions in the baseline scenario up to year *t**; t CO_2e
GHG_{WPS}	Net CO_2e emissions in the project scenario up to year *t**; t CO_2e

The allowable uncertainty is 20 percent or 30 percent of NER_t at a 90 percent or 95 percent confidence level, respectively. Where this precision level is met, no deduction must result for uncertainty. Where this precision level is exceeded, a deduction equal to the amount that the uncertainty exceeds the allowable level must be applied. The adjusted value for NER_t to account for uncertainty must be calculated as:

$$adjusted\_NER_t = NER_t \times (100\% - NER_{ERROR} + allowable\_uncert) \quad \textbf{(73)}$$

Where:

$adjusted\_NER_t$	Net GHG emission reductions in year *t* adjusted to account for uncertainty; t CO_2e
NER_t	Total net GHG emission reductions from the project activity up to year *t*; t CO_2e
NER_{ERROR}	Total uncertainty for WRC project activity; %
allowable_unsert	Allowable uncertainty; 20 percent or 30 percent at a 90 percent or 95 percent confidence level, respectively; %

8.5.3 Calculation of Verified Carbon Units

In order to calculate the number of Verified Carbon Units (VCUs) that may be issued, the project proponent must consider the number of buffer credits which must be deposited in the AFOLU pooled buffer account. The number of buffer credits which must be deposited in the AFOLU pooled buffer account is based on the net change in carbon stocks.

The number of verified carbon units (VCUs) is calculated as:

$$VCU_{t2} = \left(adjusted\_NER_{t2} - adjusted\_NER_{t1}\right) - Bufferw_{t2} \quad \textbf{(74)}$$

Where:

VCU_{t2}	Number of VCUs in year *t2*
$adjusted\_NER_{t1}$	Total net GHG emission reductions from the project activity up to year *t1* adjusted to account for uncertainty; t CO_2e
$adjusted\_NER_{t2}$	Total net GHG emission reductions from the project activity up to year *t2* adjusted to account for uncertainty; t CO_2e
$Bufferw_{t2}$	Number of buffer credits to be contributed to the AFOLU pooled buffer account in year *t2*

$$Bufferw_{t2} = \left(NER_{stock,t2} - NER_{stock,t1}\right) \times Buffer\%_{t2} \quad \textbf{(75)}$$

Where:

$Bufferw_{t2}$	Number of buffer credits to be contributed to the AFOLU pooled buffer account in year *t2*
$NER_{stock,\ t1}$	Net GHG emission reductions from the project activity up to year *t1*, discarding

non-CO_2 emissions from soil and biomass burning and emissions from fossil fuel use; t CO_2e

$NER_{stock,\ t2}$ Net GHG emission reductions from the project activity up to year *t2*, discarding non-CO_2 emissions from soil and biomass burning and emissions from fossil fuel use; t CO_2e

$Buffer\%_{t2}$ Percentage of buffer credits to be contributed to the AFOLU pooled buffer account in year *t2*; %

The percentage of buffer credits to be contributed to the AFOLU pooled buffer account must be determined by applying the latest version of the *VCS AFOLU Non-Permanence Risk Tool*.

9 MONITORING

9.1 Data and Parameters Available at Validation

Data / Parameter	$Depth_{peat,i,t0}$
Data unit	m
Description	Average organic soil depth above the drainage limit in stratum *i* at the project start date; m
Equations	1, 7, 8
Source of data	Direct measurement or literature involving the project area or similar areas
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Organic soil depths at the project start date may be derived from: • Surface height measurements relative to a fixed reference point in m asl (eg, using poles fixed in the underlying mineral soil or rock) within the project area; where relevant in combination with gauge measurement of the water table to determine the drainage limit • Literature involving the project area or similar areas
Purpose of data	Calculation of baseline emissions Calculation of the maximum quantity of GHG emission reductions that may be claimed by the project
Comments	Reassessed when baseline is reassessed

Data / Parameter	$Rate_{peatloss\text{-}BSL,i}$
Data unit	m yr^{-1}
Description	Rate of organic soil loss due to subsidence and fire in the baseline scenario in stratum *i*

Equations	1, 7, 13
Source of data	The rate of organic soil loss due to subsidence must be based on verifiable information and may be derived from: 1) Expert judgment, datasets and/or literature of historic subsidence involving the project or similar areas. Data must be based on surface height measurements relative to a fixed reference point in m asl, following methods described in Ballhorn *et al*. 2009 (eg, using poles fixed in the underlying mineral soil or rock, or by remote sensing) or similar. Or 2) CO_2 emissions derived from GHG emission proxies (see Section 8.1.4.2.1 above) in combination with data on volumetric carbon content of the organic soil. Divide the annual CO_2 emission (t CO_2 ha^{-1}) by 44/12, then divide by volumetric carbon content (g C cm^{-3}) to obtain height loss in m. The average depth of burn scars may be derived from expert judgment, datasets and/or literature of historic burn depths involving the project or similar areas. Data must be based on surface height measurements, using field measurements or remote sensing (eg, following methods described in Ballhorn *et al*. 2009). The areal extent of burn scars may be obtained from statistics and/or maps in official reports and/or field measurements or remote sensing data. For organic soil loss due to fire, based on the areal extent of burnt and non-burnt areas, a mean annualized burn depth must be calculated and applied to the entire project area. The project proponent must demonstrate, using expert judgment, datasets and/or scientific literature that the accuracy of the derived rate of organic soil loss is sufficient to fulfill the criteria set out in Section 5.2.2 (Stratification). Similarity of areas must be demonstrated (via direct measurements, literature resources, datasets or a combination of these) with respect to organic soil type, climatic conditions, land use (forestry, agriculture, peat extraction, or abandonment after these activities), and average annual water table depth (±20 percent). In case of dissimilarity, the project proponent must demonstrate that such difference gives a conservative result for the net GHG benefits of the project. Forecasting organic soil subsidence rates must be based on the conservative extrapolation of a historic trend, or conservative modeling of proxies such as water table depth and land use type.

Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Source of data above
Purpose of data	Calculation of baseline emissions Calculation of the maximum quantity of GHG emission reductions that may be claimed by the project
Comments	In the absence of an accurate value for the determination of PDT, a conservative (high) value may be applied, while for the determination of the maximum quantity of GHG emission reductions which may be claimed from the soil carbon pool, a conservative (low) value may be applied that remains constant over time. The use of a relatively low value for a constant rate of organic soil loss may not be confused with a relatively high value when determining the need for stratification of organic soil depth. Reassessed when baseline is reassessed

Data Unit / Parameter	$Rate_{peatloss\text{-}WPS,i,t}$
Data unit	m yr^{-1}
Description	Rate of organic soil loss due to subsidence in the project scenario in stratum *i* in year *t*
Equations	8
Source of data	The rate of organic soil loss due to subsidence must be based on verifiable information and may be derived from: 1) Expert judgment, datasets and/or literature of subsidence involving areas representing conditions similar to the project. Data must be based on surface height measurements relative to a fixed reference point in m asl, following methods described in Ballhorn *et al*. 2009 (eg, using poles fixed in the underlying mineral soil or rock, or by remote sensing or similar). Or 2) CO_2 emissions derived from GHG emission proxies, see Section 8.1.4.2.1 above, in combination with data on volumetric carbon content of the organic soil. Divide the annual CO_2 emission (t CO_2 ha^{-1}) by 44/12, then divide by volumetric carbon content (g C cm^{-3}) to obtain height loss in m. The project proponent must demonstrate, using expert judgment,

	datasets and/or scientific literature that the accuracy of the derived rate of organic soil loss is sufficient to fulfill the criteria set out in Section 5.2.2 (Stratification). Similarity of areas must be demonstrated (by direct measurements, literature resources, datasets or a combination of these) with respect to organic soil type, climatic conditions, land use (forestry, agriculture, peat extraction, or abandonment after these activities), and average annual water table depth (±20 percent). In case of dissimilarity, the project proponent must demonstrate that such difference gives a conservative result for the net GHG benefits of the project.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Source of data above
Purpose of data	Calculation of project emissions Calculation of the maximum quantity of GHG emission reductions that may be claimed by the project
Calculation method	N/A
Comments	In the absence of an accurate value, for the determination of the maximum quantity of GHG emission reductions which may be claimed from the soil carbon pool, a conservative (high) value may be applied that remains constant over time. Reassessed when baseline is reassessed

Data / Parameter	$Rate_{Closs\text{-}BSL,i,t}$
Data unit	t C ha^{-1} yr^{-1}
Description	Rate of organic carbon loss in mineral soil due to oxidation in the baseline scenario in stratum *i* in year *t*
Equations	2, 9, 15
Source of data	May be estimated using published values (see Sections 8.1.4.1 and 8.1.4.2.2) or either historical data collected from the project site or chronosequence data collected at similar sites (see Sections 8.1.4.1 and 8.1.4.2.6). Alternatively, a conservative (low) value may be applied that remains constant over time.
Value applied	N/A

Justification of choice of data or description of measurement methods and procedures applied	Extrapolation of $Rate_{Closs-BSL,i}$ over the entire project crediting period must account for the possibility of a non-linear decrease of soil organic carbon over time, including the tendency of organic carbon concentrations to approach steady-state equilibrium (see Section 5.1)
Purpose of data	Calculation of baseline emissions Calculation of the maximum quantity of GHG emission reductions that may be claimed by the project
Comments	In the absence of an accurate value for the determination of the SDT, a conservative (high) value may be applied, while for the determination of the maximum quantity of GHG emission reductions which may be claimed from the soil carbon pool, a conservative (low) value may be applied that remains constant over time. Reassessed when baseline is reassessed

Data / Parameter	$Rate_{Closs-WPS,i,t}$
Data unit	t C ha^{-1} yr^{-1}
Description	Rate of organic carbon loss in mineral soil due to oxidation in the project scenario in stratum *i* in year *t*
Equations	16
Source of data	N/A
Value applied	0
Justification of choice of data or description of measurement methods and procedures applied	This value is conservatively set to zero as loss rates are likely to be negative. The value must be reassessed when the baseline is reassessed. If at that event there is evidence that SOC has decreased, the calculation must be adjusted using the carbon loss rate to date, unless it can be justified that the carbon loss was temporary.
Purpose of data	Calculation of project emissions Calculation of the maximum quantity of GHG emission reductions that may be claimed by the project
Comments	Reassessed when baseline is reassessed

Data / Parameter	$\Delta C_{TREE\_BSL,t}$
Data unit	t CO_2-e yr^{-1}
Description	Change in carbon stock in baseline tree biomass within the project

	area in year *t*
Equations	23
Source of data	Derived from application of *AR-Tool14*
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	N/A
Purpose of data	Calculation of baseline emissions
Comments	Calculations are done for each stratum *i* Reassessed when baseline is reassessed

Data / Parameter	$\Delta C_{SHRUB\_BSL,t}$
Data unit	t CO_2-e yr^{-1}
Description	Change in carbon stock in baseline shrub biomass within the project area in year *t*
Equations	23
Source of data	Derived from application of *AR-Tool14*
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	N/A
Purpose of data	Calculation of baseline emissions
Comments	Calculations are done for each stratum *i* Reassessed when baseline is reassessed

Data / Parameter	$Rate_{subs\text{-}BSL,i}$
Data unit	m yr^{-1}
Description	Rate of organic soil loss due to subsidence in the baseline scenario in stratum *i*
Equations	28
Source of data	The rate of organic soil loss due to subsidence must be based on verifiable information and may be derived from:

	1) Expert judgment, datasets and/or literature of historic subsidence involving the project or similar areas. Data must be based on surface height measurements relative to a fixed reference point in m asl, following methods described in Ballhorn *et al*. 2009 (eg, using poles fixed in the underlying mineral soil or rock, or by remote sensing) or similar. Or 2) CO_2 emissions derived from GHG emission proxies, see Section 8.1.4.2.1 above, in combination with data on volumetric carbon content of the organic soil. Divide the annual CO_2 emission (t CO_2 ha^{-1}) by 44/12, then divide by volumetric carbon content (g C cm^{-3}) to obtain height loss in m. The average depth of burn scars may be derived from expert judgment, datasets and/or literature of historic burn depths involving the project or similar areas. Data must be based on surface height measurements, using field measurements or remote sensing (eg, following methods described in Ballhorn *et al*. 2009). The areal extent of burn scars may be obtained from statistics and/or maps in official reports and/or field measurements or remote sensing data. The project proponent must demonstrate, using expert judgment, datasets and/or scientific literature that the accuracy of the derived rate of organic soil loss is sufficient to fulfill the criteria set out in Section 5.2.2 (Stratification). Similarity of areas must be demonstrated (via direct measurements, literature resources, datasets or a combination of these) with respect to organic soil type, climatic conditions, land use (forestry, agriculture, peat extraction, or abandonment after these activities), and average annual water table depth (±20 percent). In case of dissimilarity, the project proponent must demonstrate that such difference gives a conservative result for the net GHG benefits of the project. Forecasting organic soil subsidence rates must be based on the conservative extrapolation of a historic trend, or conservative modeling of proxies such as water table depth and land use type.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Source of data above and Couwenberg & Hooijer (2013).
Purpose of data	Calculation of baseline emissions

Comments	In the absence of an accurate value, for the determination of subsidence a conservative (low) value may be applied. Reassessed when baseline is reassessed

Data / Parameter	$C_{BSL\text{-}soil,i,t}$
Data unit	t C ha^{-1}
Description	Soil organic carbon stock in the baseline scenario in stratum *i* in year *t*
Equations	29
Source of data	Soil coring may be used to generate a value of $C_{BSL\text{-}soil,i,t}$ as specified in Section 9.3.7
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	For the baseline scenario, soil cores must be collected within 2 years prior to the project start date. Where using an installed reference plane for the baseline scenario, it must have been installed at least 4 years prior to the baseline measurement, which is good practice to ensure that a reliable average accumulation rate is obtained.
Purpose of data	Calculation of baseline emissions
Comments	Reassessed when baseline is reassessed

Data / Parameter	$Depth_{soil,i,t0}$
Data unit	m
Description	Average mineral soil depth in stratum *i* at the project start date
Equations	11
Source of data	Direct measurements and/or literature involving the project area or similar areas
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Mineral soil depths at the project start date may be derived from direct measurements within the project area or literature involving the project area or similar areas
Purpose of data	Calculation of baseline emissions Calculation of the maximum quantity of GHG emission reductions

	that may be claimed by the project
Comments	N/A

Data / Parameter	*VC*
Data unit	kg C m^{-3}
Description	Volumetric organic carbon content of organic or mineral soil
Equations	5, 6, 11, 13, 14, 15, 16
Source of data	Direct measurements and/or literature involving the project area or similar areas
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Determined through procedures specified in Section 9.3.7
Purpose of data	Calculation of baseline emissions Calculation of project emissions Calculation of the maximum quantity of GHG emission reductions that may be claimed by the project
Comments	

Data / Parameter	$A_{BSL,i}$ (or $A_{i,t}$)
Data unit	ha
Description	Area of baseline stratum *i* (in year *t*)
Equations	4, 12, (25, 61, 63, 64)
Source of data	Delineation of strata is done preferably using a Geographical Information System (GIS), which allows for integrating data from different sources (including GPS coordinates and remote sensing data).
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Source of data above
Purpose of data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	$C_{BSL\text{-}herb,i,t}$
Data unit	t C ha^{-1}
Description	Carbon stock in herbaceous vegetation in the baseline scenario in stratum *i* in year *t*
Equations	22, 24
Source of data	Direct measurements or default factor
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	A default factor[23] of 3 t C ha^{-1} may be applied for strata with 100 percent herbaceous cover. For areas with a vegetation cover <100 percent, a 1:1 relationship between vegetation cover and $C_{BSL,\text{-}herb,i,t}$ must be applied. The default may be claimed for one year only during the project crediting period as herbaceous biomass quickly reaches a steady state. Vegetation cover must be determined by commonly used techniques in field biology. Procedures for measuring carbons stocks in herbaceous vegetation are provided in Section 9.3.6 above.
Purpose of data	Calculation of baseline emissions
Comments	Reassessed when baseline is reassessed

Data / Parameter	*%OM* (or $\%OM_{soil}$)
Data unit	%
Description	Percentage of soil organic matter
Equations	33, 34, 36, 38, 76, 77, 78, 79
Source of data	Direct measurements based on loss-on-ignition or may be derived from direct measurements of soil carbon. These measurements may be made using samples collected in Section 9.3.7 or indirectly from the soil carbon percentage as described in Section 8.1.4.3.
Value applied	N/A

[23] Calculated from peak aboveground biomass data from 20 sites summarized in Mitsch & Gosselink. The median of these studies is 1.3 t d.m. ha^{-1}. This was converted to the default factor value as follows: 1.3 × 0.45 × 0.5 × 10. The factor 0.45 converts organic matter mass to carbon mass; the factor 0.5 is a factor that averages annual peak biomass (factor = 1) and annual minimum biomass (factor = 0, assuming ephemeral aboveground biomass and complete litter decomposition.

Justification of choice of data or description of measurement methods and procedures applied	The equations provided were developed for tidal marsh soils by Craft *et al*. 1991 and for mangrove soils by Allen 1974
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comments	N/A

Data / Parameter	$\%C_{soil}$
Data unit	%
Description	Percentage of soil organic C
Equations	33, 37, 39
Source of data	Direct measurements or may be derived from direct measurements of soil organic matter. These measurements may be made using samples collected in Section 9.3.7 or indirectly from the soil organic matter percentage determined through loss-on-ignition as described in Section 9.3.6.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Source of data above
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comments	N/A

Data / Parameter	*BD*
Data unit	kg m^{-3}
Description	Dry bulk density
Equations	80
Source of data	Direct measurements or, for the determination of allochthonous carbon, may be derived from soil carbon percentage as described in Section 8.1.4.3.
Value applied	N/A
Justification of choice of data or description of	Mass of soil material after drying to removed water per volume of soil material

measurement methods and procedures applied	
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comments	N/A

Data / Parameter	$\%OM_{depsed}$
Data unit	%
Description	Percentage of organic matter in deposited sediment
Equations	34, 38, 40
Source of data	May be estimated directly using loss-on-ignition (LOI) data, indirectly from soil carbon percentage as described in Section 8.1.4.3, or from the default value provided in Section 8.1.4.3. These measurements may be made using samples collected on sediment tiles or through collection and carbon analysis (see Section 9.3.7) of suspended sediments in tidal channels or sediments deposits in tidal flats.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	LOI may be assessed using standard laboratory procedures
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comments	N/A

Data / Parameter	$\%C_{depsed}$
Data unit	%
Description	Percentage of carbon in deposited sediment; %
Equations	38, 40
Source of data	May be estimated directly using loss-on-ignition (LOI) data or indirectly from soil carbon percentage as described in Section 8.1.4.3. These measurements may be made using samples collected on sediment tiles or through collection and carbon analysis (see

	Section 9.3.7) of suspended sediments in tidal channels or sediments deposits in tidal flats.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	The default factor is derived from the maximum value (conservative) provided by Andrews *et al.* 2011
Purpose of data	Calculation of baseline emissions Calculation of project emissions
Comments	N/A

Data / Parameter	$EF_{N2O,burn}$
Data unit	g N_2O / kg dry biomass
Description	Emission factor for N_2O emissions from vegetation burning
Equations	63
Source of data	The project proponent may use factors that have been determined for grassland vegetation. A suitable EF_{N2O} value is 0.21, from Table 2.5 of the 2006 IPCC Guidelines for National Greenhouse Inventories.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Nitrous oxide emission factors for the combustion of herbaceous wetland vegetation are not currently available in scientific literature. However, these emissions are expected to be similar to those for grassland vegetation.
Purpose of data	Calculation of project emissions
Comments	N/A

Data / Parameter	$EF_{CH4,burn}$
Data unit	g CH_4 / kg dry biomass
Description	Emission factor for CH_4 emissions from vegetation burning
Equations	64
Source of data	The project proponent may use factors that have been determined for grassland vegetation. A suitable EF_{CH4} value is 2.3, from Table 2.5 of the 2006 IPCC Guidelines for National Greenhouse Inventories.
Value applied	N/A

Justification of choice of data or description of measurement methods and procedures applied	Methane emission factors for the combustion of herbaceous wetland vegetation are not currently available in scientific literature. However, these emissions are expected to be similar to those for grassland vegetation.
Purpose of data	Calculation of project emissions
Comments	N/A

Data / Parameter	*allowable_uncert*
Data unit	%
Description	Allowable uncertainty; 20 percent or 30 percent at a 90 percent or 95 percent confidence level, respectively
Equations	73
Source of data	N/A
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	N/A
Purpose of data	Calculation of net GHG emissions reductions
Comments	N/A

Data / Parameter	$V_{ex,ty,i,t}$
Data unit	m^3
Description	Volume of timber extracted from within stratum *i* (does not include slash left onsite) by species *j* and wood product class *ty* in year *t*
Equations	83
Source of data	Data representing common practice in harvesting
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This volume does not include logging slash left onsite. The project proponent should also make sure that extracted volumes are gross volumes removed (ie, not already discounting for estimated wood waste). Assignment of volume extracted to wood product class(es), must be substantiated on the basis of participatory rural appraisal (PRA) findings or records of timber sales. Assignment of volume extracted to species, must be substantiated on the basis of either PRA findings, harvest records, or a commercial

	inventory.
Purpose of Data	Calculation of project emissions
Comments	N/A

Data / Parameter	D_j
Data unit	t d.m. m^{-3}
Description	Basic wood density in t d.m. m^{-3} for species *j*
Equations	83
Source of data	The source of data shall be chosen with priority from higher to lower preference as follows: (a) National species-specific or group of species-specific (eg, from National GHG inventory); (b) Species-specific or group of species-specific from neighboring countries with similar conditions. Sometimes (b) may be preferable to (a); (c) Global species-specific or group of species-specific (eg, IPCC 2006 INV GLs AFOLU Chapter 4 Tables 4.13 and 4.14). Species-specific wood densities may not always be available, and may be difficult to apply with certainty in the typically species rich forests of the humid tropics, hence it is acceptable practice to use wood densities developed for forest types or plant families or species groups.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Where using wood densities developed outside of the project country (cases (b) and (c) above under Source of data), wood densities must be validated with either limited destructive sampling or direct measurement of wood hardness (eg, with a Pilodyn wood tester) in the field and correlating with wood density. Samples or measurements should be from 20-30 trees. For validation of mean forest type or species group wood densities, representation of species in the sample should be proportional to their occurrence in terms of basal area or volume in the project area (not abundance or stem density). Samples should provide representation across the length of the tree. Wood samples are cut in discs and thickness and diameter measured to calculate green volume. Samples are oven dried (105° C) to a constant weight in the laboratory, and density calculated as dry weight (g) per unit green volume (cm^3). If the density of the samples/measurements (or mean density in the

	case of forest type or species group means) is within ±10 percent of the selected density values, then the selected density values may be used. Otherwise, a new density value must be developed with more extensive sampling, using the validation samples as a base. Where new species are encountered in the course of monitoring, new wood density values must be sourced from the literature and validated, if necessary, as per requirements and procedures above.
Purpose of Data	Calculation of project emissions
Comments	N/A

Data / Parameter	CF_j
Data unit	t C t-1 d.m.
Description	Carbon fraction of dry matter in t C t^{-1} d.m. for species *j*
Equations	83
Source of data	Species- or family-specific values from the literature (eg, IPCC 2006 INV GLs AFOLU Chapter 4 Table 4.3) shall be used if available, otherwise default value of 0.47 t C t^{-1} d.m. can be used.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	N/A
Purpose of Data	Calculation of project emissions
Comments	N/A
Data / Parameter	WW_{ty}
Data unit	dimensionless
Description	Fraction of extracted biomass effectively emitted to the atmosphere during production by class of wood product *ty*
Equations	84
Source of data	The source of data is the published paper of Winjum *et al*. 1998[24]
Value applied	Winjum *et al*. 1998 indicate that the proportion of extracted biomass that is oxidized (burning or decaying) from the production of commodities to be equal to 19 percent for developed countries, 24 percent for developing countries. *WW* is therefore equal to $C_{XB,ty}$

[24] Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284

	multiplied by 0.19 for developed countries and 0.24 for developing countries.
Justification of choice of data or description of measurement methods and procedures applied	Parameter values to be updated if new empirically-based peer-reviewed findings become available.
Purpose of Data	Calculation of project emissions
Comments	N/A

Data / Parameter	SLF_{ty}
Data unit	Dimensionless
Description	Fraction of wood products that will be emitted to the atmosphere within 5 years of production by class of wood product *ty*
Equations	84
Source of data	The source of data is the published paper of Winjum *et al*. 1998[25]
Value applied	Winjum *et al.* 1998 give the following proportions for wood products with short-term (<5 yr) uses after which they are retired and oxidized (applicable internationally): Sawnwood 0.2 Woodbase panels 0.1 Other industrial roundwood 0.3 Paper and Paperboard 0.4 The methodology makes the assumption that all other classes of wood products, and where wood product class *ty* is unknown, are 100 percent oxidized within 5 years. Therefore SLF, by wood product class, is equal to: Wood Product Class – SLF Sawnwood – 0.2 Woodbase panels – 0.1 Other industrial roundwood – 0.3 Paper and paperboard – 0.4 Other classes of wood products – 1.0
Justification of choice of	Parameter values to be updated if new empirically-based peer-

[25] Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284

data or description of measurement methods and procedures applied	reviewed findings become available.
Purpose of Data	Calculation of project emissions
Comments	N/A

Data / Parameter	OF_{ty}
Data unit	Dimensionless
Description	OF = Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years after production by class of wood product *ty*
Equations	84
Source of data	The source of data is the published paper of Winjum *et al*. 1998[26]
Value applied	Winjum *et al*. 1998 gives annual oxidation fractions for each class of wood products split by forest region (boreal, temperate and tropical). This methodology projects these fractions over 95 years to give the additional proportion (*OF* value) that is oxidized between the 5th and 100th years after initial harvest: <table><tr><th rowspan="2">Wood Product Class</th><th colspan="3">OF</th></tr><tr><th>Boreal</th><th>Temperate</th><th>Tropical</th></tr><tr><td>Sawnwood</td><td>0.36</td><td>0.60</td><td>0.84</td></tr><tr><td>Woodbase panels</td><td>0.60</td><td>0.84</td><td>0.97</td></tr><tr><td>Other industrial roundwood</td><td>0.84</td><td>0.97</td><td>0.99</td></tr><tr><td>Paper and paperboard</td><td>0.36</td><td>0.60</td><td>0.99</td></tr></table>
Justification of choice of data or description of measurement methods and procedures applied	Parameter values to be updated if new empirically-based peer-reviewed findings become available. Every 10 years, project proponents should review research findings to identify further refinements to the emission factors that are empirically-based and peer-reviewed.
Purpose of Data	Calculation of project emissions
Comments	N/A

[26] Winjum, J.K., Brown, S. and Schlamadinger, B. 1998. Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science* 44: 272-284

Data / Parameter	*BCEF*
Data unit	Dimensionless
Description	Biomass conversion and expansion factor for conversion of commercial wood volume per unit area to total aboveground tree biomass per unit area; note that BCEF as defined here, and in most applications, is not applied on a per stem basis
Equations	85
Source of data	Equations must have been derived using a wide range of measured variables (commercial wood volume per unit area and total aboveground biomass per unit area) based on datasets that comprise at least 30 trees. Equations must be based on statistically significant regressions and must have an r^2 that is ≥ 0.8. The source of data shall be chosen with priority from higher to lower preference as follows: (a) Existing local forest type-specific; (b) National forest type-specific or eco-region-specific (eg, from national GHG inventory); (c) Forest type-specific or eco-region-specific from neighboring countries with similar conditions. Sometimes (c) might be preferable to (b); (d) Global forest type or eco-region-specific (eg, IPCC 2006 INV GLs AFOLU Chapter 4 Table 4.5) The project volume data to which the selected BCEF is applied must conform to the data the BCEF was originally derived from, in particular, it must match forest type, stand structure, minimum DBH, and cover the range of potential independent variable values (commercial volumes) likely to be encountered in the project area. Care must be taken to ensure that the selected BCEF does not account for non-commercial species not represented in commercial volume estimates (ie, is restricted to expanding merchantable volumes to account for only non-merchantable tree components).
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Alternatively, BCEF, where not directly available, can be calculated as wood density (t dry mass m^{-3} green volume) × BEF (Biomass Expansion Factor = ratio of aboveground biomass to biomass of the commercial volume). If using BCEFs developed outside the project country (cases (c) and (d) above under Source of data), it is necessary to validate the applicability of BCEFs used. Validation is performed by: 1. Limited Measurements

	Select at least 20 plots in the project area covering a wide range of commercial volumes. Obtain tree measurements (e.g. DBH, height to a 10 cm diameter top) from which to calculate commercial volume and total biomass. Calculate commercial volume per unit area (e.g. using Smalian's formula) and total biomass per unit area (using the biomass equation(s) selected for application in CP-AB) for each plot Calculate BCEF for each plot (biomass (t) / commercial volume (m^3) Graph the plot-level estimates of BCEF versus commercial volume along with the BCEF equation (predicted) to be validated. If the estimated BCEFs of the measured plots are distributed both above and below the predicted value the BCEF equation may be used. The BCEF equation may also be used if the measured plots have a BCEF consistently lower than that predicted. If graphing the BCEF of the measured plots indicates a systematic bias to overestimation of BCEF (>75 percent of the plots below the predicted value) then another BCEF equation must be selected or developed anew.
Purpose of Data	Calculation of project emissions
Comments	N/A

Data / Parameter	$Pcom_{i,t}$
Data unit	Dimensionless
Description	Commercial volume as a percent of total aboveground volume in stratum *i* in year *t*
Equations	85
Source of data	The source of data shall be chosen with priority from higher to lower preference as follows: (a) Direct forest inventory of the project area, distinguishing commercially viable stocks on the basis of species and tree size, referencing local expert knowledge or a participatory rural assessment (PRA) of harvest practices and markets; (b) Forest inventory from a proxy area in the same region, representing the same forest type and age class, distinguishing commercially viable stocks on the basis of species and tree size, referencing local expert knowledge of harvest practices and markets National and forest type-specific or eco-region-specific (eg, from National GHG inventory).
Value applied	N/A

Justification of choice of data or description of measurement methods and procedures applied	N/A
Purpose of Data	Calculation of project emissions
Comments	N/A

9.2 Data and Parameters Monitored

Data Unit / Parameter	$Biomass_{i,t}$
Data unit	kg d.m. ha^{-1}
Description	Aboveground shrub biomass in stratum *i* in year *t*
Equations	63, 65
Source of data	Measured using field collected data at time of burning or conservatively estimated from data collected during a period with greater biomass within year *t*
Description of measurement methods and procedures to be applied	This value may be obtained from $B_{SHRUB,i,t}$ in *AR-Tool14* where $B_{SHRUB,i,t}$ (shrub biomass per hectare in shrub biomass stratum *i* at a given point of time in year *t*; t d.m. ha^{-1}) is quantified. Convert from t d.m. ha^{-1} to kg d.m. ha^{-1}.
Frequency of monitoring/recording	One time measurement for each burn event
QA/QC procedures to be applied	See Section 9.3.2
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	N/A

Data Unit / Parameter	$\Delta C_{TREE\_PROi,t}$
Data unit	t CO_2-e yr^{-1}
Description	Change in carbon stock in tree biomass in the project scenario in year *t*
Equations	57
Source of data	Derived from application of *AR-Tool14*
Description of measurement methods and procedures to be	See *AR-Tool14*

applied	
Frequency of monitoring/recording	See *AR-Tool14*
QA/QC procedures to be applied	See *AR-Tool14*
Purpose of data	Calculation of project emissions
Calculation method	See *AR-Tool14*
Comments	Calculations are done for each stratum *i*

Data Unit / Parameter	$\Delta C_{SHRUB\_PROi,t}$
Data unit	t CO_2-e yr^{-1}
Description	Change in carbon stock in shrub biomass in the project scenario in year *t*
Equations	57
Source of data	Derived from application of *AR-Tool14*
Description of measurement methods and procedures to be applied	See *AR-Tool14*
Frequency of monitoring/recording	See *AR-Tool14*
QA/QC procedures to be applied	See *AR-Tool14*
Purpose of data	Calculation of project emissions
Calculation method	See *AR-Tool14*
Comments	Calculations are done for each stratum *i*

Data / Parameter	$C_{WPS\text{-}herb,i,t}$
Data unit	t C ha^{-1}
Description	Carbon stock in herbaceous vegetation in the project scenario in stratum *i* in year *t*
Equations	56, 60
Source of data	Direct measurements or default factor
Value applied	N/A
Justification of choice of	A default factor of 3 t C ha^{-1} may be applied for strata with 100

data or description of measurement methods and procedures applied	percent herbaceous cover. For areas with a vegetation cover <100 percent, a 1:1 relationship between vegetation cover and $C_{WPS,\text{-}herb,i,t}$ must be. The default factor may be claimed for one year only during the project crediting period as herbaceous biomass quickly reaches a steady state. Vegetation cover must be determined by commonly used techniques in field biology. Procedures for measuring carbons stocks in herbaceous vegetation are specified in Section 9.3.6.
QA/QC procedures to be applied	See Section 9.3.2
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	N/A

Data / Parameter	$A_{WPS,i}$ (or $A_{i,t}$)
Data unit	ha
Description	Area of project stratum *i* (in year *t*)
Equations	3, 4, 12, (25, 61, 63, 64)
Source of data	Delineation of strata must be done preferably using a Geographical Information System (GIS), which allows for integrating data from different sources (including GPS coordinates and Remote Sensing data)
Justification of choice of data or description of measurement methods and procedures applied	See Source of data above
QA/QC procedures to be applied	See Section 9.3.2
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	N/A

Data / Parameter	$C_{WPS\text{-}soil,i,t}$
Data unit	t C ha^{-1}

Description	Carbon stock in the project scenario in stratum *i* in year *t*
Equations	Similar to 29
Source of data	Soil coring may be used to generate a value of $C_{WPS-soil,i,t}$ as specified in Section 9.3.7
Description of measurement methods and procedures to be applied	See Section 9.3.7
QA/QC procedures to be applied	See Section 9.3.2
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	N/A

Data / Parameter	$Rate_{subs-WPS,i}$
Data unit	m yr^{-1}
Description	Rate of organic soil loss due to subsidence in the project scenario in stratum *i*
Equations	Similar to 28
Source of data	The rate of organic soil loss due to subsidence must be based on verifiable information and may be derived from: 1) Data must be based on surface height measurements relative to a fixed reference point in m asl, following methods described in Ballhorn *et al*. 2009 (eg, using poles fixed in the underlying mineral soil or rock, or by remote sensing) or similar. Or 2) CO_2 emissions derived from GHG emission proxies, see Section 8.1.4.2.1 above, in combination with data on volumetric carbon content of the organic soil. Divide the annual CO_2 emission (t CO_2 ha^{-1}) by 44/12, then divide by volumetric carbon content (g C cm^{-3}) to obtain height loss in m. The average depth of burn scars may be derived from expert judgment, datasets and/or literature of historic burn depths involving the project or similar areas. Data must be based on surface height measurements, using field measurements or remote sensing (eg, following methods described in Ballhorn *et al*. 2009). The areal extent of burn scars may be obtained from statistics and/or maps in official reports and/or field measurements

	or remote sensing data.
Justification of choice of data or description of measurement methods and procedures applied	See *Source of data* above and Couwenberg & Hooijer (2013).
QA/QC procedures to be applied	See Section 9.3.2
Purpose of data	Calculation of project emissions
Calculation method	See Source of data above
Comments	Refer to procedures set out in Sections 8.1.4.2.1 – 8.1.4.2.6. For all equations in these sections, the subscript *BSL* must be substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario.

Data / Parameter	$C_{WPS\text{-}soil,i,t}$
Data unit	t C ha^{-1}
Description	Soil organic carbon stock in the project scenario in stratum *i* in year *t*
Equations	Similar to 29
Source of data	Soil coring may be used to generate a value of $C_{WPS\text{-}soil,i,t}$ *as* specified in Section 9.3.7
Justification of choice of data or description of measurement methods and procedures applied	Specified in Section 9.3.7
Purpose of data	Calculation of project emissions
Comments	Refer to procedures set out in Sections 8.1.4.2.1 – 8.1.4.2.6. For all equations in these sections, the subscript *BSL* must be substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario.

Data / Parameter	$\%OM$ (or $\%OM_{soil}$)
Data unit	%
Description	Percentage of soil organic matter
Equations	34, 35, 37, 39, 76, 77, 79, 79

Source of data	Direct measurements based on loss-on-ignition or may be derived from direct measurements of soil carbon. These measurements may be made using samples collected in Section 9.3.7 or indirectly from the soil carbon percentage as described in Section 8.1.4.3.
Description of measurement methods and procedures to be applied	The equations provided were developed for tidal marsh soils by Craft *et al*. 1991 and for mangrove soils by Allen 1974
QA/QC procedures to be applied	See Section 9.3.2
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	Refer to procedures set out in Sections 8.1.4.2.1 – 8.1.4.2.6. For all equations in these sections, the subscript *BSL* must be substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario.

Data / Parameter	$\%C_{soil}$
Data unit	%
Description	Percentage of soil organic C
Equations	33, 37, 39
Source of data	Direct measurements or may be derived from direct measurements of soil organic matter. These measurements may be made using samples collected in Section 9.3.7 or indirectly from the soil organic matter percentage determined through loss-on-ignition as described in Section 9.3.6.
Value applied	N/A
Description of measurement methods and procedures to be applied	See Source of data above
QA/QC procedures to be applied	See Section 9.3.2
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	Refer to procedures set out in Sections 8.1.4.2.1 – 8.1.4.2.6. For all equations in these sections, the subscript *BSL* must be

	substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario.

Data / Parameter	*BD*
Data unit	kg m^{-3}
Description	Dry bulk density
Equations	80
Source of data	Direct measurements or, for the determination of allochthonous carbon, may be derived from soil carbon percentage as described in Section 8.1.4.3.
Description of measurement methods and procedures to be applied	Mass of soil material after drying to removed water per volume of soil material
QA/QC procedures to be applied	See Section 9.3.2
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	Refer to procedures set out in Sections 8.1.4.2.1 – 8.1.4.2.6. For all equations in these sections, the subscript *BSL* must be substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario.

Data / Parameter	$\%OM_{depsed}$
Data unit	%
Description	Percentage of organic matter in deposited sediment
Equations	34, 38, 40
Source of data	May be estimated directly using loss-on-ignition (LOI) data, indirectly from soil carbon percentage as described in Section 8.1.4.3, or from the default value provided in Section 8.1.4.3. These measurements may be made using samples collected on sediment tiles or through collection and carbon analysis (see Section 9.3.7) of suspended sediments in tidal channels or sediments deposits in tidal flats
Description of measurement methods	LOI may be assessed using standard laboratory procedures

and procedures to be applied	
QA/QC procedures to be applied	See Section 9.3.2
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	Refer to procedures set out in Sections 8.1.4.2.1 – 8.1.4.2.6. For all equations in these sections, the subscript *BSL* must be substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario.

Data / Parameter	$\%C_{depsed}$
Data unit	%
Description	Percentage of carbon in deposited sediment; %
Equations	38, 40
Source of data	May be estimated directly using loss-on-ignition (LOI) data or indirectly from soil carbon percentage as described in Section 8.1.4.3. These measurements may be made using samples collected on sediment tiles or through collection and carbon analysis (see Section 9.3.7) of suspended sediments in tidal channels or sediments deposits in tidal flats.
Description of measurement methods and procedures to be applied	The default factor is derived from the maximum value (conservative) provided by Andrews *et al.* 2011
QA/QC procedures to be applied	See Section 9.3.2
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	Refer to procedures set out in Sections 8.1.4.2.1 – 8.1.4.2.6. For all equations in these sections, the subscript *BSL* must be substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario.

Data Unit / Parameter	$ET_{FC,y}$

Data unit	t CO_2-e yr^{-1}
Description	CO_2 emissions from fossil fuel combustion during the year *y*; t CO_2 yr^{-1}
Equations	65
Source of data	Derived from application of CDM tool Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities
Description of measurement methods and procedures to be applied	See *AR-Tool14*
Frequency of monitoring/recording	See the *AR Tool*
QA/QC procedures to be applied	See the *AR Tool*
Purpose of data	Calculation of project emissions
Calculation method	See the *AR Tool*
Comments	Calculations are done for each stratum *i*

Data / Parameter	NER_{ERROR}
Data unit	%
Description	Total uncertainty for project activity
Equations	72, 73
Source of data	*N/A*
Description of measurement methods and procedures to be applied	N/A
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of net GHG emission reductions
Calculation method	N/A
Comments	N/A

Data / Parameter	$V_{ex,ty,i,t}$
Data unit	m^3

Description	Volume of timber extracted from within stratum *i* (does not include slash left onsite) by species *j* and wood product class *ty* in year *t*
Equations	83
Source of data	Estimates derived from field measurements or remote assessments with aerial photography or satellite imagery.
Justification of choice of data or description of measurement methods and procedures applied	See Section 9.1
QA/QC procedures to be applied	
Purpose of Data	Calculation of project emissions
Comments	N/A

9.3 Description of the Monitoring Plan

9.3.1 General

The main objective of project monitoring is to reliably quantify carbon stocks and GHG emissions in the project scenario during the project crediting period, prior to each verification, with the following main tasks:

- Monitor project carbon stock changes and GHG emissions
- Estimate *ex-post* net carbon stock changes and GHG emissions, and GHG emission reductions

The monitoring plan must contain at least the following information:

- A description of each monitoring task to be undertaken, and the technical requirements therein
- Parameters to be measured
- Data to be collected and data collection techniques
- Frequency of monitoring
- Quality assurance and quality control (QA/QC) procedures
- Data archiving procedures
- Roles, responsibilities and capacity of monitoring team and management

9.3.2 Uncertainty and quality management

Quality management procedures are required for the management of data and information, including the assessment of uncertainty relevant to the project and baseline scenarios. As far as practical, uncertainties related to the quantification of GHG emission reductions and removals by sinks should be reduced.

To help reduce uncertainties in the accounting of emissions and removals, this methodology uses whenever possible the methods from the GPG-LULUCF, GPG-2000, the IPCC's Revised 2006 Guidelines and peer-reviewed literature. Despite this, potential uncertainties still arise from the choice of parameters to be used. Uncertainties arising from input parameters would result in uncertainties in the estimation of both baseline net GHG emissions and project net GHG emissions, especially when global default factors are used. The project proponent must identify key parameters that would significantly influence the accuracy of estimates. Local values that are specific to the project circumstances must then be obtained for these key parameters, whenever possible. These values should be based on:

- Data from well-referenced peer-reviewed literature or other well-established published sources[27];
- National inventory data or default data from IPCC literature that has, whenever possible and necessary, been checked for consistency against available local data specific to the project circumstances; or
- In the absence of the above sources of information, expert opinion may be used to assist with data selection. Experts will often provide a range of data, as well as a most probable value for the data. The rationale for selecting a particular data value must be described in the project description.

In choosing key parameters, or making important assumptions based on information that is not specific to the project circumstances, such as in use of default data, the project proponent must select values that will lead to an accurate estimation of net GHG emission reductions, taking into account uncertainties.

If uncertainty is significant, the project proponent must choose data such that it indisputably tends to under-estimate, rather than over-estimate, net GHG project benefits.

To ensure that carbon stocks are estimated in a way that is accurate, verifiable, transparent, and consistent across measurement periods, the project proponent must establish and document clear standard operating procedures and procedures for ensuring data quality. At a minimum, these procedures must include:

- Comprehensive documentation of all field measurements carried out in the project area.

[27] Typically, citations for sources of data used should include: the report or paper title, publisher, page numbers, publication date, etc. (or a detailed web address). If web-based reports are cited, hardcopies should be included as annexes in the project description if there is any likelihood that such reports may not be permanently available.

This document must be detailed enough to allow replication of sampling in the event of staff turnover between monitoring periods.

- Training procedures for all persons involved in field measurement or data analysis. The scope and date of all training must be documented.
- A protocol for assessing the accuracy of plot measurements using a check cruise and a plan for correcting the inventory if errors are discovered.
- Protocols for assessing data for outliers, transcription errors, and consistency across measurement periods.
- Data sheets must be safely archived for the life of the project. Data stored in electronic formats must be backed up.

9.3.3 Expert judgment

The use of expert judgment for the selection and interpretation of methods, selection of input data to fill gaps in available data, and selection of data from a range of possible values or uncertainty ranges, is well established in the IPCC 2006 good practice guidance. Obtaining well-informed judgments from domain experts regarding best estimates and uncertainties is an important aspect in various procedures throughout this methodology. The project proponent must use the guidance provided in Chapter 2 (Approaches to Data Collection), in particular, Section 2.2 and Annex 2A.1 of the IPCC 2006 good practice guidance.

9.3.4 Monitoring of project implementation

Information must be provided and recorded in the project description to establish that:

1) The geographic position of the project area is recorded for all areas of wetland. The geographic coordinates of the project area (and any stratification or buffer zones inside the area are established, recorded and archived. This can be achieved by field survey (eg, using GPS), or by using georeferenced spatial data (eg, maps, GIS datasets, orthorectified aerial photography or georeferenced remote sensing images). The above also applies to the recording of strata.
2) Commonly accepted principles of land use inventory and management are implemented.
    - Standard operating procedures (SOPs) and quality control/quality assurance (QA/QC) procedures for inventories including field data collection and data management must be applied. Use or adaptation of SOPs already applied in national land use monitoring, or available from published handbooks, or from the IPCC GPG LULUCF 2003, is recommended.
    - Apply SOPs, especially, for actions likely to cause soil disturbances.
    - Project planning documentation, together with a record of the plan as actually implemented during the project must be available for validation or verification, as appropriate.

Continued compliance with the applicability conditions of this methodology must be ensured by monitoring that:

- The water table is not lowered except where the project converts open water to tidal wetlands, or improves the hydrological connection to impounded waters.
- The burning of organic soil as a project activity does not occur.
- Peatland fires within the project area do not occur in the project scenario. If they do occur as non-catastrophic events, they are accounted for by cancelling the *Fire Reduction Premium* for the entire project or the individual project activity instance.
- N-fertilizers are not used within the project area in the project scenario.

Where the project proponent chooses to monitor alterations of water table depth in the project area to demonstrate no alteration of mean annual water table depths in adjacent areas, or that such alteration is limited to levels that do not influence GHG emissions, the project proponent must use water level gauges or vegetation assessments, or a combination of these. Water level gauges must be installed in the project area and readings must be compared with the hydrological modeling results or expert judgment on which the establishment of the project area was based. The number and spacing of water level gauges must be based on hydrological modeling or expert judgment.

9.3.5 Stratification and sampling framework

Stratification of the project area into relatively homogeneous units may either increase the measuring precision without increasing the cost unduly, or reduce the cost without reducing measuring precision because of the lower variance within each homogeneous unit. The project proponent must present in the project description an *ex-ante* stratification of the project area or justify the lack of it. The number and boundaries of the strata defined *ex ante* may change during the project crediting period (*ex post*).

The *ex-post* stratification must be updated where the following occur:

- Unexpected disturbances occurring during the project crediting period (eg, due to changes in the hydrology, fire, pests or disease outbreaks), affecting differently various parts of an originally homogeneous stratum;
- Management activities (forestry, agriculture, hydrology) that are implemented in a way that affects the existing stratification.

Established strata may be merged if the reasons for their establishment are no longer relevant.

The sampling framework, including sample size, plot size, plot shape, and determination of plot location must be specified in the project description. Where changes in carbon stocks are to be monitored (eg, in trees), permanent sampling plots must be used, noting the following:

1) To determine the sample size and allocation among strata, the latest version of the CDM tool *Calculation of the number of sample plots for measurements within A/R CDM project activities* may be used. The targeted confidence interval must be 90 percent or 95 percent. Where a 90 percent confidence interval is adopted and the width of the confidence interval exceeds 20 percent of the estimated value or where a 95 percent confidence interval is adopted and the width of the confidence interval exceeds 30 percent of the estimated value, an appropriate confidence deduction must be applied, as specified in Section 8.5.2.
2) In order to avoid bias, sample plots should be marked inconspicuously.
3) The sample plot size must be established according to common practice in forest, vegetation and soil inventories.
4) To avoid subjective choice of plot locations, the permanent sample plots must be located either systematically with a random start or completely randomly inside each defined stratum. The geographical position (GPS coordinate), administrative location, stratum and stand, series number of each plot, as well as the procedure used for locating them must be recorded and archived. The sampling plots are to be as evenly distributed as possible, where larger strata have more plots than smaller strata. However, remote areas and areas with poor accessibility may be excluded for the location of sampling plots. Such areas must be mapped as separate strata and for these strata accounting of carbon stocks in tree biomass in the project scenario is conservatively omitted (see Section 8.2.2).

The choice of monitoring frequency must be justified in the project description.

9.3.6 Sampling of herbaceous vegetation

Aboveground herbaceous mass (herb) is defined as a pool that includes both living plant mass (ie, biomass) and dead plant mass (ie, litter). All living and dead herbaceous mass is clipped above the soil surface from inside each sample frame. Dry mass is determined by either drying the entire wet sample to a constant weight, or drying a subsample of the wet mass to determine a dry-to-wet mass ratio conversion factor. Because aboveground mass can be highly seasonal, the average pool must be calculated from at least two samples representing the minimum and maximum standing stocks. Alternatively, a conservative estimate of the pool may be determined from a sample taken at the time of minimum standing stock.

9.3.7 Soil coring approach for estimating soil carbon

Soil organic carbon may be estimated by determining the organic carbon accumulated above a consistent reference plane and then dividing by the years since the date of the reference plane (for the baseline scenario) or the start of project activities (for the project scenario). The reference plane must be established using a marker horizon (most commonly using feldspar)[28], a strongly contrasting soil layer (such as the boundary between organic and mineral soil materials), an

[28] Cahoon & Turner 1989

installed reference plane (such as the shallow marker in a surface elevation table)[29], a layer identified biogeochemically (such as through radionuclide, heavy metal, or biological tracers)[30], a layer with soil organic carbon indistinguishable from the baseline SOC concentration (as determined in Section 8.1.4.2)[31] or other accepted technologies. Note that feldspar marker horizons should not be used in systems where they are unstable, such as some sandy soils and systems with significant bioturbation. The material below the reference plane may be conservatively assumed to have zero change due to project activities.

The material located above the reference plane must be analyzed for total carbon and bulk density. Sediment samples may be collected for the estimation of $\%C_{depsed}$ (see Section 8.1.4.3) using sediment tiles,[32] through collection of suspended sediments in tidal channels during a period of high suspended sediment concentration or by collecting cores of sediment deposits in tidal flats. Total organic carbon must be analyzed directly using CHN elemental analysis or the Walkley-Black chromic acid wet oxidation method or determined from loss-on-ignition (LOI) data using the following equation:

$\%C = 0.04 \times \%OM + 0.0025 \times \%OM^2$ (only for marsh soils)[33] **(76)**

$\%C = \%OM / 1.724$ (only for mangrove soils)[34] **(77)**

$\%C = -0.21 + 0.40\ (\%OM)$ (only for seagrass soils with $\%OM < 20$ percent) [35] **(78)**

$\%C = -0.33 + 0.43\ (\%OM)$ (only for seagrass soils with $\%OM > 20$ percent) [36] **(79)**

Alternatively, an equation developed using site-specific data may be used or an equation from peer-reviewed literature may be used if the equation represents soils from the same or similar systems as those in the project area.

Inorganic carbon should be removed from samples if present in significant quantities, usually through acid treatment (such as sulfurous or hydrochloric acid). Live coarse below-ground tree biomass should be removed from soil samples prior to analysis. Additional live below-ground biomass may be removed or included. Soil samples collected may be aggregated to reduce the variability.

The mass of carbon per unit area is calculated as follows:

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[29] Cahoon *et al.* 2002
[30] DeLaune *et al.* 1978
[31] Greinier *et al.* 2013
[32] Pasternack and Brush 1998
[33] Craft *et al.* 1993
[34] Allen 1974
[35] Fourqurean *et al*. 2012 as summarized in Howard *et al*. 2014
[36] Fourqurean *et al*. 2012 as summarized in Howard *et al*. 2014

$$C_{WP,SOCacc} = 44/12 \times \sum_{i=1}^{Ndepth} \left(CF_{SOC,sample} \times BD \times Thickness \times 100 \right) \quad \textbf{(80)}$$

Where:

$C_{WP,SOCacc}$	Average accumulation of soil/sediment over reference plane in the project; t CO_2e ha^{-1}
44/12	Ratio of molecular weight of CO_2 to carbon; dimensionless
Ndepth	Number for soil horizons, based on subdivisions of soil cores
CF_{SOC_sample}	Carbon fraction of the sample, as determined in laboratory; %
BD	Bulk density, as determined in laboratory; g cm^{-3}
Thickness	Thickness of soil horizon; cm
100	Conversion factor of g cm^{-3} to Mg ha^{-1}

9.3.8 Monitoring CH_4 and N_2O emissions

Direct measurement of CH_4 and/or N_2O emissions may be made with either a closed chamber technique or a chamber-less technique such as eddy covariance flux. For eddy covariance methods, the guidelines presented in VCS methodology *VM0024 Methodology for Coastal Wetland Creation* must be followed, taking into account the additional guidance below.

Flux measurements are expected to conform to standard best practices used in the scientific community[37]. The basic design of the closed chamber for wetlands requires a base that extends into the soil (5 cm minimum), and a chamber that is placed over the plants and sealed to the base. To prevent the measurement from disturbing CH_4 emissions, the base should be placed at least one day in advance, and the plot should be approached on an elevated ramp or boardwalk when taking samples, although failure to do so is conservative because it will cause higher fluxes. CH_4 flux is calculated as the difference in initial and final headspace CH_4 concentration, without removing non-linear increases caused by bubble (ebullition) fluxes that may have occurred. Initial and final concentrations will be determined as the average of duplicate determinations. Because CH_4 and N_2O emissions can be low from tidal wetlands, it may be necessary to enclose large areas (≥ 0.25 m^2) or lengthen the measurement period to improve sensitivity.

Methane emissions from strata lacking vegetation (<25 percent cover), such as open water, hollows or ponds, can be dominated by episodic bubble emissions (ie, ebullition). Chambers for open water emissions are typically a single piece that floats such that the bottom extends under the water surface (5 cm minimum). Floating chambers must be deployed for a minimum of 4 days.

Eddy covariance techniques sense total CH_4 and N_2O emissions (diffusive and ebullition) at high temporal resolution; such systems must be deployed for a minimum of 48 hours of useable data.

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[37] *Oremland 1975*

CH_4 and N_2O emission estimates must be either accurate or conservative. Accurate estimates must account for variation in time caused by changes in plant activity, temperature, water table depth, salinity and other sources of variation, and in space caused by factors such as topography (eg, hummocks versus hollows) or plant cover. A conservative estimate may be based on direct measurements taken at times and places in which CH_4 or N_2O emissions are expected to be the highest based on expert judgment, datasets or literature.

Fluxes must be measured in the stratum with the highest emissions. For CH_4, these are likely to be strata in the wettest strata that support emergent vegetation, but may include stagnant pools of water. Eddy flux towers must be placed so that the footprint lies in the stratum with the highest CH_4 or N_2O emissions for 50 percent of the time. CH_4 fluxes must be measured when the water table is <10 cm from the soil surface, during times of year when emissions are highest, such as the warmest month and/or wettest month. When CH_4 emission rates incorporate measurements from periods of time outside the peak, they must be made at approximately monthly intervals.

In addition to the conservative principles above, the project proponent must consider other factors that are specific to the method applied. In particular, closed chambers must be transparent and deployed in daylight unless it is can be shown that CH_4 emissions are not sensitive to light.

Regardless of method, emissions must be averaged and expressed as daily (24 hour) rates and converted to annual estimates using the following equations:

$$GHG_{WPS\text{-}soil\text{-}CH4,i,t} = GHG_{CH4\text{-}daily,i,t} \times 365 \times CH_4\text{-}GWP \quad \textbf{(81)}$$

Where:

$GHG_{WPS\text{-}soil\text{-}CH4,i,t}$	CH_4 emissions from the SOC pool in the project scenario in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}
$GHG_{CH4\text{-}daily,i,t}$	Average daily CH_4 emissions in the baseline scenario based on direct measurements of stratum *i* in year *t*; mg CH_4 m^{-2} d^{-1}
$CH_4\text{-}GWP$	Global warming potential of CH_4; dimensionless
i	1, 2, 3 …M_{WPS} strata in the baseline scenario
t	1, 2, 3, … *t** years elapsed since the project start date

$$GHG_{WPS\text{-}soil\text{-}N2O,i,t} = GHG_{N2O\text{-}daily,i,t} \times 365 \times N2O\text{-}GWP \quad \textbf{(82)}$$

Where:

$GHG_{WPS\text{-}soil\text{-}N2O,i,t}$	N_2O emissions from the SOC pool in the project scenario in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}
$GHG_{N2O\text{-}daily,i,t}$	Average daily N_2O emissions in the baseline scenario based on direct measurements of stratum *i* in year *t*; mg N_2O m^{-2} d^{-1}
$N_2O\text{-}GWP$	Global warming potential of N_2O; dimensionless
i	1, 2, 3 …M_{WPS} strata in the baseline scenario

t 1, 2, 3, … *t** years elapsed since the project start date

Where the default factor approach is used for CH_4 emissions (see Section 8.1.4.4.4), the salinity average or salinity low point will be measured on shallow pore water (within 30 cm from soil surface) using a handheld salinity refractometer or other accepted technology. The salinity average must be calculated from observations that represent variation in salinity during periods of peak CH_4 emissions (eg, during the growing season in temperate ecosystems or the wet season in tropical ecosystems). When the number of observations during this period is small (fewer than one per month for one year), the salinity low point from these data must be used. The salinity of the floodwater source (eg, an adjacent tidal creek) during this period may be used as a proxy for salinity in pore water provided there is regular hydrologic exchange between the source and the wetland (ie, the source floods the wetland at least on 20 percent of high tides).

9.3.9 Monitoring of soil subsidence

Where soil subsidence on drained wetlands is used as a proxy for carbon loss and CO_2 emissions, applied techniques and calculations must follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks. The lowering of the organic soil surface over time (subsidence) must be measured relative to a fixed point (datum) (eg, using a pole fixed in the mineral subsoil). Dipwells used for water table depth monitoring may be used for subsidence monitoring with the advantage that water table depth and subsidence are monitored at the exact same location. In areas where fire may occur, it is best (also) to place iron poles. If poles are lost due to fire, new poles must be installed. Height losses due to fire must be treated separately from those caused by microbial oxidation of the organic soil in assessing carbon losses.

Interpolation of the trend in organic soil height loss over a longer period surrounding the fire event allows for quantifying height loss due to the fire. At least 10 replicate subsidence poles must be evenly distributed per stratum. To prevent disturbance, poles may need to be fenced in. In order to avoid disturbance of the organic soil surface during readings it is advisable to place boardwalks. For remote and inaccessible areas, the project proponent may rely on vegetation cover as an indicator for water table depth and associated subsidence rates as supported by data or literature references in a conservative way. The minimum monitoring frequency for soil subsidence is once a year.

Consolidation of the saturated organic soil below the water table may contribute to subsidence over multiple years. The project proponent must conservatively assess the contribution of consolidation to overall subsidence by reference to literature values or expert judgment or demonstrate that consolidation plays an insignificant role in overall subsidence (< 5 percent).

The calculation of carbon loss rates from subsidence data must follow pertinent scientific literature (eg, Couwenberg & Hooijer 2013) and usually requires data on the volumetric carbon content of the organic soil. When subsidence measurements are used to establish emission factors to be associated with other proxies, measurements must be carried out over a period of at least 24 months to cover intra- and inter-annual variability.

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APPENDIX 1: LONG-TERM CARBON STORAGE IN WOOD PRODUCTS

Introduction

The procedures included in this appendix allow for the *ex-ante* estimation of carbon stocks in the long-term wood products pool in the project scenario. The procedures are applicable to all cases where wood is harvested for conversion to wood products for commercial markets, for all forest types and age classes.

The approach outlined employs an emission factor (*WW*) derived by Winjum *et al.* 1998. In the event that new research findings updating or refining (eg, for specific countries) the WW factor become available in the future (during the project crediting period), they must be used in place of the factors included in this appendix; otherwise the factors will remain valid. The use of this appendix requires that project proponents review research findings (that produce emissions factors compatible with the conceptual framework here) at least every 10 years to identify further refinements to the emission factors that are empirically based and peer reviewed.

All factors are derived from Winjum *et al*. 1998.

If approved timber harvest plans, specifying harvest intensity per strata in terms of volume extracted per ha, are available for the project area, use Option 1. If approved harvest plans are not available, use Option 2.

Once actual extraction data is obtained from the project site, they must be monitored and used for calculations. At each verification event, the long-term average must be recalculated based on past harvested volumes and most recent forecasts.

Option 1: Direct Volume Extraction Estimation

Step 1: Identify the wood product class(es) (*ty*; defined here as sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other) that are the anticipated end use of the extracted carbon calculated in Step 2.

Step 2: Calculate the biomass carbon of the volume extracted by wood product type *ty* from within the project boundary:

$$C_{XB,ty,i,t} = \sum_{j=1}^{S}(V_{ex,ty,j,i} \times D_j \times CF_j \times \frac{44}{12}) \qquad (\mathbf{83})$$

Where:

$C_{XB,ty,i}$	Extracted biomass carbon by class of wood product *ty* from stratum *i* in year *t*; t CO_2e
$V_{ex,ty,i,t}$	Volume of timber extracted from within stratum *i* (does not include slash left onsite) by species *j* and wood product class *ty* in year *t*; m^3
D_j	Mean wood density of species *j*; t d.m.m^{-3}
CF_j	Carbon fraction of biomass for tree species *j*; t C t^{-1} d.m.

j	1, 2, 3, … S tree species
ty	Wood product class – defined here as sawnwood (s), wood-based panels (w), other industrial roundwood (oir), paper and paper board (p), and other (o)
i	1, 2, 3 …*M* strata
t	1, 2, 3, … *t** years elapsed since the project start date
44/12	Ratio of molecular weight of CO_2 to carbon, t CO_2e t C^{-1}

Step 3: Calculate the proportion of biomass carbon extracted that remains sequestered in long-term wood products.

$$C_{WP,i,t} = \sum_{ty=s,w,oir,p,o} C_{XB,ty,i} \times (1 - WW_{ty}) \times (1 - SLF_{ty}) \times (1 - OF_{ty}) \quad \textbf{(84)}$$

Where:

$C_{WP,i,t}$	Extracted carbon in the wood products pool from stratum *i* in year *t*; t CO_2e
$C_{XB,ty,i,t}$	Mean stock of extracted biomass carbon by class of wood product *ty* from stratum *i*; in year *t* t CO_2e
WW_{ty}	Wood waste. The fraction immediately emitted through mill inefficiency by class of wood product *ty*; dimensionless
SLF_{ty}	Fraction of wood products that will be emitted to the atmosphere within 5 years of timber harvest by class of wood product *ty*; dimensionless
OF_{ty}	Fraction of wood products that will be emitted to the atmosphere between 5 and 100 years of timber harvest by class of wood product *ty*; dimensionless
ty	Wood product class – defined here as sawnwood (s), wood-based panels (w), other industrial roundwood (oir), paper and paper board (p), and other (o)
i	1, 2, 3, … *M* strata
t	1, 2, 3, … *t** years elapsed since the project start date

Option 2: Commercial Inventory Estimation

Step 1: Calculate the biomass carbon of the commercial volume extracted prior to or in the process of harvesting:

$$C_{XB,i,t} = C_{AB\_tree,i,t} \times \frac{1}{BCEF} \times Pcom_{i,t} \quad \textbf{(85)}$$

Where:

$C_{XB,i,t}$	Extracted biomass carbon from stratum *i* in year *t*; t CO_2e
$C_{AB\_tree,i,t}$	Aboveground biomass carbon stock in stratum *i* in year *t*; t CO_2e
BCEF	Biomass conversion and expansion factor (BCEF) for conversion of merchantable

	volume to total aboveground tree biomass; dimensionless
$Pcom_{i,t}$	Commercial volume as a percent of total aboveground volume in stratum *i*; dimensionless
i	1, 2, 3, … *M* strata
t	1, 2, 3, … *t** years elapsed since the project start date

Step 2: Identify the wood product class(es) (*ty*; defined here as sawnwood, wood-based panels, other industrial roundwood, paper and paper board, and other) that are the anticipated end use of the extracted carbon calculated in Step 1.

Step 3: Same as Step 3 in Option 1 above.

Data and parameters available at validation are provided in Section 9.1.

Data and parameters monitored are provided in Section 9.2.

APPENDIX 2: ACTIVITY METHOD

Introduction and Approach

Tidal wetland restoration activities in the United States are at a low level of penetration relative to their maximum adoption potential. Specifically, the activity penetration level of such activities is 2.74 percent (or lower), as demonstrated below. This level is below the 5 percent threshold specified in the *VCS Standard*. Therefore, tidal wetland restoration projects meeting the applicability conditions of this methodology and occurring within the 35 coastal states, commonwealths or territories of the United States of America are deemed additional.

Activity penetration is given as:

$$APy = OAy / MAPy$$

Where:

APy Activity penetration of the project activity in year y (percentage)

OAy Observed adoption of the project activity in year y

MAPy Maximum adoption potential of the project activity in year y

In determining the activity penetration for tidal wetlands, it is necessary to address seagrass meadows and other tidal wetlands separately due to how these ecosystems are treated in the data sources.

For tidal wetland restoration (excluding seagrass meadows) in the United States, these terms are further defined as follows:

OAy The average annual aggregate of tidal wetlands restored from 2000 to 2013 as reported by the 28 National Estuary Programs (NEPs) and their partners to the U.S. Environmental Protection Agency (measured in acreage), and expanded to include restoration activities that occur in a U.S. estuary that is not an NEP.

MAPy The sum of the following:

- A portion of the 1991 100-year Coastal Floodplain as determined by the Federal Emergency Management Agency (FEMA)
- Past tidal wetland losses to shallow open water in Louisiana due to coastal erosion
- Tidal wetland losses reported by the U.S. Fish and Wildlife Service (USFWS) from 1991 to 2013

For seagrass meadow restoration in the United States, these terms are defined as follows:

OAy The percentage of seagrass meadow restoration projects compared to other estuary restoration projects funded by NOAA since 2000.

MAPy The estimated acreage of seagrass meadow losses in the U.S.

Justification for Tidal Wetland Restoration Penetration Levels (Non-Seagrass)

The United States is a developed country where states have equal access to the nation's resources. Factors causing degradation are substantially the same throughout the United States. Climate is not a factor in degradation of tidal wetlands, which occur across all climatic regions in the United States.

No complete national data sets exist for either tidal wetland loss or restoration in the United States. However, for both *MAPy* and *OAy*, conservative approximations can be made by examining the data from several sources.

Time Period

The time period selected for determining the *OAy* is 2000 to 2013. This is an appropriate time period for the following reasons:

- The NEPs began reporting annual activities in 2000 and have been required to do so since 1993 by the Government Performance Results Act. The NEP database captures activities prior to 2000 as well as those from 2000 forward.
- The Estuary Restoration Act[38] was signed into law in 2000. The Act made restoring estuaries a national priority and represents a recognition of the growing importance of estuary habitat restoration, including tidal wetlands. It provided funding authorization and appropriations for restoration projects, and created a federal interagency council to promote a coordinated Federal approach to estuary habitat restoration; forge effective partnerships among public agencies and between the public and private sectors; provide financial and technical assistance for estuary habitat restoration projects; and, develop and enhance monitoring and research capabilities. Prior to 2000, the lack of interagency coordination created sporadic and uncoordinated restoration actions.
- NOAA's Community-based Restoration Program was created in 1999 within its Restoration Center and began funding projects that year with just $500,000 in funding[39]. The creation of this national center for restoration also indicates that a turning point for restoration was anticipated at that time. Since then, NOAA's annual funding for restoration has grown to well over 10 million dollars.
- Restore America' Estuaries (RAE) was established in 1997 as a national umbrella organization for regional non-profit organizations. These organizations identified estuary restoration as an emerging opportunity and established RAE to promote estuary restoration at the national level and to provide financial support for new restoration activities. The creation of RAE at this time reflects the need for a national voice to catalyze increased investment in estuary restoration.

[38] http://www.era.noaa.gov/information/act.html

[39] Personal communication in 2000 with the Restoration Center Director, James Burgess.

Collectively these milestones represented a sea change in the restoration community that has greatly increased funding and capacity for restoration activities since the year 2000, and therefore the time period 2000 to 2013 will capture the preponderance of restoration activities.

Activity Penetration

The 28 National Estuary Programs are an appropriate means to quantify restoration activity. The National Estuary Program (NEP) was established under Section 320 of the 1987 Clean Water Act as a U.S. Environmental Protection Agency program to protect and restore the water quality and ecological integrity of estuaries of national significance. The NEP consists of 28 individual estuary programs in the United States. Each NEP has a Management Conference consisting of diverse stakeholders including citizens, local, state and federal agencies, as well as non-profit and private sector interests. They emphasize a collaborative approach to establishing and implementing locally-based Comprehensive Conservation and Management Plans (CCMP).

The 28 estuaries with NEPs are the most advanced in conservation planning and implementation, including ecological restoration, and as such will have the greatest activity penetration levels of estuaries in the United States. They are also among the largest and most populated estuary regions in the U.S. Estuaries not included in the NEP will typically have a much lower penetration level for tidal wetland restoration.

That estuaries in NEPs face the same or similar barriers to implementation of tidal wetland restoration projects as estuaries that do not have an NEP is supported by the expert opinions supporting this document. The experts also confirm that the levels of restoration in NEPs are much greater than the levels of restoration occurring in non-NEP estuaries in the United States.

To undertake tidal wetland restoration requires significant scientific, regulatory and ecological expertise, substantial financial resources, cooperating partners, and the ability to make long-term commitments. As a participating estuary, each of the 28 NEPs receive strong federal and state financial assistance and programmatic support in these areas - support which non-NEP estuaries do not receive.

Moreover, because the NEPs are collaborative partnerships of agencies, organizations, businesses, and others, the data reported for each NEP represents a comprehensive reporting of the restoration and creation activities undertaken by the partners. This demonstrates that the 28 NEPs are an appropriate measure of the most significant observed restoration activities in the U.S.

Additional project activities occur in non-NEP estuaries. To account for these activities, a corrective factor equal to the ratio of NEP estuary land area to non-NEP estuary land area is applied. The land area of the contiguous U.S. is 2,961,266 square miles[40]. Coastal counties represent 17 percent of this area[41]. Therefore, coastal counties in the contiguous U.S. cover approximately 503,415 square miles of land (17

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[40] U.S. Census Bureau, https://www.census.gov/geo/reference/state-area.html

[41] NOAA's List of Coastal Counties for the Bureau of the Census Statistical Abstract Series, https://www.census.gov/geo/landview/lv6help/coastal_cty.pdf

percent of geographic extent). The land area of the 28 NEPs is 246,338 square miles[42]. The ratio of land area in NEPs to total land area of coastal counties is 49 percent (246,338/503,415). Because the NEPs represent the most advanced and most supported estuary programs (see expert opinions below), we discount the non-NEP estimate by 50 percent. A correction factor of 50 percent therefore more than adequately captures activity in the non-NEP estuaries and the total *OAy* is equal to 1.5 times the *OAy* for NEPs.

The Environmental Protection Agency maintains an on-line database of projects reported by the 28 NEPs. Four years of data were reviewed to calculate an average rate of adoption for 2009 through 2012, which was then applied to the 2000 to 2014 period. This time period includes a one-time, significant infusion of federal government funding for estuary restoration in 2009. Through the American Recovery and Reinvestment Act of 2009, the National Oceanic and Atmospheric Administration received $165 million for projects, which had to be completed within 12-18 months. This one-time investment in restoration is highly unusual over the past 14 years (since the NEP data was first captured in 2000). Including this anomalous year in establishing an average adoption rate for the selected time period is a conservative approach to estimating activity penetration because it yields an average rate of restoration that is higher than the most likely rate, and applies that rate to the entire time period for determining *OAy*.

All United States estuaries face a common set of barriers to tidal wetland restoration including insufficient funding, lack of willing landowners and community support, and physical and ecological limitations and changes, such as sea level rise (Vigmostad *et al* 2005, Restore America's Estuaries and the Estuarine Research Federation, undated). In 2000, recognizing the critical need to provide funding for estuary habitat restoration, including tidal wetlands, and help to counter the mentioned socio-economic factors, the United States Congress passed and President Clinton signed into law, the Estuary Act of 2000, which authorized $275 million over five years for restoration activities.

OA*y* Method of Analysis

OAy for the NEPs was determined through a systematic review of the data sets provided by the EPA for each of the NEPs. In reviewing each data set, the analysis only includes project acreage resulting from projects, which (1) are not required by any rule, regulation, law, statute, court settlement or other mandatory action and (2) meet the definition of tidal wetland restoration provided in this methodology. Where a project description included multiple habitat types (eg, tidal wetland, shoreline, agriculture, etc.) and/or the project description included one or more activities in addition to restoration (eg, acquisition and barrier removal), the entire project acreage was included in the calculation. This is conservative because it will lead to a higher activity penetration. The NEP *OAy* calculation is provided in Table A1.

[42] National Estuary Program Coastal Condition Report, Chapter 2: Condition of National Estuary Program Sites - A National Snapshot, June 2007, http://water.epa.gov/type/oceb/nep/upload/2007_05_09_oceans_nepccr_pdf_nepccr_nepccr_natchap.pdf

Table A1: Calculation of *OAy* for the NEPs

	Tidal Wetland Acres Restored				
Estuary Program	2009	2010	2011	2012	4 year average
Peconic Bay Estuary Program	-	-	-	-	-
Piscataqua Region Estuaries Partnership	-	-	12.00	0.05	3.01
Buzzards Bay National Estuary Program	3.74	-	-	-	0.94
Tillamook Estuaries Partnership	46.00	44.00	16.00	4.40	27.60
Mobile Bay National Estuary Program	137.00	-	6.50	2.00	36.38
Santa Monica Bay Restoration Commission	-	21.00	-	-	5.25
Tampa Bay Estuary Program	142.70	61.28	-	44.54	62.13
Delaware Center for the Inland Bays	26.00	4.00	-	-	7.50
Lower Columbia River Estuary Partnership	-	-	184.00	58.00	60.50
Indian River Lagoon National Estuary Program	1,395.75	21.26	419.00	140.30	494.08
Maryland Coastal Bays Program	64.43	1.80	104.00	189.00	89.81
Galveston Bay Estuary Program	158.00	46.81	407.06	9.00	155.22
New York-New Jersey Harbor Estuary Program	11.00	34.00	65.80	50.00	40.20
Chesapeake Bay Program	622.00	1,005.00	3,775.00	n/a	1,800.67
Puget Sound Partnership	1,277.00	140.00	505.40	101.00	505.85
Charlotte Harbor National Estuary Program	600.50	496.00	795.00	140.00	507.88
San Francisco Estuary Partnership	1,469.00	401.00	3,250.00	983.36	1,525.84
Barataria-Terrebonne Estuary Program	673.58	n/a	35.00	182.00	296.86
Sarasota Bay Estuary Program	516.00	-	30.00	5.00	137.75
Long Island Sound Study	58.65	88.00	42.56	137.70	81.73
Partnership for the Delaware Estuary	1.30	6.50	-	-	1.95
Albemarle-Pamlico National Estuary Program	1.10	4.00	84.20	0.31	22.40
Barnegat Bay Partnership	-	-	-	-	-
Narragansett Bay Estuary Program	63.00	58.00	-	-	30.25
Massachusetts Bays Program	1,442.00	133.00	54.00	21.00	412.50
Casco Bay Estuary Partnership	-	-	-	21.80	5.45
Coastal Bend Bays and Estuaries Program	1,597.00	568.00	351.00	72.00	647.00
Morro Bay National Estuary Program	n/a	n/a	n/a	n/a	n/a
One year average, 2009-2012					6,958.73
2000 to 2013 total estimate = 14*One year average					97,422.17

Sources:

1. All 2009 data are from "NEP Project Information and Maps 2000-2009," http://gispub2.epa.gov/NEPMap/archivetree/archivetree.html. (U.S. Environmental Protection Agency). From each table, only tidal wetland restoration and creation projects are counted.
2. All 2010, 2011 and 2012 data are from the "NEP Projects Table Tool," http://gispub2.epa.gov/NEPmap/NEPTable_allyears/index.html. (National Estuary Program). From each table, only tidal wetland restoration and creation projects are counted.

Once the *NEP OAy* was determined, to ensure capture of non-NEP activities, it is increased by 50 percent for the Activity Penetration calculation.

$OAy = NEP\ OAy \times 1.5 = 97{,}422.17$ acres * 1.5 = 146,133 acres

Maximum Adoption Potential

To determine *MAPy*, an estimate of the available area for tidal wetland restoration needs to be established. The starting point for this estimate is the "Projected Impact of Relative Sea Level Rise on the National Flood Insurance Program" prepared by the Federal Emergency Management Agency (FEMA

1991). FEMA calculated the area of coastal floodplain that would flood under a 100-year coastal flood event for 1990 to be 19,500 mi^2 (12,800,000 acres). A 100-year flood event is defined as a flood that statistically has a 1 percent chance of occurring in any given year. By definition, the coastal floodplain does not include either upland areas or existing wetland areas (wetland areas do not flood because they are already regularly inundated). The coastal floodplain consists substantially of former wetland areas that were drained and/or filled and converted to other land uses, such as agricultural, commercial, or residential uses. This area includes many but not all former tidal wetland areas that were diked or drained for agriculture and other uses (some former wetland areas are no longer in the floodplain as they are now well protected by dikes or levees, eg, and therefore are not included in this estimate, which is conservative). Not all of the coastal floodplain area identified by FEMA is restorable or suitable for wetland creation. But for establishing an estimate of *MAPy*, 33 percent of this area (4,224,000 acres) is used as a conservative (low) estimate.

The FEMA estimate was made in 1991 and only includes land areas subject to flooding. Therefore, we also include in the *MAPy* tidal wetland losses since 1991 and tidal wetlands that have drowned or converted to open water in coastal Louisiana. Virtually all of these areas are suitable for tidal wetland restoration.

Louisiana wetland losses from 1900 to 1978 are reported to be 901,200 acres (U.S. Department of the Interior 1994). The *MAPy* estimate does not include Louisiana coastal wetland losses between 1978 and 1986, and it is conservative to exclude that area from the *MAPy*.

Tidal wetland losses from 1986 to 1997 were reported to be 8,450 acres (Dahl 2000). The 1991 to 1997 portion of these losses is assumed to be 4,225 acres, a pro-rated portion of the total.

Tidal wetland losses from 1998 to 2004 were reported to be 32,400 acres (Dahl 2006).

Tidal wetland losses from 2004 to 2009 were reported to be 124,290 acres (Dahl 2011).

No data exists for 2010 to 2013 (four years). We apply the average rate of loss from the previous five year period, 2004 to 2009, which is 124,290 acres /6 years = 20,715 acres /year.

Table A: Calculation of Maximum Adoption Potential for tidal wetland restoration (non-seagrass)

Maximum Adoption Potential	Acres
33% of FEMA 1991 Floodplain Estimate	4,244,000
Louisiana Delta Wetland Losses	901,200
Tidal Wetland Losses 1991 to 1997	4,228
Tidal Wetland Losses 1998 to 2004	32,400
Tidal Wetland Losses 2004 to 2009	124,290
Tidal Wetland Losses 2010 to 2013	82,860
Total MAPy (non-seagrass)	5,388,978

Activity Penetration Calculation for Tidal Wetlands (non-seagrass)

$APy = OAy / MAPy$

APy = 146,133 acres / 5, 338,978 acres

APy = 2.71%

Justification for Seagrass Meadow Restoration Penetration Levels

OAy Method of Analysis

Seagrass meadow restoration also occurs at a very low level relative to its maximum adoption level in the U.S. Evidence of this is provided by the National Oceanic and Atmospheric Administration, which maintains a Restoration Atlas (NOAA 2014). NOAA is the lead federal agency mandated with coastal and marine fisheries habitat restoration and protection, including seagrass meadow habitat. NOAA's level of funding for seagrass meadow restoration is therefore a sufficient estimate of the total level of seagrass restoration.

The NOAA database contains information on about 2,701 habitat projects that have occurred since 2000, and only 120, or 4 percent, are seagrass meadow projects. The database includes numerous habitats (eg, dune, in-stream, kelp, mangrove, oyster reef) as well as numerous activities in wetland habitats (restoration, invasive species removal, marine debris removal). Only a portion of the 120 seagrass meadow projects would meet the applicability conditions of this methodology. Therefore, including all of identified seagrass meadow restoration projects is conservative. The total acreage of estuary habitat restoration projects in the NOAA database is 49,837 acres. Seagrass meadow projects are typically conducted at a smaller scale than other habitat activities; therefore assuming that 4 percent of the total acreage can be attributed to seagrass restoration is conservative. The *OAy* for seagrass restoration is therefore 4 percent of 49,837 = 1,993 acres.

Maximum Adoption Potential Method of Analysis for Seagrass Restoration

Waycott *et al* (2009) demonstrated that seagrass meadow habitat losses in the U.S. were 853,845 acres between 1937 and 2006. The primary causes of the loss of seagrass meadows – sediment deposition, declining water quality, scarring from vessels, and disease – are typically reversible. Therefore, all of the area documented as lost is restorable. *MAPy* for seagrass meadow restoration is therefore 853,845 acres.

Activity Penetration Calculation for Seagrass Restoration

$APy = OAy / MAPy$

APy = 1,993 / 853,845 = 0.2%.

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Expert Credentials

Debbie DeVore is the Gulf Restoration Program Coordinator for the US Fish & Wildlife Service, where she coordinates restoration activities for the Service offices and programs along the Gulf Coast. She has more than 15 years of experience in coastal resource management and has received numerous awards in her career.

Curtis D. Tanner is Acting Manager for the Division of Environmental Assessment and Restoration (EAR) in the U.S. Fish and Wildlife Service, where he manages staff and activities in the Watershed Protection and Restoration Branch. He provided leadership for the Puget Sound Nearshore Ecosystem Restoration Project, and has more than twenty years of experience in coastal resource management and restoration.

EXPERT OPINION I

Debbie L. DeVore
Gulf Coast Restoration Program Manager
U.S. Fish & Wildlife Service

Question 1 – To what extent do estuaries without a National Estuary Program face the same barriers to tidal wetland restoration activities as estuaries, which are part of a National Estuary Program? We have identified the following barriers, among others: funding, land ownership/control, political will, a local environment, which encourages partnerships, and social acceptability. Please note that we only need to consider barriers to tidal wetland restoration where it has already been identified as possible in the landscape. Based on your experience and expert judgment, do estuaries in NEPs face the same or similar barriers to implementation of tidal wetland restoration projects as estuaries that do not have an NEP? Please explain.

Answer:

While there are, no doubt, advantages afforded an estuary which has an established National Estuary Program (NEP) this does not preclude or exempt projects in these geographies from many of the same hurdles that projects face in an estuary outside the geographic of an NEP.

For example, funding is commonly the largest limiting factor in bringing a tidal restoration project to implementation, regardless of the project's location. Projects with involvement from an NEP must apply for the same limited funding as any other project (raising the same amount of match, etc.) and be held to the same reporting and fiduciary responsibilities as well. NEP supported projects must also go through the same scrutiny to obtain regulatory permission to conduct work, just as a non-NEP project does.

Both political will and public support for projects are also similar issues faced by projects both within an NEP and outside a NEP geography. In fact, projects with NEP support or in a NEP geography may even sometimes have a bigger stigma as the public may not have a high level of trust for governmental organizations and be much less supportive of their actions. As well, working with landowners (particularly private landowners) may prove more difficult for projects with an governmental agency connection.

Tidal restoration projects and activities, while often a high priority based upon the result of natural resource partners coming together for a common restoration objective, are not necessarily given special preference towards implementation simply because they are facilitated by such a collaboration. These projects are held to the same standards (and hence work through the same barriers and hurdles) as projects in a non-NEP geography.

Question 2 – How likely is it that the rates of restoration in National Estuary Programs are greater than the rates of restoration occurring in non-NEP estuaries in the U.S.? It is our assumption that NEPs will have an overall higher rate of restoration than other estuaries because NEPs benefit from a shared state and federal commitment to estuary health, which may be absent in other estuaries. Moreover, because of the status of being an NEP, they are more likely to receive scarce federal and state resources, as well as funding from other partners. NEPs are multi-stakeholder collaborative efforts that are not found in other estuaries in the U.S. Based on your experience and expert judgment, are NEPs substantially likely to have a higher rate of restoration than non-NEP estuaries? Please explain.

Answer:

Although I may paint a picture of hard times for NEPs above - having to jump through the same regulatory hoops as other projects - that is part of doing business in coastal restoration. NEPs and their restoration partners understand this and support that we should be held to the same regulatory and accountability standards as projects in non-NEP geographies or with no connection to the Program itself. NEPs and their partners do, however, recognize the tremendous benefit to a voluntary, collaborative and strategic approach to tidal restoration (as well as other coastal conservation issues NEPs address). Many funding agencies give credit to project proponents who work as a collective multi-stakeholder partnership. There is an assumption that such a partnership represents an agreed upon set of goals, objectives, implementation procedures and monitoring for a given project. This gives a funding agency a certain level of confidence that the project will be successful and supported at a local level. Project proposals written by NEP partners are also often more well defined and in concert with requested information outlined in a funding opportunity.

To answer your question specifically, yes, I do think NEPs have a higher likelihood of receiving funds for coastal restoration. I say this for a few reasons. In today's world of limited federal and state budgets and fewer dollars to put "on-the-ground" for projects, the conservation community has been pushed to become much more strategic in our thinking. By this I mean that we are looking at how projects fit into the larger watershed or landscape, we strive to accomplish as many partners' goal and objectives as possible, and we must leverage our funds as much as we possibly can. The NEP structure, their associated advisory committees and public outreach capabilities, lends itself to a role in facilitating such a strategic approach.

I worked for the FWS Coastal Program nearly 10 years and can say that for many of the reasons I described above, our Program encourages and actively engages in partnership with our local NEPs. In my tenure with the Coastal Program I have worked with NEPs in both Texas and Florida. When possible, our Program staff serve on technical advisory committees, participate in strategic planning and assist in project implementation. In fact, I was involved in drafting the current Strategic Plan for our southwest Florida focal area where I identified working with the NEPs as a priority for our Program. When appropriate and feasible, the Coastal Program has and continues to invest funding towards projects such as tidal restoration activities.

Original request to expert:

On Wed, Oct 23, 2013 at 4:57 PM, Steve Emmett-Mattox wrote:

Dear Ms. Devore,

Restore America's Estuaries is seeking to demonstrate the "additionality" of tidal wetland restoration in the U.S. for the purposes of generating carbon offsets under the Verified Carbon Standard. The VCS revised its rules in 2012 to include a standardized approach to demonstrate additionality. In order to comply with this approach, RAE has assembled a substantial data set and analysis. The data, analysis and discussion are attached. In a recent review by the VCS, they raised two questions that we would like your help in answering. I believe you to be an expert in tidal wetland restoration programs and activities in the U.S., and now seek your opinion on the following:

1 – to what extent do estuaries without a National Estuary Program face the same barriers to tidal wetland restoration activities as estuaries, which are part of a National Estuary Program? We have identified the following barriers, among others: funding, land ownership/control, political will, a local environment, which encourages partnerships, and social acceptability. Please note that we only need to consider barriers to tidal wetland restoration where it has already been identified as possible in the landscape. Based on your experience and expert judgment, do estuaries in NEPs face the same or similar barriers to implementation of tidal wetland restoration projects as estuaries that do not have an NEP? Please explain.

2 – how likely is it that the rates of restoration in National Estuary Programs are greater than the rates of restoration occurring in non-NEP estuaries in the U.S.? It is our assumption that NEPs will have an overall higher rate of restoration than other estuaries because NEPs benefit from a shared state and federal commitment to estuary health, which may be absent in other estuaries. Moreover, because of the status of being an NEP, they are more likely to receive scarce federal and state resources, as well as funding from other partners. NEPs are multi-stakeholder collaborative efforts that are not found in other estuaries in the U.S. Based on your experience and expert judgment, are NEPs substantially likely to have a higher rate of restoration than non-NEP estuaries? Please explain.

And last, please provide an up to date resume/CV, which we will share with the VCS.

Please let me know if you have any questions about this request, and thank you for your timely response.

Cheers,
Steve Emmett-Mattox
Senior Director for Strategic Planning and Programs

Restore America's Estuaries

EXPERT OPINION II

Curtis Tanner
Acting Manager, Environmental Restoration and Assessment Division
U.S. Fish and Wildlife Service

18 November 2013

Steve Emmet-Mattox
Senior Director for Strategic
Planning and Programs
Restore America's Estuaries

Dear Steve:

I am writing in response to your September 23, 2013, email requesting my expert opinion regarding tidal wetland restoration and greenhouse gas offsets. As you know, I have over twenty years of experience working on coastal wetland restoration and protection for the U.S. Fish and Wildlife Service. The views expressed in this letter are based on my own experience and perspective, and do not reflect an official agency position. I have attached a copy of my current resume for your use in assessing my credentials.

As I understand it, you are working to establish the viability of tidal wetland restoration as a tool for use in sequestering carbon dioxide to mitigate anthropogenic greenhouse gas emissions. You seek to establish the fact that at a National scale, tidal wetland restoration in the United States is limited in spatial scale and impact. Specifically, "activity penetration", or the prevalence of restoration project implementation relative to the opportunity for tidal wetland restoration, is relatively small. In your assessment of tidal restoration in the U.S., you estimate the "…Activity Penetration is 1.06 percent, which is less than 5 percent, and therefore tidal wetland restoration in the U.S. is additional…" as defined by the Verified Carbon Standard. In short, you assert that given the relatively small amount of tidal wetland restoration in the U.S. (as compared to opportunity and demonstrated need), investment in restoration would provide a viable alternative for carbon offset funds. I concur with your assessment.

Your analysis relied upon the most comprehensive data set available at the National level for tidal wetland restoration, accomplishment reporting from the National Estuary Program (NEP). You have specifically requested that I provide an assessment based on my experience and expert judgment whether use of these data are appropriate. First, you have asked whether estuaries covered by the NEP provide a representative sample, facing the same or similar barriers to tidal wetland restoration project implementation. Based on 20+ years of experience working on coastal restoration and protection issues and projects, it is my opinion that tidal wetland restoration is typically limited by a set of barriers common to estuaries throughout the United States; funding, land owner willingness, and social acceptability are nearly universal challenges for all projects and estuaries. Taken together as a whole, the geographic distribution of NEP sites provides a broad cross section of National estuarine ecosystem conditions, encompassing a range of ecological threats, fish and wildlife resource assets, and socio/political contexts.

This representative diversity applies to both human and non-human aspects of coastal ecosystems.

Second, you post the question as to whether the rate of restoration derived from analysis of NEP estuaries is representative. As I understand your analysis, if NEP estuaries had a substantially lower rate of restoration than non-NEP estuaries, your activity penetration estimate of 1.06 percent, as compared the VCS threshold of 5 percent, could be challenged. Based on my experience derived from project implementation and program management, NEP estuaries likely deliver a higher rate of restoration as compared to non-NEP estuaries, if significant differences do in fact exist. I base this assertion on observations of the opportunity space provided for restoration that NEP designation provides coastal ecosystems. The Clean Water Act directs each NEP to develop and implement a Comprehensive Conservation and Management Plan (CCMP). Agencies including the U.S. Fish and Wildlife Service respond to policies and Congressional funding directives to focus restoration efforts in NEP systems, often in response to the CCMP. NEP designation also works to focus the work of state agency, tribal government, and non-governmental organization partners to address restoration needs defined by the CCMP. In Puget Sound, development and implementation of the CCMP is the role of the Puget Sound Partnership (PSP), a Washington State cabinet-level agency. PSP has led development of the current CCMP for Puget Sound, referenced as the “Action Agenda”. PSP’s Action Agenda includes specific targets for estuarine restoration required to recover the health of Puget Sound. Other non-NEP coastal ecosystems in Washington State lack this political focus and dedicated state and National funding for tidal wetland restoration.

In summary, while I have not provided a detailed review of your data sources and analysis, I am familiar with the approach you have applied in your analysis. NEP estuaries provide applicable data set for your assessment of activity penetration for restoration. CCMP’s for NEP estuaries provide a numeric objective for restoration and thus a quantifiable estimate of opportunity and need. Accomplishment reporting required by U.S. EPA delivers an accounting of acres restored which can be compared to numeric targets. The 28 NEP systems distributed throughout the United States provide a representative cross section of coastal ecosystems and the challenges and opportunities faced by restoration projects proponents. NEP designation leads to a regional focus of efforts, that delivers activity penetration rates likely equal or greater than that of non-NEP systems.

Thank-you for the opportunity to provide my perspective on your assessment. Please contact me directly if you have questions or if I can be of additional assistance.

Sincerely,
Curtis D. Tanner
Original request to expert:

From: Steve Emmett-Mattox
Sent: Monday, September 23, 2013 1:42 PM
To: 'Tanner, Curtis'
Subject: expert guidance sought, Restore America's Estuaries tidal wetland restoration and ghg offsets

Dear Mr. Tanner,

Restore America's Estuaries is seeking to demonstrate the "additionality" of tidal wetland restoration in the U.S. for the purposes of generating carbon offsets under the Verified Carbon Standard. The VCS revised its rules in 2012 to include a standardized approach to demonstrate additionality. In order to comply with this approach, RAE has assembled a substantial data set and analysis. The data, analysis and discussion are attached. In a recent review by the VCS, they raised two questions that we would like your help in answering. I believe you to be an expert in tidal wetland restoration activities in the U.S., and now seek your opinion on the following:

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And last, please provide an up to date resume/CV, which we will share with the VCS.

Please let me know if you have any questions about this request, and thank you for your timely response.

Cheers,
Steve Emmett-Mattox
Senior Director for Strategic Planning and Programs
Restore America's Estuaries

DOCUMENT HISTORY

Version	Date	Comment
v1.0	20 Nov 2015	Initial version

VCS Methodology

VM0035

Methodology for Improved Forest Management through Reduced Impact Logging

Version 1.0

28 April 2016

Sectoral Scope 14

This methodology was developed by:

The Nature Conservancy

Protecting nature. Preserving life.™

The Nature Conservancy

TerraCarbon LLC

TerraCarbon, LLC

Table of Contents

1 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	Performance Method
Crediting Baseline	Performance Method

This methodology is applicable to projects which implement reduced impact logging practices to reduce greenhouse gas (GHG) emissions (hereafter termed *RIL-C practices*) in one or more of three GHG emission source categories (ie, timber felling, skidding and hauling). RIL-C practices may entail a range of improved logging and harvest planning practices, including, but not limited to, directional felling, improved log bucking (to permit greater recovery), improved harvest planning via pre-harvest inventory, skid trail planning and/or monocable winching, and reduction in width of haul roads and size of log landings.

The effectiveness of RIL-C practices, and accounting of emission reductions attributable to those practices, is assessed on the basis of their impacts post-harvest. Emission reductions are accounted for by applying a performance method approach, whereby emission reductions (net of baseline and project emissions) are assigned as a function of the difference between a set crediting baseline for each emission source category (ie, felling, skidding and hauling) and the measured impact of those parameters in the project scenario.

To ensure credible estimation of emission reductions, the impact parameters applied by this methodology are quantitative and outcome-based, rather than process-based (which are typically limited to demonstrating that the practice is in place, but may provide no information on how successful the implementation of the practice is). Further, emission reductions are estimated as a continuous function of the impact parameter values with which they correspond, providing better resolution of outcomes than a flat default factor. This methodology has been designed to ensure that emission reductions achieved based on one impact parameter are not reversed by excessive emissions with respect to another impact parameter, by requiring that all impact parameters must be at or below the crediting baseline in order for credits to be generated based on any one impact parameter.

Accounting is further simplified by incorporating the assumption that leakage equals zero and the wood products pool can be excluded because the methodology requires that there is no reduction in harvest levels.

Accounting is focused on emissions at the time of harvest from operations including felling, skidding and hauling, and delayed emissions from belowground biomass. Any net sequestration from comparatively improved growth post-RIL-C harvest is conservatively ignored.

Accounting of emission reductions begins on the project start date and is determined on all harvests through the project crediting period.

This document provides the framework for the methodology, and serves to outline core accounting procedures. Key parameters such as additionality benchmarks, crediting baselines, impact parameters, emission reduction equations and monitoring procedures are provided in corresponding geographic-specific RIL-C performance method modules. This methodology must be used in conjunction with a region-specific performance method module. The list of approved performance method modules applicable to this methodology can be found on the VCS website.

2 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions apply to this methodology:

Additionality Benchmark
The level of a given impact parameter below which a project is deemed additional, specified in terms of impact parameter values which represent a certain base level of performance among logging operations within a sampled logging landscape.

Crediting Baseline
The level of a given impact parameter below which emission reductions may be credited, specified in terms of impact parameter values which represent a certain base level of performance among logging operations within a sampled logging landscape. The corresponding baseline scenario is represented by an aggregate of individual logging operations from the logging landscape operating at this specified level of performance.

Impact Parameter
Quantitative parameter based on field measurements which defines both the crediting baseline and the additionality benchmark. Each impact parameter has an established empirical relationship with emissions levels, and is thus used as a proxy for emissions that can be readily measured in the field.

Logging Landscape
The geography, class of actors/sector, major logging system (eg, selective harvest) and timeframe within which the relationships of the impact parameter (with emission reductions) are applicable, and which is defined in the corresponding region-specific RIL-C performance method module.

Reduced Impact Logging (RIL-C)
Measures that reduce emissions from timber harvest in one or more of three emission source categories: felling, skidding and hauling. Component practices may include, but are not limited to, directional felling, improved log bucking, improved harvest planning via pre-harvest inventory, skid trail planning, mapping, and oversight and/or long cable winching, and reduction in width of haul roads and size of log landings.[1, 2]

3 APPLICABILITY CONDITIONS

This methodology applies to project activities which implement RIL-C practices in forests. Projects applying this methodology must meet the following applicability conditions:

1) The project activity does not involve a deliberate reduction in harvest levels. The criteria to demonstrate no intentional reduction in harvest level are provided in the applicable RIL-C performance method module.
2) The project activity and the baseline scenario do not involve conversion of forest to a non-forest land use/land cover (ie, both represent forests remaining as forests, *sensu* IPCC GL 2006).
3) In every year credited, the project proponent must hold legal authorization for all logging activities referenced in the project from the relevant government authority.
4) The project area must be located in a logging landscape developed for a corresponding region-specific RIL-C performance method module. It must be demonstrated that the entire project area is contained within the applicable logging landscape.
5) The entire project area meets the definition of forest, either host country-specific, UNFCCC or FAO definition.
6) RIL-C practices implemented as part of the project activity must not increase business-as-usual levels of impact on pre-existing dead wood stocks through slash management, salvage harvesting or other planned removal of dead wood.[3]

Requirements for developing a new region-specific performance method can be found in 0.

[1] Note that some practices may apply to more than one emission source category. Directional felling, for example, can serve to align logs with the planned skidding network, reducing skidding damage, and reduce damage to the felled log, improving roundwood recovery.

[2] Note that RIL-C practices do not include slash management, salvage harvesting or other planned removal of dead wood.

[3] VVBs need only confirm that this is the case through one of the following: a qualitative assessment of no evidence of removal of dead wood onsite (ie, looking for evidence of removal, or comparing dead wood carbon stocks in the project area to surrounding areas), interviewing project proponents, reviewing management plans, or a quantitative assessment of inventory data of dead wood carbon stocks (if they exist).

4 PROJECT BOUNDARY

Geographic boundary

The project area is defined as the area over which the project proponent holds authorization to conduct timber harvest over the length of the project crediting period. The area in its entirety must meet the definition of *forest* (see Section 3 above for definition of *forest*). The project area may be a subset of the concession holdings of the project proponent, but that the full extent of the project area must be defined at validation.

The boundary of the project area must be clearly delineated and documented with digital maps in the format specified by the VCS rules.

Temporal boundary

The temporal boundary of the project is set from the project start date, marking the initial harvest on which RIL-C practices are implemented, and the end of the project crediting period.

Pools and Sources

Table 1 below discusses the carbon pools included in the project boundary. Pools included in the project boundary are restricted to above- and below-ground tree biomass.

Table 2 below discusses the emission sources that are included in the project boundary. Emissions from fossil fuel combustion are conservatively excluded. Note that there are no optional pools, and that the included pools/sources (above- and belowground tree biomass) are accounted in both the baseline and project scenarios.

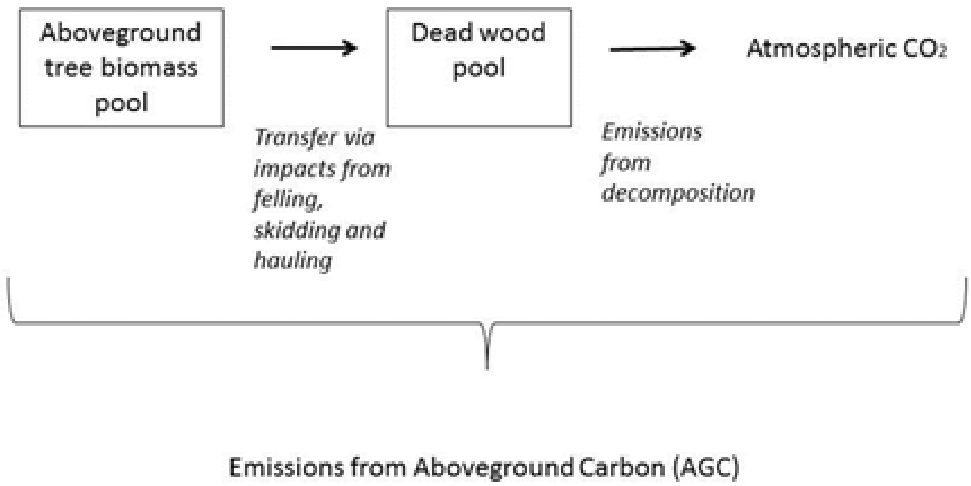
Table 1: GHG Pools Included in or Excluded from the Project Boundary

Carbon pools	Included?	Justification/Explanation
Aboveground tree biomass (included in *aboveground carbon*, AGC)	Yes	Must be included – represents a significant pool affected by the project activity
Aboveground non-tree biomass	No	Conservatively excluded – this pool is expected to increase relative to the baseline as a result of the project activity (from reduced skidding damage)
Belowground biomass	Yes	Must be included in all cases – represents a significant pool affected by the project activity

Dead wood (included in *aboveground carbon*, AGC)	Yes	Standing and lying dead wood produced by harvest are included. Changes in stocks of pre-existing dead wood are conservatively ignored (further explained below).
Harvested wood products	No	Applicability condition 1 obviates the inclusion of the wood products pool because there is no difference in harvest levels between the baseline and project scenarios.
Litter	No	No significant change is expected in this pool as a result of the project activity
Soil	No	No significant change is expected in this pool as a result of the project activity

Aboveground carbon stocks include both live and dead (standing and lying) pools. Emission reductions quantified for the aboveground carbon pool represent transfer of biomass carbon from live trees to dead wood, followed by steady emissions via decomposition, without explicitly separating the accounting of these elements, as described in Figure 1 below.

Figure 1: Schematic of Pools and Fluxes Incorporated in Aboveground Carbon (AGC) Emissions



Emissions from the dead wood pool included in accounting are from dead wood produced during harvest (ie, slash and new standing dead wood from harvest and collateral damage). This methodology conservatively does not account for changes in pre-existing standing and lying dead wood after harvest; these stocks would be expected to be greater in the project scenario post-harvest due to less-impactful RIL-C practices. As RIL-C practices implemented as part of the project activity do not include slash management, salvage harvesting or other planned removal of dead wood, this assumption is further assured.

Table 2: GHG Emission Sources Included In or Excluded From the Project Boundary

Source		Gas	Included?	Justification/Explanation
Baseline	Fossil fuel emissions	CO_2	No	Conservatively excluded - project activity is expected to result in lower emissions (from more efficient use of skidders) from use of machinery
		CH_4	No	Conservatively excluded - project activity is expected to result in lower emissions (from more efficient use of skidders) from use of machinery
		N_2O	No	Conservatively excluded - project activity is expected to result in lower emissions (from more efficient use of skidders) from use of machinery
Project	Fossil fuel emissions	CO_2	No	Same as for baseline scenario
		CH_4	No	Same as for baseline scenario
		N_2O	No	Same as for baseline scenario

5 BASELINE SCENARIO

The baseline scenario is established by the applicable region-specific RIL-C performance method module, and represents logging operations in aggregate, operating at a specified level of performance, for the referenced logging landscape. The baseline scenario is represented by region-specific crediting baselines set for each impact parameter (ie, proxy factor) by the applicable region-specific RIL-C performance method module.

6 ADDITIONALITY

This methodology uses a performance method for the demonstration of additionality.

Step 1: Regulatory Surplus

The project proponent must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the *VCS Standard*.

Step 2: Performance Benchmark

Projects must exceed the region-specific performance benchmark for each impact parameter (ie, proxy factor), as provided in the applicable RIL-C performance method module. One or more impact parameters are defined in the applicable RIL-C performance method module for each of three categories: felling impacts, skidding impacts and hauling impacts.

Projects may only be credited for emission reductions from one or more impact parameters if they are deemed additional. A project is deemed additional for one or more impact parameters if the impact parameter is below the additionality benchmark assigned for that impact parameter. **The project may only be credited for emission reductions if all impact parameters are at or below their respective crediting baselines.**

This benchmark threshold should be conservative and strike a balance between restriction of freeriders and feasibility of participation. This threshold may be different from (ie, lower than) the crediting baseline. Thus, while a project must be below the additionality benchmark in order to receive any emission reductions credits, once below the additionality benchmark, the amount of credits generated is measured using the crediting baseline.

7 QUANTIFICATION OF GHG EMISSION REDUCTIONS

7.1 Baseline and Project Emissions

Baseline and project emissions are addressed simultaneously, whereby an emission reduction value (specified in tonnes of CO_2 reduced (ie, net of baseline and project emissions)) is assigned as a function of the difference between the impact parameter (proxy variable) in the project and in the crediting baseline for each emission source category (felling, skidding and hauling). Assigned emission reductions, expressed on a per hectare basis, are then summed for the three emission source categories, and multiplied by the number of hectares in the harvest area in year *t*.

Step 1: Determine Harvest Area

The harvest area in year *t* should be delineated on the basis of paper maps or GIS files specifying the actual harvest area in year *t*. From this area, the project proponent must delineate and exclude any areas where timber harvest impacts will not happen for any reason (eg, due to geographic features, low stocking, set asides or poor planning). The resulting area is specified in hectares to produce parameter A_t.

Step 2: Calculate Emission Reductions Based on Measured Impact Parameters

Calculate emission reductions for each emission source category based on measured impact parameters. Each equation below calculates emission reductions in tCO_2/ha (the dependent variable) as a function of (ie, f_{AGC}) a specific impact parameter (the independent variable). Functions and corresponding units are provided in the applicable region-specific RIL-C performance method module.

$$\mathrm{ER_{fell\_AGC,t} = f_{AGC}\ (FELL_t)} \tag{1}$$

$$\mathrm{ER_{skid\_AGC,t} = f_{AGC}\ (SKID_t)} \tag{2}$$

$$ER_{haul\_AGC,t} = f_{AGC}\ (HAUL_t) \tag{3}$$

$$ER_{fell\_BGB,t} = f_{BGB}\ (FELL_t) \tag{4}$$

$$ER_{skid\_BGB,t} = f_{BGB}\ (SKID_t) \tag{5}$$

$$ER_{haul\_BGB,t} = f_{BGB}\ (HAUL_t) \tag{6}$$

Where:

$FELL_t$	= Felling impact parameter measured in year *t* (unit specified in performance module)
$SKID_t$	= Skidding impact parameter measured in year *t* (unit specified in performance module)
$HAUL_t$	= Hauling impacts measured in year *t* (unit specified in performance module)
$ER_{fell\_AGC,t}$	= Emission reductions from aboveground carbon related to felling in year *t* (t CO_2e/ha)
$ER_{skid\_AGC,t}$	= Emission reductions from aboveground carbon related to skidding in year *t* (t CO_2e/ha)
$ER_{haul\_AGC,t}$	= Emission reductions from aboveground carbon related to hauling in year *t* (t CO_2e/ha)
$ER_{fell\_BGB,t}$	= Emission reductions from belowground biomass related to felling in year *t* (t CO_2e/ha)
$ER_{skid\_BGB,t}$	= Emission reductions from belowground biomass related to skidding in year *t* (t CO_2e/ha)
$ER_{haul\_BGB,t}$	= Emission reductions from belowground biomass related to hauling in year *t* (t CO_2e/ha)
t	= 1, 2, 3, …*t* time elapsed since the start of project activity (years)

Step 3: Sum Emission Reductions

Sum all emission reductions to determine the combined emission reductions from above- and belowground biomass.

For any time *t,* if any impact parameter is greater than or equal to the crediting baseline for that year, parameters $RILC_{,AGC,t}$ and $RILC_{,BGB,t}$ must be set to zero.

$$\mathrm{RILC_{AGC,t} = ER_{fell\_AGC,t} + ER_{skid\_AGC,t} + ER_{haul\_AGC,t}} \quad (7)$$

$$\mathrm{RILC_{BGB,t} = ER_{fell\_BGB,t} + ER_{skid\_BGB,t} + ER_{haul\_BGB,t}} \quad (8)$$

If ER_{Fellt} and/or ER_{Skidt} and/or ER_{Hault} < 0 then $RILC_{AGCt}$ = 0 and $RILC_{BGBt}$ = 0.

Where:

$RILC_{,AGC,t}$ = Combined emission reductions from aboveground carbon from RIL-C in year *t* (t CO_2e/ha)

$RILC_{,BGB,t}$ = Combined emission reductions from belowground biomass from RIL-C in year *t* (t CO_2e/ha)

$ER_{fell\_AGC,t}$ = Emission reductions from aboveground carbon related to felling in year *t* (t CO_2e/ha)

$ER_{skid\_AGC,t}$ = Emission reductions from aboveground carbon related to skidding in year *t* (t CO_2e/ha)

$ER_{haul\_AGC,t}$ = Emission reductions from aboveground carbon related to hauling in year *t* (t CO_2e/ha)

$ER_{fell\_BGB,t}$ = Emission reductions from belowground biomass related to felling in yer *t* (t CO_2e/ha)

$ER_{skid\_BGB,t}$ = Emission reductions from belowground biomass related to skidding in year *t* (t CO_2e/ha)

$ER_{haul\_BGB,t}$ = Emission reductions from belowground biomass related to hauling in year *t* (t CO_2-e/ha)

t = 1, 2, 3 …*t* time elapsed since the start of project activity (years)

Step 4: Determine Emission Reductions by Harvest Area

Emissions from aboveground carbon result from transfer of aboveground live biomass to the dead wood pool followed by steady decomposition.

Emission reductions from the aboveground carbon pool are determined either by applying an applicable dead wood decomposition rate, using equation 9a, or by applying a 10-year linear decay rate, using equation 9b.

Emission reductions from the belowground biomass pool must apply a 10-year linear decay rate (in both equations 9a and 9b). Thus, for a given year *t*, annual emission reductions from above- and belowground carbon are summed across areas previously harvested.

$$C_{RIL,t} = \sum_{t=1}^{t} A_t * RILC_{AGC,t} * (1-K)^{t-t*} * K + \sum_{t-10}^{t} A_t * RILC_{BGB,t} * (\frac{1}{10}) \quad (9a)$$

Where:

$C_{RIL,t}$ = Total emission reductions at time *t* (t CO_2e)

$RILC_{,AGC,t}$ = Combined emission reductions from aboveground carbon from RIL-C in year *t* (t CO_2e/ha)

$RILC_{,BGB,t}$ = Combined emission reductions from belowground biomass from RIL-C in year *t* (t CO_2e/ha)

K = Dead wood annual decomposition rate (percent/year)

A_t = Harvest area in year *t* (ha)

t = 1, 2, 3… *t* time elapsed since the start of the RIL project activity (years)

$$C_{RIL,t} = \sum_{t-10}^{t} A_t * RILC_{AGC,t} * (\frac{1}{10}) + \sum_{t-10}^{t} A_t * RILC_{BGB,t} * (\frac{1}{10}) \quad (9b)$$

Where:

$C_{RIL,t}$ = Total emission reductions at time *t* (t CO_2e)

$RILC_{,AGC,t}$ = Combined emission reductions from aboveground carbon from RIL-C in year *t* (t CO_2e/ha)

$RILC_{,BGB,t}$ = Combined emission reductions from belowground biomass from RIL-C in year *t* (t CO_2e/ha)

A_t = Harvest area in year *t* (ha)

t 1, 2, 3, …*t* time elapsed since the start of the RIL project activity (years)

***Ex-ante* Projections of GHG Emission Reductions**

At project validation and 10 year baseline re-assessment, an ex-ante estimate of GHG emission reduction must be produced in accordance with VCS rules. The projection will apply all calculations outlined above, incorporating impact parameters and functions to estimate emission reductions (ie, f_{AGC} and f_{BGB}) provided in the applicable region-specific RIL-C performance method module. Anticipated area harvested per year (A_t) will be referenced from annual authorized harvest areas specified in the project management authorization; it is understood that these areas may differ from the areas actually harvested ex post.

For each impact parameter (eg, $FELL_t$) that will be addressed through the project activity and for each year, the project proponent must assume a conservative level of effectiveness achieved, as a percent improvement from the crediting baseline value provided in the applicable region-specific RIL-C performance method module. The anticipated percent improvement is a value <1.0, and must be justified referencing specific operational management procedures and/or infrastructure to be put in place during project implementation.

For example, if a 30% improvement (indicating reduced emissions) from baseline is anticipated for a given impact parameter, and assuming that level of improvement meets the additionality benchmark, then multiply the crediting baseline value of the impact parameter by (1 – 0.30) = 0.70. The resulting value of the impact parameter is the basis for calculating emission reductions from the crediting baseline. Note that if a given impact parameter is constructed to increase from the baseline value with a decline in associated emission levels (rather than decline from baseline value with declining emissions as assumed above), then the example equation above would be modified accordingly.

7.2 Leakage

Since the applicability conditions do not allow for changes in harvest levels, it can be conservatively assumed that leakage is zero because there is no difference in harvest levels between the baseline and project scenarios.

7.3 Summary of GHG Emission Reduction and/or Removals

Uncertainty

Sources of uncertainty include uncertainty with respect to the calculation of emission reductions from impact parameters, and uncertainty with respect to estimates of impact parameters. These two sources of uncertainty are addressed by setting demonstrably conservative emission reductions associated with each impact parameter and through imposed minimum sampling intensity requirements for estimation of impact parameters, all established in the applicable region-specific RIL-C performance method module. Therefore, no uncertainty deduction is necessary. It is assumed that project area boundaries, A_t, are known exactly.

Net GHG emission reductions are calculated as follows:

$$ER_t = C_{RIL,t} \quad \textbf{(10)}$$

Where:

ER_T = Net GHG emission reductions in year *t* (t CO_2e)
$C_{RIL,t}$ = Total emission reductions at time *t* (t CO_2e)

Emission reductions eligible for issuance as Verified Carbon Units (VCUs) are calculated by subtracting the AFOLU pooled buffer account contribution from ER_t, referencing the project's risk rating at time *t* using the most recent version of the VCS *AFOLU Non-Permanence Risk Tool*.

8 MONITORING

The purpose of monitoring is to generate field measurements after each harvest from which emission reductions can be estimated. Thus, following completion of each harvest, all impact parameters from all logging emission source categories (felling, skidding and hauling), as identified in the applicable region-specific RIL-C performance method module, must be sampled in the field and estimated according to procedures detailed in the applicable region-specific RIL-C performance method.

Throughout the project crediting period, monitoring must be conducted within five years after each harvest unless otherwise specified in the applicable geographic-specific performance method module.

The expectation of users of this methodology and future modules developed based on this methodology is that verification audit teams are able to resample monitoring activities that have occurred over an entire verification period. The appropriate monitoring time frame will be dictated by regional forest regrowth rates and decomposition rates. For example, areas in dry forest with slow forest regrowth and decomposition may be able to monitor every 5 years, and areas in wet tropical forest with very fast growth rates and decomposition may need to be monitored every 2 years.

8.1 Data and Parameters Available at Validation

Data / Parameter	f_{AGC} $(FELL_t)$
Data unit	Dimensionless
Description	Equation estimating emission reductions from aboveground carbon related to felling in year *t* ($ER_{fell\_AGC,t}$) as a function of felling impacts measured in year *t* ($FELL_t$)
Equation	1
Source of data	Applicable RIL-C performance module

Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Refer to applicable RIL-C performance method
Purpose of data	Calculation of emission reductions
Comment	

Data / Parameter:	f_{BGB} $(FELL_t)$
Data unit	Dimensionless
Description	Equation estimating emission reductions from belowground carbon related to felling in year *t* $(ER_{fell\_BGB,t})$ as a function of felling impacts measured in year *t* $(FELL_t)$
Equation	4
Source of data	Applicable RIL-C performance module
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Refer to applicable RIL-C performance method
Purpose of data	Calculation of emission reductions
Comment	

Data / Parameter:	f_{AGC} $(SKID_t)$
Data unit	Dimensionless
Description	Equation estimating emission reductions from aboveground carbon related to skidding in year *t* $(ER_{skid\_AGC,t})$ as a function of skidding impacts measured in year *t* $(SKID_t)$
Equation	2
Source of data	Applicable RIL-C performance module
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Refer to applicable RIL-C performance method

Purpose of data	Calculation of emission reductions
Comment	

Data / Parameter:	f_{BGB} $(SKID_t)$
Data unit	Dimensionless
Description	Equation estimating savings factor for emissions from belowground carbon related to skidding in year t $(ER_{skid\_BGB,t})$ as a function of skidding impacts measured in year t $(SKID_t)$
Equation	3
Source of data	Applicable RIL-C performance module
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Refer to applicable RIL-C performance method
Purpose of data	Calculation of emission reductions
Comment	

Data / Parameter:	f_{AGC} $(HAUL_t)$
Data unit	Dimensionless
Description	Equation estimating savings factor for emissions from aboveground carbon related to hauling in year t $(ER_{haul\_AGC,t})$ as a function of hauling impacts measured in year t $(HAUL_t)$
Equation	3
Source of data	Applicable RIL-C performance module
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Refer to applicable RIL-C performance method
Purpose of data	Calculation of emission reductions
Comment	

Data / Parameter:	f_{BGB} $(HAUL_t)$
Data unit	Dimensionless
Description	Equation estimating savings factor for emissions from belowground carbon related to hauling in year t $(ER_{haul\_BGB,t})$ as a function of hauling impacts measured in year t $(HAUL_t)$
Equation	6
Source of data	Applicable RIL-C performance module
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Refer to applicable RIL-C performance method
Purpose of data	Calculation of emission reductions
Comment	

Data / Parameter:	K
Data unit	Percent/year
Description	Dead wood annual decomposition rate
Equation	9a
Source of data	Values from the literature (eg, Chambers *et al.* 2000) must be used
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	The rate used should be derived from a similar climate regime and forest type as the project area
Purpose of data	Calculation of emission reductions
Comment	Note that this rate is justified and applied in project accounting (using equation 9a ex post), and is not specified or incorporated in the RIL-C performance method modules.

8.2 Data and Parameters Monitored

Data / Parameter	A_t.
Data unit	Ha
Description	Area of actual harvest area in year *t.* It is expected that this area may be smaller than the authorized area of harvest due to un-stocked areas or areas where timber harvest and skidding are infeasible (eg, due to geographic features), or areas set aside from logging activity.
Equations	9a, 9b
Source of data	Paper maps or GIS files
Description of measurement methods and procedures to be applied	
Frequency of monitoring/recording	Following completion of each annual harvest
QA/QC procedures to be applied	Any imagery or GIS datasets used must be geo-registered referencing corner points, clear landmarks or other intersection points.
Purpose of data	Calculation of emission reductions
Calculation method	.
Comment	

Data / Parameter:	$FELL_t$
Data unit	Units as specified in the applicable RIL-C performance module
Description	Felling impact parameter, measured in year *t*
Equation	1, 4
Source of data	
Description of measurement methods and procedures to be applied	See procedures as specified in applicable RIL-C Performance Method
Frequency of monitoring/recording	Following completion of each annual harvest
QA/QC procedures to be applied	See applicable RIL-C performance module
Purpose of data	Calculation of emission reductions
Calculation method	

Comment	

Data / Parameter	$SKID_t$
Data unit	Units as specified in the applicable performance module
Description	Skidding impact parameter, measured in year *t*
Equation	2, 5
Source of data	
Description of measurement methods and procedures to be applied	See procedures as specified in the applicable performance module
Frequency of monitoring/recording	Following completion of each annual harvest
QA/QC procedures to be applied	See applicable performance module
Purpose of data	Calculation of emission reductions
Calculation method	
Comment	

Data / Parameter	$HAUL_t$
Data unit	Units as specified in the applicable performance module
Description	Hauling impact parameter, measured in year *t*
Equation	4, 6
Source of data	
Description of measurement methods and procedures to be applied	See procedures as specified in the applicable performance module
Frequency of monitoring/recording	Following completion of each annual harvest
QA/QC procedures to be applied	See applicable performance module
Purpose of data	Calculation of emission reductions
Calculation method	
Comment	

Data / Parameter	$ER_{fell\_AGC,t}$
Data unit	t CO_2 /ha
Description	Emission reductions from aboveground carbon related to felling in year *t*
Equation	1, 7
Source of data	Applicable RIL-C performance module
Description of measurement methods and procedures to be applied	
Frequency of monitoring/recording	Following completion of each annual harvest
QA/QC procedures to be applied	
Purpose of data	Calculation of emission reductions
Calculation method	
Comment	

Data / Parameter	$ER_{skid\_AGC,t}$
Data unit	t CO_2 /ha
Description	Emission reductions from aboveground carbon related to skidding in year *t*
Equation	2, 7
Source of data	Applicable RIL-C performance module
Description of measurement methods and procedures to be applied	
Frequency of monitoring/recording	Following completion of each annual harvest
QA/QC procedures to be applied	
Purpose of data	Calculation of emission reductions
Calculation method	
Comment	

Data / Parameter	$ER_{haul\_AGC,t}$
Data unit	t CO_2 /ha
Description	Emission reductions from aboveground carbon related to hauling in year *t*

Equation	3, 7
Source of data	Applicable RIL-C performance module
Description of measurement methods and procedures to be applied	
Frequency of monitoring/recording	Following completion of each annual harvest
QA/QC procedures to be applied	
Purpose of data	Calculation of emission reductions
Comment	

Data / Parameter	$ERf_{ell\_BGB,t}$
Data unit	t CO_2 /ha/year
Description	Emission reductions from belowground biomass related to felling in year *t*
Equation	4, 8
Source of data	Applicable RIL-C performance module
Description of measurement methods and procedures to be applied	
Frequency of monitoring/recording	Following completion of each annual harvest
QA/QC procedures to be applied	
Purpose of data	Calculation of emission reductions
Calculation method	
Comment	Emission reductions from the belowground biomass pool are applied annually over a 10 year period post-harvest (annual emission reductions from belowground biomass are equal to 1/10 of the total emission reduction)

Data / Parameter	$ER_{skid\_BGB,t}$
Data unit	t CO_2 /ha/year
Description	Emission reductions from belowground biomass related to skidding in year *t*
Equation	5, 8

Source of data	Applicable RIL-C performance module
Description of measurement methods and procedures to be applied	
Frequency of monitoring/recording	Following completion of each annual harvest
QA/QC procedures to be applied	
Purpose of data	Calculation of emission reductions
Calculation method	
Comment	Emission reductions from the belowground biomass pool are applied annually over a 10 year period post-harvest (annual emission reductions from belowground biomass are equal to 1/10 of the total emission reduction)

Data / Parameter	$ER_{haul\_BGB,t}$
Data unit	t CO_2 /ha/year
Description	Emission reductions from belowground biomass related to hauling in year *t*
Equation	6, 8
Source of data	Applicable RIL-C performance module
Description of measurement methods and procedures to be applied	
Frequency of monitoring/recording	Following completion of each annual harvest
QA/QC procedures to be applied	
Purpose of data	Calculation of emission reductions
Comment	Emission reductions from the belowground biomass pool are applied annually over a 10 year period post-harvest (annual emission reductions from belowground biomass are equal to 1/10 of the total emission reduction)

Data / Parameter	$RILC_{,AGC,t}$
Data unit	t CO_2 /ha

Description	Emission reductions from aboveground carbon from RIL-C in year *t*
Equation	7, 9a, 9b
Source of data	Calculated
Description of measurement methods and procedures to be applied	
Frequency of monitoring/recording	Following completion of each annual harvest
QA/QC procedures to be applied	
Purpose of data	Calculation of emission reductions
Calculation method	
Any comment	

Data / Parameter	$RILC_{,BGB,t}$
Data unit	t CO_2 /ha/year
Description	Emission reductions from belowground biomass from RIL-C in year *t*
Equation	8, 9a, 9b
Source of data	Calculated
Description of measurement methods and procedures to be applied	
Frequency of monitoring/recording	Following completion of each annual harvest
QA/QC procedures to be applied	
Purpose of data	Calculation of emission reductions
Calculation method	
Comment	Emission reductions from the belowground biomass pool are applied annually over a 10 year period post-harvest (annual emission reductions from belowground biomass are equal to 1/10 of the total emission reduction).

Data / Parameter	$C_{RIL,t}$
Data unit	t CO_2-e

Description	Total emission reductions at time *t*
Equation	9a, 9b
Source of data	Calculated
Description of measurement methods and procedures to be applied	
Frequency of monitoring/recording	Following completion of each annual harvest
QA/QC procedures to be applied	
Purpose of data	Calculation of emission reductions
Calculation method	
Comment	

8.3 Description of the Monitoring Plan

Monitored parameters, and sampling and measurement procedures are specified in the applicable region-specific RIL-C performance method module.

9 REFERENCES

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APPENDIX 1: REGION-SPECIFIC PERFORMANCE METHOD REQUIREMENTS

Performance method modules may be developed for various geographies. General requirements for crediting and additionality benchmarks, and proxy emission reduction relationships, include:

1) The performance method must clearly specify the logging landscape and timeframe within which the values/relationships are applicable (ie, the sample population[4]). The logging landscape must be defined by broad parameters of consistent forest structure and composition (eg, the WWF Forested Ecoregions (Olson *et al.* 2001)).

2) The performance method must define additionality and crediting baselines in terms of impact parameters. Impact parameters must cover the following three sources of logging emissions: felling, skidding and hauling. One or more impact parameters may be identified for each of the three emissions source categories. When more than one impact parameter is identified for an emission source category, they must be measures of distinct (non-overlapping) components of that emissions source category.

3) The performance method must relate emission reductions to impact parameters and quantify and discount uncertainty in the dependent variable (ie, emission reductions). Emission reductions are calculated from (baseline) emissions associated with the crediting baseline value. Relationships between impact parameters and emission reductions must be developed for above and belowground tree biomass for each emission category (logging, felling and hauling) and expressed in units of tCO_2e/ha.

4) The performance method must specify monitoring procedures for all defined impact parameters.

An example of the derivation of applicable benchmarks and proxy relationships is provided in *VMD0047 Performance Method for Reduced Impact Logging (RIL-C) in East and North Kalimantan*.

[4] Note that conservative bias is allowed in sampling (ie, skewed toward logging operations allowing access to researchers).

DOCUMENT HISTORY

Version	Date	Comment
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VCS Methodology

VM0036

Methodology for Rewetting Drained Temperate Peatlands

Version 1.0

17 July 2017

Sectoral Scope 14

The methodology was developed by:

Silvestrum Climate Associates

University of Greifswald

Partner in the Greifswald Mire Centre

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Authors:

Dr. Igino Emmer, Silvestrum Climate Associates
John Couwenberg, Greifswald University, Partner in the Greifswald Mire Centre

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1 SOURCES

The methodology makes use of the following approved methodologies and methodological tools[1]:

- CDM methodology *AR-ACM0001 Afforestation or reforestation of degraded land*
- CDM methodological tool *Calculation of the number of sample plots for measurements within A/R CDM project activities*
- CDM methodological tool *Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities*
- CDM methodological tool *Tool for testing significance of GHG emissions in A/R CDM project activities*

This methodology uses the latest versions of the following module[2]:

- VCS module *VMD0019 Methods to project future conditions*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

This methodology outlines procedures to estimate the reduction of net greenhouse gas emissions resulting from project activities implemented to rewet drained peatlands in temperate climatic regions. It allows for the estimation of GHG emissions from drained and rewetted peatlands and also accounts for changes in carbon stocks in selected non-peat carbon pools.

The scope of this methodology is essentially limited to project activities that aim at the rewetting of peatlands that have been drained for forestry, peat extraction or agriculture, but where these activities are not or no longer profitable. Post-rewetting land use is limited to forestry, agriculture, nature conservation/recreation, or activities limited to those aiming at GHG emission reductions, or a combination of these activities.

This methodology uses ground vegetation composition and water table depth as proxies for peatland GHG emissions, known as the 'GEST' approach (GEST: Greenhouse gas Emission Site Type). Vegetation is well qualified for indicating greenhouse gas fluxes (Couwenberg *et al.* 2011) due to the following:

- It is a good indicator of water table depth, which in turn strongly correlates with GHG fluxes;

[1] CDM tools are available at https://cdm.unfccc.int/methodologies/ARmethodologies/tools
[2] VCS modules are available at the VCS website.

- It is controlled by various other site factors that determine GHG emissions from peatland, such as nutrient availability, soil reaction (acidity) and land use (history);
- It is itself directly and indirectly responsible for the predominant part of the GHG emissions by regulating CO_2 exchange, supplying organic matter (including root exudates) for CO_2 and CH_4 formation, reducing peat moisture, and by providing possible bypasses for increased methane emission via aerenchyma ('shunt species');
- It reflects long-time water table conditions and thus provides indication of average GHG fluxes on an annual time scale;
- It allows fine-scaled mapping (e.g., at scales 1:2,500 – 1:10,000).

Procedures are provided for the estimation of the Peat Depletion Time (PDT) and the assessment of the maximum eligible quantity of GHG emission reductions by rewetting, and is based either on the difference between the remaining peat carbon stock in the project and baseline scenarios after 100 years (total stock approach), or the difference in cumulative carbon loss in both scenarios since project start (stock loss approach).

Transient peaks of CH_4 emissions after rewetting may occur. For their quantification, conservative estimates from peer-reviewed literature sources must be used.

This methodology addresses anthropogenic peat fires occurring in drained peatland and establishes a conservative default value (*Fire Reduction Premium*), based on fire occurrence and extension in the project area in the baseline scenario, so as to avoid the direct assessment of GHG emissions from fire in the baseline and the project scenarios.

Under the applicability conditions of this methodology, market leakage, activity shifting and ecological leakage do not occur and the methodology provides criteria for justification of the absence of such leakage.

The methodology provides for the determination of the project's net GHG benefits and the resulting Verified Carbon Units (VCUs) that are generated. The methodology details the steps necessary to come to the final calculation of the project's net GHG benefits, represented by NER_{RDP}.

$$NER_{RDP} = GHG_{BSL} - GHG_{WPS} + Fire\ Reduction\ Premium - GHG_{LK}$$

Where:

NER_{RDP}	Total net CO_2 equivalent emission reductions from the rewetting of drained peatland (RDP) project activity
GHG_{BSL}	Net CO_2 equivalent emissions in the baseline scenario
GHG_{WPS}	Net CO_2 equivalent emissions in the project scenario
Fire Reduction Premium	Net CO_2 equivalent emission reductions from peat combustion due to

	rewetting and fire management
GHG_{LK}	Net CO_2 equivalent emissions due to leakage

3 DEFINITIONS

Greenhouse gas Emission Site Type (GEST)
A combination of plant species indicating long-term water table depths and other characteristics relevant to GHG fluxes (e.g., peat type, pH, nutrient status), associated with annual mean GHG fluxes of carbon dioxide and methane (expressed as CO_2e) based on literature or country-specific measurements. In absence of vegetation, water table depth is used as the main proxy (Couwenberg *et al.* 2011).

Net Ecosystem Exchange (NEE)
An instantaneous measurement of the inward and outward flows of carbon within an ecosystem. NEE is measured by eddy-flux towers to determine the amount of CO_2 entering an ecosystem and the amount of carbon being lost through respiration simultaneously.

Net Ecosystem Production (NEP)
A measurement of the net gain (or loss) of carbon in a system over a period of time. NEP is estimated based on long-term averages of NEE measurements.

Peatland
The definition is provided in the *VCS Program Definitions*. For the purpose of this methodology, organic soils that do not meet the depth requirement in the used definition but that are connected to the peatland area may be deemed part of the peatland area included in the GHG accounting. Isolated areas of organic soil that do not meet the depth requirements are not considered peatland.

Water table depth[3]
Depth of sub-soil or above-soil surface of water, relative to the soil surface.

4 APPLICABILITY CONDITIONS

This methodology is applicable under the following conditions:

1) The project activity is the rewetting of drained peatland.
2) The project area:
   a) Meets the definition of a peatland;
   b) Is located in a temperate[4] climatic region.
3) The project area was drained for the following land use scenarios or a combination of the

[3] In other methodologies, this term may be referred to as ‘drainage depth’, where it is implied to have the same meaning.
[4] The GEST approach has, so far, only been developed for temperate climates.

following land use scenarios:

a) Forestry that is not or no longer profitable (as determined on the basis of annual reports, annual accounts, market studies, government studies, or land use planning reports and documents);

b) Peat extraction that has been abandoned at least 2 years prior to the project start date; and/or,

c) Agriculture that has been abandoned at least 2 years prior to the project start date or will be continued in the project, or where drainage of additional peatland for new agricultural sites will not occur or is prohibited by law.

4) Post-rewetting land use is limited to the following or a combination of the following:

   a) Forestry (including biomass production but excluding IFM and REDD activities);

   b) Agriculture (excluding ALM activities); and/or,

   c) Nature conservation/recreation.

5) The following activities may occur in the baseline scenario:

   a) Biomass burning.

6) The following activities must not occur in the baseline scenario:

   a) Harvesting for commercial purposes; or,

   b) Collection of firewood for commercial purposes.

7) The following activities may not occur in the project scenario:

   a) Peat extraction;

   b) Burning of peat;

   c) Burning of biomass; and,

   d) N-fertilizer usage.

8) Project design and site selection must include the following:

   a) Project GHG benefits are not negatively affected by drainage activities that occur outside the project area[5].

   b) Leakage caused by activity shifting, market effects and hydrological connectivity is avoided[6].

9) Live tree vegetation may be present and subject to carbon stock changes (e.g., due to harvesting) in both the baseline and project scenarios.

10) Where GHG emission reductions from reducing peat fires are claimed by the project, the following must be met:

[5] This is further specified in Section 5.2

[6] This is further specified in Section 8.4.

a) A threat of frequent on-site fires must be been demonstrated[7].

b) Where the default procedure provided by this methodology for assessing GHG emissions due to peat fires in the baseline scenario cannot be used, such baseline emissions must conservatively not accounted for; and,

c) Peatland rewetting must be combined with fire management.

11) It must be demonstrated by referring to peer-reviewed literature and by sufficient rewetting that N_2O emissions will not increase in the project scenario compared to the baseline scenario.

12) In the baseline scenario, the peatland must be drained.

5 PROJECT BOUNDARY

5.1 Temporal Boundaries

Project Crediting Period

The temporal boundary for projects applying this methodology is equal to the project crediting period. The project must have a robust operating plan covering this period.

Where emissions increase during a transient period after rewetting, this is regarded as a negative emission reduction and falls within the project crediting period.

Project proponents must determine the project crediting period, the project crediting period start date and the project start date and provide verifiable evidence to support these claims.

Peat Depletion Time (PDT)

Peat depletion may be accelerated by peat fires and is attained if the peat has disappeared or if a stable water table inhibits further oxidation of the peat. The PDT for a stratum in the baseline scenario equals the period during which the project can claim emission reductions from rewetting and is, per stratum *i*, at the project start date and at each reassessment of the baseline scenario (as outlined in Section 6.2) estimated as:

$$t_{PDT\text{-}BSL,i} = Depth_{peat\text{-}BSL,i} \,/\, Rate_{peatloss\text{-}BSL,i} \qquad \textbf{(1)}$$

Where:

$t_{PDT\text{-}BSL,i}$	PDT in the baseline scenario in stratum *i* in years elapsed since the project start; yr
$Depth_{peat\text{-}BSL,i}$	Average peat depth above the drainage limit in the baseline scenario in stratum *i* at project start; m

[7] RWE projects may generate GHG credits from the reduction of GHG emissions associated with avoiding peat fires on drained or partially drained peatlands.

$Rate_{peatloss\text{-}BSL,i}$	Rate of peat loss due to subsidence and fire in the baseline scenario in stratum *i*; a conservative (high) value must be applied; m yr^{-1}
i	1, 2, 3, … M_{BSL} strata in the baseline scenario

Peat depths, depths of burn scars and subsidence rates must be derived from data sources as described in Section 9.1.

5.2 Geographic Boundaries

Project proponents must define the project boundary at the beginning of a proposed project activity and must provide the geographical coordinates of lands to be included, so as to allow clear identification for the purpose of verification. Remotely sensed data, officially certified topographic maps, land administration and tenure records, and/or other official documentation that facilitates the clear delineation of the project boundary may be used.

The RDP project activity may contain more than one discrete area of land. Each discrete area of land must have a unique geographical identification.

When describing physical project boundaries, the following information must be provided per discrete area:

- Name of the project area (including compartment numbers, local name (if any))
- Unique identifier for each discrete parcel of land
- Map(s) of the area (preferably in digital format)
- The data must be geo-referenced, and provided in digital format in accordance with the VCS rules.
- Total area
- Details of land rights holder and user rights

Stratification

If the project area at the start of the project is not homogeneous, stratification may be carried out to improve the accuracy and the precision of peat depth, carbon stock and GHG flux estimates. Different stratifications may be required for the baseline and project scenarios in order to achieve optimal accuracy of the estimates of net GHG emissions or removals.

Strata are defined on the basis of peat depth (including eligibility as assessed below), water table depth (e.g., at 0 cm defining a level of zero emission, a deep water table depth defining the high end of emissions, and arbitrary levels in between), tree cover and/or vegetation composition, or expected changes in these.

In case of the presence of a tree cover, the GEST approach (Section 8.1.3) must be supplemented by procedures to estimate tree carbon stock change and therefore separate strata must be established for forested land. Furthermore, different GESTs give rise to different strata.

Stratification on the basis of peat depth must be based on a peat depth map for the entire project area. Existing peat depth maps can be used in combination with interpolation techniques to derive conservative peat depth maps of the required accuracy (see below). Stratification of the project area by peat depth is required:

a) When in more than 5% of the project area peat is absent or the depth of the peat is below a threshold value (e.g., 10 cm); the peat depth map only needs to distinguish where peat depth exceeds this threshold. It is conservative to omit shallow peat strata in accounting.

b) When, using a conservative (high) value for subsidence rates, in the project scenario in more than 5% of the project area the peat is depleted within 100 years ($\leq t$=100); the peat depth map only needs to distinguish where peat will be depleted at t=100.

c) When, using a conservative (high) value for subsidence rates, in the baseline scenario in more than 5% of the project area the project crediting period exceeds the PDT ; the peat depth map must distinguish with a depth resolution of 10 cm strata where peat will be depleted within the project crediting period. Areas where peat will not be depleted need not be further stratified.

No stratification on the basis of peat depth is required if the peat depth in 95% or more of the project area exceeds the required minimum peat depth for any of the above conditions.

Areas with a peat layer at project start shallower than required by the adopted definition of peatland may be included if such areas are connected with areas that meet the definition. Isolated pockets that do not meet the definition must not be included.

When using existing peat depth maps or data, these must be corrected, in a conservative way, for peat excavation and subsidence. When, after correction, strata exceed the required minimum peat depth by less than 50 cm, these strata must be verified using field observations (e.g., using a peat auger following the procedures to create a peat depth map outlined below).

To create a peat depth map, depth measurements must be conducted along transects that cover the peatland in a systematic way. Distance between transects must be 200 m at maximum. Starting from the peatland margin, the initial distance between depth observations along transects must not be greater than 100 m with a depth accuracy of at least 10 cm. When two subsequent depth observations along a transect fulfill the required depth criteria by a margin of at least 50 cm, the distance between transects and observation points can be raised to 500 m. Transects must cross the entire peatland and must be initiated from opposed margins. If transects cross mineral soil areas present inside a contiguous peat area, transects departing from these mineral soil areas must also have an initial distance between depth observations of not greater than 100 m. Peat depth maps must be based on peat depth measurements in combination with interpolation techniques to derive conservative peat depth maps of the required accuracy.

In case shallow peat areas are conservatively neglected, it is sufficient to conduct depth measurements that cover the peatland in a systematic way, with at least 4 measurement points per km^2 or at a distance of 500 m.

Strata must be spatially discrete and stratum areas must be known. Areas of individual strata must sum to the total project area. Strata must be identified with spatial data (e.g., maps, GIS coverage, classified imagery, or sampling grids) from which the area can be determined accurately. Land use/land cover maps in particular must be ground-truthed and less than 10 years old. Strata must be discernible taking into account good practice in terms of the accuracy requirements for the definition of strata limits / boundaries. This must be indicated in the project documentation and the choice must be justified.

The project area may be stratified *ex ante*, and this stratification may be revised *ex post* for monitoring purposes. Established strata may be merged if reasons for their establishment have disappeared or have proven irrelevant to key variables for estimating net GHG emissions or removals.

Baseline stratification must remain fixed until a reassessment of the baseline scenario occurs.

Stratification in the project scenario will be updated at each monitoring event prior to verification.

The area of channels and ditches must be quantified and treated as separate strata. CH_4 emissions from these channels and ditches will not increase in the project scenario compared to the baseline scenario (Couwenberg *et al.* 2011) and therefore, CH_4 emissions from these channels and ditches can be excluded from GHG accounting.

Peatland areas eligible for carbon crediting

The maximum eligible quantity of GHG emission reductions by rewetting is limited to the difference between the remaining peat carbon stock in the project and baseline scenarios after 100 years (total stock approach), or the difference in cumulative carbon loss in both scenarios over a period of 100 years since project start (stock loss approach). If a significant difference (≥ 5%) at the 100-years mark cannot be demonstrated, the project area is not eligible for carbon crediting. This assessment must be executed *ex ante* using conservative parameters.

The procedure assumes a variable rate of peat loss in the baseline and project scenarios, or, alternatively, a conservative – as explained in footnote 7 – value that remains constant over time, based on expert judgment[8], datasets and/or literature (see Section 9.1).

[8] Requirements for expert judgment are provided in Section 9.3.2.

1. Total stock approach

The difference between peat carbon stock in the project scenario and baseline scenario at t=100 is estimated as:

$$C_{WPS-BSL,t100} = \sum_{i=1}^{M_{WPS}} \left(C_{WPS,i,t100} \times A_{WPS,i,t100} \right) - \sum_{i=1}^{M_{BSL}} \left(C_{BSL,i,t100} \times A_{BSL,i,t100} \right) \quad (2)$$

$$C_{WPS,i,t100} = Depth_{peat\text{-}WPS,i,\,t100} \times VC_{peat} \times 10 \quad (3)$$

$$C_{BSL,i,t100} = Depth_{peat\text{-}BSL,i,\,t100} \times VC_{peat} \times 10 \quad (4)$$

$$Depth_{peat-BSL,i,t100} = Depth_{peat-BSL,i,t0} - \sum_{t=1}^{t=100} Rate_{peatloss-BSL,i,t} \quad (5)$$

$$Depth_{peat-WPS,i,t100} = Depth_{peat-WPS,i,t0} - \sum_{t=1}^{t=100} Rate_{peatloss-WPS,i,t} \quad (6)$$

If a conservative constant subsidence rate is applied, a possible negative outcome is substituted by zero.

Where:

$C_{WPS\text{-}BSL,t100}$	Difference between peat carbon stock in the project scenario and baseline scenario at t=100 ; t C
$C_{WPS,i,t100}$	Peat carbon stock in the project scenario in peat depth stratum i at t=100;t C ha^{-1}
$C_{BSL,i,t100}$	Peat carbon stock in the baseline scenario in peat depth stratum i at t=100; t C ha^{-1}
$Depth_{peat\text{-}BSL,i,t100}$	Average peat depth above the drainage limit in the baseline scenario in stratum i at t=100; m
$Depth_{peat\text{-}WPS,i,t100}$	Average peat depth above the drainage limit in the project scenario in stratum i at t=100; m
$Depth_{peat\text{-}BSL,i,t0}$	Average peat depth above the drainage limit in the baseline scenario in stratum i at project start; m
$Depth_{peat\text{-}WPS,i,t0}$	Average peat depth above the drainage limit in the project scenario in stratum i at project start; m
$Rate_{peatloss\text{-}BSL,i,t}$	Rate of peat loss due to subsidence and fire in the baseline scenario in stratum i at time t; alternatively, a conservative (low[9]) value may be applied that remains constant over time; m yr^{-1}

[9] Note that the use of a relatively low value for a constant rate of peat loss may not be confused with a relatively high value when determining the need for stratification of peat depth (p7).

$Rate_{peatloss,WPS,i,t}$	Rate of peat loss due to subsidence in the project scenario in stratum *i* at time *t*; alternatively, a conservative (high) value may be applied that remains constant over time; m yr^{-1}
VC_{peat}	Volumetric carbon content of peat; kg C m^{-3}
$A_{WPS,i,t100}$	Area of project stratum *i* at *t*=100; ha
$A_{BSL,i,t100}$	Area of baseline stratum *i* at *t*=100; ha
i	1, 2, 3, … M_{BSL} or M_{WPS} peat depth strata in the baseline scenario or project scenario
t_{100}	100 years since project start

The volumetric carbon content in peat can be taken from measurements within the project area or from literature involving the project or similar areas.

$C_{WPS,i,t100}$ needs no adjustments since under the applicability conditions leakage emissions are absent.

The difference between peat carbon stock in the project scenario and baseline scenario at *t*=100 ($C_{WPS-BSL,t100}$) is significant if:

$$\sum_{i=1}^{M_{WPS}}\left(C_{WPS,i,t100}\times A_{WPS,i,t100}\right)\geq 1.05\times\sum_{i=1}^{M_{BSL}}\left(C_{BSL,i,t100}\times A_{BSL,i,t100}\right) \quad (7)$$

<u>2. Stock loss approach</u>

As $Depth_{peat-BSL,i,t0} = Depth_{peat-WPS,i,t0}$ the assessment can also be based on cumulative subsidence up to *t*=100 as follows:

$$C_{WPS-BSL,t100}=\sum_{i=1}^{M_{BSL}}\left(C_{peatloss-BSL,i,t100}\times A_{BSL,i,t100}\right)-\sum_{i=1}^{M_{WPS}}\left(C_{peatloss-WPS,i,t100}\times A_{WPS,i,t100}\right) \quad (8)$$

$$C_{peatloss-BSL,i,t100}=10\times\sum_{t=1}^{100}\left(Rate_{peatloss-BSL,i,t}\times VC_{peat}\right) \quad (9)$$

$$C_{peatloss-WPS,i,t100}=10\times\sum_{t=1}^{100}\left(Rate_{peatloss-WPS,i,t}\times VC_{peat}\right) \quad (10)$$

Where:

$C_{WPS-BSL,t100}$	Difference between peat carbon stock in the project scenario and baseline scenario at *t*=100; t C
$C_{peatloss-BSL,i,t100}$	Cumulative peat carbon loss due to subsidence and fire in the baseline scenario in subsidence stratum *i* at *t*=100; t C ha^{-1}

$C_{peatloss\text{-}WPS,i,t100}$	Cumulative peat carbon loss due to subsidence in the project scenario in subsidence stratum *i* at *t*=100; t C ha^{-1}
$Rate_{peatloss\text{-}BSL,i,t}$	Rate of peat loss due to subsidence and fire in the baseline scenario in stratum *i* in year *t*; alternatively, a conservative (low) value may be applied that remains constant over time; m yr^{-1}
$Rate_{peatloss\text{-}WPS,i,t}$	Rate of peat loss due to subsidence in the project scenario in stratum *i* in year *t*; alternatively, a conservative (high) value may be applied that remains constant over time; m yr^{-1}
VC_{peat}	Volumetric carbon content of peat; kg C m^{-3}
$A_{WPS,i,t100}$	Area of project stratum *i* at *t*=100; ha
$A_{BSL,i,t100}$	Area of baseline stratum *i* at *t*=100; ha
i	1, 2, 3, … M_{BSL} or M_{WPS} subsidence strata in the baseline scenario or project scenario
t_{100}	100 years after project start

Using short-term or historic subsidence rates for the entire period of 100 years is conservative since subsidence rates are likely to decline over time (Stephens *et al.*, 1984).

The difference between peat carbon stock in the project scenario and baseline scenario at *t*=100 ($C_{WPS\text{-}BSL,t100}$) is significant if:

$$\sum_{i=1}^{M_{BSL}}\left(C_{peatloss-BSL,i,t100}\times A_{BSL,i,t100}\right)\geq 1.05\times\sum_{i=1}^{M_{WPS}}\left(C_{peatloss-WPS,i,t100}\times A_{WPS,i,t100}\right) \tag{11}$$

Buffer zones

Under the applicability conditions of this methodology, the project boundary must be designed such that the project GHG benefits are not affected by drainage activities that occur outside the project area (e.g., enhanced drainage, groundwater extraction, and changing water supply). This can be achieved either by an appropriate design (e.g., by establishing an impermeable dam) or by a buffer zone within the project boundary for which conservatively no GHG benefits are accounted. This buffer zone, if employed, must be mapped and is not eligible for carbon crediting. The size and shape of the buffer zone must be determined on the basis of quantitative hydrological modeling, or expert judgment.

Procedures for buffer zones against ecological leakage are provided in Section 8.4.

5.3 Carbon Pools

The carbon pools that are included and excluded from the project boundary are shown in Table 5.1.

In addition, carbon pools may be deemed *de minimis* and do not have to be accounted for if together the omitted decrease in carbon stocks or increase in GHG emissions (Table 5.2) amounts to less than 5% of the total GHG benefit generated by the project. Peer reviewed literature or the CDM A/R methodological tool *Tool for testing significance of GHG emissions in A/R CDM project activities* may be used to determine whether decreases in carbon pools are *de minimis*.

Table 5.1: Carbon Pools Included In or Excluded From the Project Boundary

Carbon pools	Included?	Justification/Explanation of choice
Above-ground tree biomass	Yes	Major carbon pool may significantly increase in the baseline, or decrease in the project, or both, in case of establishment or presence of tree vegetation. Tree vegetation in the baseline scenario must be included. Tree vegetation in the project scenario may be conservatively set to zero.
Above-ground non-tree biomass	Optional	This pool is only included if GESTs are based on vegetation cover. In such cases, changes in lower vegetation are included in the estimates of NEE (or NEP) represented by GESTs.
Below-ground biomass	Yes	Major carbon pool may significantly increase in the baseline, or decrease in the project, or both, in case of presence of tree vegetation Tree vegetation in the baseline scenario: must be included. Tree vegetation in the project scenario: may be conservatively set to zero. Lower (herb) vegetation: included in the NEE (or NEP).
Tree litter	Optional	The litter layer must only be included if it forms part of a GEST.
Wood products	Optional	This pool is optional.
Dead wood	Optional	This pool is optional.
Soil organic carbon	Yes	Major carbon pool subject to the project activity. The soil organic carbon component is represented by the peat component.

5.4 Greenhouse Gases

The emission sources included in or excluded from the project boundary are shown in Table 5.2.

In addition, GHG sources may be deemed *de minimis* and do not have to be accounted for if together the omitted decrease in carbon stocks (Table 5.1) or increase in GHG emissions amounts to less than 5% of the total GHG benefit generated by the project. Peer reviewed literature or the CDM A/R methodological tool *Tool for testing significance of GHG emissions in A/R CDM project activities* may be used to determine whether increases in GHG emissions are *de minimis*.

Table 5.2: GHG Sources Included In or Excluded From the Project Boundary

Source		Gas	Included?	Justification/Explanation
Baseline	Changes in stocks in carbon pools in biomass	CO_2	Yes	Potential major source of removals considered under carbon pools
	Oxidation of drained peat	CO_2	Optional	May be conservatively excluded in the baseline scenario
		CH_4	Optional	Potentially significant emission; may be conservatively excluded in the baseline scenario
		N_2O	No	Excluded as per applicability condition
	Burning of biomass	CO_2	No	Not accounting in baseline scenario is conservative
		CH_4	No	Not accounting in baseline scenario is conservative
		N_2O	No	Not accounting in baseline scenario is conservative
	Peat burning	CO_2	Yes	Fire may occur in the baseline scenario and is accounted for with a default approach
		CH_4	No	Conservatively excluded in the baseline scenario
		N_2O	No	Conservatively excluded in the baseline scenario
Project	The production of methane by bacteria	CH_4	Yes	Potential major source of emissions in the project in low salinity and freshwater areas

Source		Gas	Included?	Justification/Explanation
	Accumulation of peat in project scenario	CO_2	No	Conservatively excluded in the project scenario
	Burning of biomass	CO_2	No	CO_2 is addressed in carbon stock change procedures
		CH_4	No	Accounting in project scenario is excluded as per applicability condition
		N_2O	No	Accounting in project scenario is excluded as per applicability condition
	Fossil fuel combustion from transport and machinery use in project activities	CO_2	No	Deemed *de minimis*
		CH_4	No	Deemed *de minimis*
		N_2O	No	Deemed *de minimis*
	Peat burning	CO_2	Yes	Fire may occur in the project scenario and is accounted for with a *Fire Reduction Premium* approach
		CH_4	No	Not included in the *Fire Reduction Premium* approach
		N_2O	No	Not included in the *Fire Reduction Premium* approach

6 BASELINE SCENARIO

6.1 Determination of the Most Plausible Baseline Scenario

At the project start date, the baseline scenario must consist of drained peatland with a land use that can be forestry, peat extraction or agriculture, abandonment after such activities, or a combination of these, but where these activities are not or no longer profitable. Continuations of these land uses and possible subsequent changes in various alternative baseline scenarios are determined using the latest version of the CDM tool *Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities*.

The tool has been designed for A/R CDM project activities, but must be used for the purpose of this methodology, noting the following:

Where the tool refers to	It must be understood as referring to
A/R, afforestation, reforestation, or forestation	WRC, or rewetting
Net greenhouse gas removals by sinks	Net greenhouse gas emission reductions
CDM	VCS
DOE	VVB
tCERs, lCERs	VCUs

Step 0 and Sub-step 2b – 15 (regarding forested areas since 31 December 1989) must be omitted. Footnote No 1-3 must be omitted[10].

In instances where there is a conflict between the CDM tool requirements and the VCS rules, the VCS rules must be followed.

6.2 Re-assessment of the Baseline Scenario

The project proponent must reassess the baseline scenario in accordance with the VCS rules.

For this assessment, the historic reference period is extended to include the original reference period and all subsequent monitoring periods up to the beginning of the current monitoring period. The fire reference period must not be extended, as this is a fixed 10-year period ending 5 years before the project start date.

The project proponent must, for the duration of the project, re-determine the PDT every 10 years. This reassessment must use the procedure provided in Section 5.1. Data sources for peat depths, depths of burn scars and subsidence rates must be updated if new information relevant to the project area has become available.

7 ADDITIONALITY

This methodology uses a project method for the demonstration of additionality.

Additionality must be determined using the latest version of the CDM tool *Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities*, with additional guidance as provided in Section 6.1.

[10] Sub-step and footnotes as in version 01 of the tool, the prevailing version of the tool as of the writing of this methodology.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

8.1.1 General approach

The net CO_2 equivalent emissions in the baseline scenario may be determined by carbon stock changes in non-peat carbon pools, GHG emissions as a result of peat oxidation due to drainage, or a combination of these. In addition, emissions as a result of peat combustion due to peatland fires can be determined.

GHG emissions of non-forested areas are determined using GESTs (Section 8.1.3). For forested areas, emissions are determined using GESTs (covering peat, herb vegetation and litter) in combination with carbon stock changes of the above- and below-ground tree biomass (Section 8.1.2).

For areas for which the vegetation composition does not provide a clear indication of GHG emissions (bare peat, transient phases of vegetation development after rewetting) water table depth measurements must be used as additional input to assess GHG fluxes. However, project proponents may also opt to choose water table depth as a proxy for the entire project area.

Peat combustion due to anthropogenic peatland fires is addressed using a conservative default value (*Fire Reduction Premium*) that is expressed as a proportion of the CO_2 emissions avoided through rewetting (Section 8.3).

It must be demonstrated (e.g., by referring to peer-reviewed literature) that under the project scenario, N_2O emissions are insignificant or decrease in the project scenario compared to the baseline, and therefore N_2O emissions need not be accounted for. Project circumstances are defined by pre-project land use (e.g., forestry, peat mining, agriculture, abandonment after such activities) and its intensity (especially related to N-fertilization), climatic zone, water table depths, and peat type.

The net CO_2 equivalent emissions in the baseline are estimated as:

$$GHG_{BSL} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{BSL}} \left(-\frac{44}{12} \times \Delta C_{BSL-NP,i,t} + GHG_{drained,i,t} \right) \quad \textbf{(12)}$$

Where:

GHG_{BSL}	Net CO_2 equivalent emissions in the baseline scenario up to year t^*; t CO_2e
$\Delta C_{BSL-NP,i,t}$	Net carbon stock changes in non-peat carbon pools in the baseline scenario in stratum i in year t; t C yr^{-1}
$GHG_{drained,i,t}$	Greenhouse gas emissions from soil, lower ground vegetation and litter in the baseline scenario in stratum i in year t; t CO_2e yr^{-1}

i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the project start

The project proponent must, for the duration of the project, re-quantify the baseline every 10 years. Based on the reassessment as defined in Section 6, the new baseline scenario must be incorporated into revised estimates of baseline emissions. This baseline reassessment must include the evaluation of the validity of proxies for GHG emissions from peatlands (i.e., GESTs on the basis of vegetation composition and/or water table depth).

8.1.2 Net carbon stock change in non-peat carbon pools ($\Delta C_{BSL\text{-}NP,i,t}$)

8.1.2.1 General

The non-peat carbon pools (see Table 5.1) to be accounted for in the baseline scenario include aboveground tree biomass and belowground tree biomass. Net fluxes to and from lower ground vegetation and litter are accounted for by GESTs.

GHG emissions may arise from the burning of biomass. Biomass burning in the baseline scenario may occur but not accounting for it is conservative. This methodology does not provide procedures for estimating GHG emissions from the burning of biomass.

Net carbon stock changes in non-peat carbon pools in the baseline scenario will be determined as:

$$\Delta C_{BSL\text{-}NP,i,t} = \Delta C_{BSL\text{-}biomass,i,t} \quad \textbf{(13)}$$

Where:

$\Delta C_{BSL\text{-}NP,i,t}$	Net carbon stock change in non-peat carbon pools in the baseline scenario in stratum i in year t; t C yr^{-1}
$\Delta C_{BSL\text{-}biomass,i,t}$	Net carbon stock change in tree biomass in the baseline scenario in stratum i in year t; t C yr^{-1}
i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the project start

Assessing GHG removals in the baseline scenario consists of 3 steps:

1) Assess the pre-project spatial distribution of tree biomass
2) For the given baseline scenario, derive a time series of tree biomass development for each stratum; as per Section 6.2, *ex-ante* baseline projections beyond a 10-year period are not required
3) Determine annual GHG removals per stratum; as per Section 6.2, *ex-ante* baseline projections beyond a 10-year period are not required

To project future tree biomass within the project crediting period under the baseline scenario, use the latest version of the VCS module *VMD0019 Methods to Project Future Conditions*.

8.1.2.2 Net carbon stock change in biomass ($\Delta C_{BSLbiomass,i,t}$)

The net carbon stock change in biomass in the baseline scenario is estimated as:

$$\Delta C_{BSL\text{-}biomass,i,t} = A_{BSL,i,t} \times \Delta C_{BSL\text{-}tree,i,t} \quad (14)$$

$$\Delta C_{BSL-tree,i,t} = \sum_{j=1}^{S_{BSL}} (\Delta C_{BSL-tree,j,i,t}) \quad (15)$$

$$\Delta C_{BSL-tree,j,i,t} = \Delta C_{BSL-tree-AB,j,i,t} + \Delta C_{BSL-tree-BB,j,i,t} \quad (16)$$

$$\Delta C_{BSL-tree-BB,j,i,t} = \Delta C_{BSL-tree-AB,j,i,t} \times R_j \quad (17)$$

Where:

$\Delta C_{BSL\text{-}biomass,i,t}$	Change in carbon stock in biomass in the baseline scenario in stratum *i* in year *t*; t C yr^{-1}
$A_{BSL,i,t}$	Area of baseline stratum *i* in year *t*; ha
$\Delta C_{BSL\text{-}tree,i,t}$	Change in carbon stock in tree[11] biomass in the baseline scenario in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$\Delta C_{BSL\text{-}tree,j,i,t}$	Change in carbon stock in tree biomass in the baseline scenario for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$\Delta C_{BSL\text{-}tree\text{-}AB,j,i,t}$	Change in carbon stock in above-ground tree biomass in the baseline scenario for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$\Delta C_{BSL\text{-}tree\text{-}BB,j,i,t}$	Change in carbon stock in below-ground tree biomass in the baseline scenario for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
R_j	Root:shoot ratio for tree species *j*[12]; t root t^{-1} shoot d.m.
j	1, 2, 3, … S_{BSL} tree species in the baseline scenario
i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the project start

Above-ground tree biomass

The change in carbon stock in above-ground tree biomass is estimated using one of the following methods that can be selected on the basis of the availability of data.

[11] With DBH ≥ 5 cm.
[12] Care should be taken that the root-shoot ratio may change as a function of the above-ground biomass present at time *t* (see IPCC GPG 2003, Annex 3.A1, Table 3A1.8)

Method 1 (Gain-loss method)

$$\Delta C_{BSL\text{-}tree\text{-}AB,j,i,t} = \Delta C_{G,j,i,t} - \Delta C_{L,j,i,t} \quad \textbf{(18)}$$

$$\Delta C_{G,j,i,t} = G_{j,i,t} \times CF_j \quad \textbf{(19)}$$

$$G_{j,i,t} = I_{v,j,i,t} \times D_j \times BEF_{1,j} \quad \textbf{(20)}$$

Where:

$\Delta C_{BSL\text{-}tree\text{-}AB,j,i,t}$	Change in carbon stock in above-ground tree biomass in the baseline scenario for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$\Delta C_{G,j,i,t}$	Average annual increase in carbon stock due to above-ground biomass growth of living trees for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$\Delta C_{L,j,i,t}$	Average annual decrease in carbon stock due to above-ground biomass loss of living trees for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$G_{j,i,t}$	Average annual increment of above-ground biomass of living trees for species *j* in stratum *i* in year *t*; t dm. $ha^{-1}yr^{-1}$
CF_j	Carbon fraction[13] of dry matter for species *j*; t C t d.m.$^{-1}$
$I_{v,j,i,t}$	Average annual increment in merchantable volume for species *j* in stratum *i* in year *t*; $m^{-3}ha^{-1}yr^{-1}$
D_j	Basic wood density for species *j*; t d.m. m^{-3}
$BEF_{1,j}$	Biomass expansion factor for conversion of annual net increment (including bark) in merchantable volume to total above-ground biomass increment for species *j*
j	1, 2, 3, … *S* tree species
i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the project start

This methodology allows for the conservative assumption that, for any time *t,* $\Delta C_{L,j,i,t} = 0$ for the baseline scenario.

If biomass increment tables are available and applicable to the species present, these can directly be used in Equation 20. Note that available data on average annual increment in the volume of species *j* in stratum *i* for year *t* ($I_{v,j,i,t}$) may be expressed as a net average annual increment (i.e., the term $\Delta C_{L,j,i,t}$ is already implicitly allowed for and must be set to zero in Equation 18 in order to avoid double counting).

Alternatively, if the average annual increment in volume of species *j* in stratum *i*, for year *t* ($I_{v,j,i,t}$) is expressed as the gross average annual increment, then $\Delta C_{L,j,i,t}$ may be conservatively assumed

[13] IPCC default value = 0.5

as zero. Otherwise $\Delta C_{L,j,i,t}$ must be estimated on the basis of transparent and verifiable information on the rate at which pre-project activities (or mortality) are reducing carbon stocks in existing live trees (e.g., due to harvesting for fuelwood, or for animal consumption).

Depending on the kind of information locally available, instead of R_j and BEF_j one can use other parameters converting stem volume to total biomass, for example K_{ph} (Alexeyev coefficient; Alexeyev *et al*. (1995)).

Method 2 (Stock difference method)

$$\Delta C_{BSL\text{-}tree\text{-}AB,j,i,t} = (C_{BSL\text{-}tree\text{-}AB,j,i,t} - C_{BSL\text{-}tree\text{-}AB,j,i,(t\text{-}T)}) / T \quad \textbf{(21)}$$

Two methods are provided for this method: the biomass expansion factors (*BEF*) method and the allometric equations method.

1. *BEF* method

$$C_{BSL\text{-}tree\text{-}AB,j,i,t} = V_{j,i,t} \times D_j \times BEF_{2j} \times CF_j \quad \textbf{(22)}$$

Where:

$\Delta C_{BSL\text{-}tree\text{-}AB,j,i,t}$	Change in carbon stock in above-ground tree biomass in the baseline for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$C_{BSL\text{-}tree\text{-}AB,j,i,t}$	Carbon stock in above-ground biomass of tree species *j* in stratum *i* in year *t*; t C ha^{-1}
$V_{j,i,t}$	Stem volume of tree species *j* in stratum *i* in year *t*; m^3 ha^{-1}
D_j	Basic wood density of species *j*; t d.m. m^{-3}
BEF_{2j}	Biomass expansion factor for conversion of stem biomass to above-ground tree biomass for species *j*
CF_j	Carbon fraction[14] of dry matter for species *j*; t C t $d.m.^{-1}$
i	1, 2, 3, … M_{WPS} strata in the project scenario
j	1, 2, 3 ,… S_{WPS} tree species in the project scenario
t	1, 2, 3 … t^* years elapsed since the start of the project activity
T	Number of years between times *t* and t_{-1}

[14] IPCC default = 0.5

2. Allometric Equations method

$$C_{BSL\text{-}tree\text{-}AB,j,i,t} = nTR_{j,i,t} \times f_j(X,Y,\ldots) \times CF_j \quad \textbf{(23)}$$

Where:

$C_{BSL\text{-}tree\text{-}AB,j,i,t}$	Carbon stock in above-ground biomass of species *j* in stratum *i* in year *t*; t C ha^{-1}
$nTR_{j,i,t}$	Tree stand density of species *j* in stratum *i* in year *t*; trees ha^{-1}
$f_j(X, Y, \ldots)$	Allometric equation for species *j* linking measured tree dimension variables (e.g., diameter at breast height (*DBH*) and possibly height (*H*)) to above-ground biomass of living trees; t d.m. tree^{-1}
CF_j	Carbon fraction of dry matter for species *j*; t C t^{-1} d.m.
i	1, 2, 3, … M_P strata in the project scenario
j	1, 2, 3, … S_{WPS} tree species in the project scenario
t	1, 2, 3, … *t** years elapsed since the start of the project activity

It is acceptable to estimate initial stocks (*t*=0) using pre-existing forest inventory data, provided that the pre-existing data (1) represents the project strata, (2) is not more than 10 years old and represents the age and site class, and (3) that the stock estimate derived from the pre-existing data has been validated with limited sampling within the project area. If the estimate is within the 90% confidence interval of the corresponding estimate calculated from pre-existing forest inventory data, the initial stock at *t*=0 is set at the higher bound of the 90% confidence interval of the estimate from pre-existing data. If the validation estimate is outside (i.e., greater than or less than) the corresponding estimate calculated from pre-existing forest inventory data, the estimate from pre-existing data cannot be used.

8.1.3 Greenhouse gas emissions due to peat drainage ($GHG_{drained,i,t}$)

8.1.3.1 The GEST approach

In this methodology, the GEST (Greenhouse Gas Emission Site Type) approach forms the basis for the estimation of GHG fluxes from drained and rewetted peatlands (Couwenberg *et al.* 2011). The GEST approach uses primarily vegetation types as the indicator of annual greenhouse gas fluxes. Vegetation is well qualified for indicating greenhouse gas fluxes (Couwenberg *et al.* 2011) as outlined in Section 9.3.6.

GHG emissions from drained peat, litter and ground vegetation are estimated based on the presence of GESTs with calibrated GHG emission profiles in strata *i*. As a general rule:

- for a non-forested area a GEST will determine average annual net CO_2 equivalent emissions
- for a forested area a GEST in combination with carbon stock changes in tree biomass will

determine average annual net CO_2 equivalent emissions.

In addition, for GESTs in which the vegetation composition does not provide a clear indication of GHG emission-related site conditions (e.g., bare peat), water table depth measurements must be used as additional input to assess GHG fluxes. Areas within the project boundary with different GESTs will be treated as different strata.

For each stratum:

$$GHG_{drained,i,t} = GHG_{GESTbsl,i,t} \quad \textbf{(24)}$$

$$\text{For } t > t_{PDT\text{-}BSL,i}: GHG_{drained,i,t} = 0 \quad \textbf{(25)}$$

Where:

$GHG_{drained,i,t}$	Greenhouse gas emissions from soil, lower ground vegetation and litter in the baseline scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
$t_{PDT\text{-}BSL,i}$	PDT in the baseline scenario in stratum *i* in years elapsed since the project start; yr
$GHG_{GESTbsl,i,t}$	GHG emissions from GESTs in the baseline scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … *t** years elapsed since the project start

Assessing GHG emissions in the baseline scenario consists of 4 steps (see Section 9.3.6 for additional guidance on each of these steps):

1) Determine GESTs
2) Assess the pre-project spatial distribution of GESTs
3) For the given baseline scenario, derive a time series of GEST development for each stratum; as per Section 6.2, *ex-ante* baseline projections beyond a 10-year period are not required
4) Determine annual GHG emissions per stratum; as per Section 6.2, *ex-ante* baseline projections beyond a 10-year period are not required

To project future GHG emissions due to peat drainage within the project crediting period under the baseline scenario, use the latest version of the VCS module *VMD0019 Methods to Project Future Conditions*, with the following additional guidance.

1. To derive trends and developments in water table management, the baseline scenario must take into account the current and historic layout of the drainage system and the long-term average climate variables influencing water table depths (precipitation, evaporation) prior to project start, on the basis of quantitative hydrological modeling and/or expert judgment. The long-

term average climate variables must be determined using data from two climate stations nearest to the project area and must include at least 20 years' worth of data.

The drainage layout at the start of the project activity must be mapped at scale: 1:10,000 or any other scale justified for estimating water table depths. Historic drainage layout must be mapped using topographic and/or hydrological maps from (if available) the start of the major hydrological impacts but covering at least the 20 years prior to the start of the project activity. Historic drainage structures (collapsed ditches) may (still) have higher hydraulic conductivity than the surrounding areas and function as preferential flow paths. The effect of historic drainage structures on current hydrological functioning of the project area must be assessed on the basis of expert judgment and in a conservative manner. Justification may be based on hydrological models. The baseline scenario may furthermore include re-activation of collapsed ditches. Historic information on the drainage system may serve to set trends in drainage lay-out and depth as well as in frequency of dredging of ditches to maintain required water tables in the field. Derivation of such trends must be done on the basis of expert judgment and in a conservative manner. With respect to hydrological functioning, baseline scenarios must be restricted by climate variables and quantify any impacts on the hydrological functioning as caused by planned measures outside the project area (such as dam construction or groundwater extraction), by demonstrating a hydrological connection to the planned measures (e.g., through ground water carrying soil layers).

2. In case of abandonment of pre-project land use in the baseline scenario, the baseline scenario must also consider - based on expert judgment taking account of verifiable local experience and/or studies and/or scientific literature and in a conservative way - non-human induced rewetting brought about by collapsing dikes or ditches that would have naturally closed over time, and progressive subsidence, leading to raising relative water levels, increasingly thinner aerobic layers and reduced CO_2 emission rates. Unless alternative evidence is provided, annual subsidence (as derived from subsidence - water table observations or models) must be assumed to result in a 1:1 proportional rise the water table relative to the surface in the area between ditches.

In case of continued or re-instated utilization and associated drainage, it must be demonstrated that ditch water tables are controlled (e.g., by weirs and periodic deepening (dredging) of ditches to maintain the water table between ditches at the required level). Documentation may include official plans, but also personal communication with local farmers and historic trends.

Water tables in the baseline may be determined by static (including analytic) hydrologic modeling, using conservative peat hydraulic parameters, including:

- The distance between the ditches
- The water table depth in the ditches
- Hydrological conductivity of the peat

Based on the assessment of changes in water table depth, time series of vegetation composition must be derived (*ex ante*), based on vegetation succession schemes in drained peatlands from scientific literature and/or expert judgment, by defining time series of GESTs, with time steps of, for example, 5 years to allow for the inherent discrete character of the GESTs.

If a *Fire Reduction Premium* is claimed, the project proponent must demonstrate with fire maps and historical databases on fires that the project area is now and in future would be under risk of anthropogenic fires. This is further specified in Section 8.3.

8.1.3.2 Baseline CO_2 and CH_4 emissions estimated by GEST

GHG emissions per stratum as a result of peat drainage (microbial peat oxidation, net fluxes to and from litter and lower ground vegetation) in the baseline scenario are estimated as:

$$GHG_{GESTbsl,i,t} = A_{BSl,i,t} \times (GHG_{GESTbsl\text{-}CO2,i,t} + GHG_{GESTbsl\text{-}CH4,i,t}) \quad \textbf{(26)}$$

Where:

$GHG_{GESTbsl,i,t}$	GHG emissions from GEST in the baseline scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
$A_{BSL,i,t}$	Total area of baseline stratum *i* in year *t*; ha
$GHG_{GESTbsl\text{-}CO2,i,t}$	Emission of CO_2 from baseline GEST in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
$GHG_{GESTbsl\text{-}CH4,i,t}$	Emission of CH_4 from baseline GEST in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
i	1, 2, 3 …M_{BSL} strata[15] in the baseline scenario
t	1, 2, 3, … *t** years elapsed since the project start

If the vegetation composition does not provide a clear indication of GHG emission-related site conditions (e.g., bare peat) the average annual GHG emissions must be related directly to water table depth as follows:

$$GHG_{GESTbsl,i,t} = A_{BSL,i,t} \times (GHG_{WLbsl\text{-}CO2,i,t} + GHG_{WLbsl\text{-}CH4,i,t}) \quad \textbf{(27)}$$

Where:

$GHG_{GESTbsl,i,t}$	GHG emissions from GEST in the baseline scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
$A_{BSL,i,t}$	Total area of baseline stratum *i* in year *t*; ha
$GHG_{WLbsl\text{-}CO2,i,t}$	Emission of CO_2 related to water table depth in the baseline scenario in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
$GHG_{WLbsl\text{-}CH4,i,t}$	Emission of CH_4 related to water table depth in the baseline scenario in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
i	1, 2, 3, … M_{BSL} strata[16] in the baseline scenario

[15] Note that different GESTs result in different strata.

t 1, 2, 3, … t* years elapsed since the project start

The project may establish project-specific values for $GHG_{WLbsl\text{-}CO2}$ and $GHG_{WLbsl\text{-}CH4}$ (see Section 9.3.6) or apply values from appropriate literature sources pertaining to land use classes, water table depths or water table depth classes and similar project circumstances. For such literature values the accuracy must be defined or conservativeness must be justified in the project description. Project circumstances are defined by pre-project land use (e.g., forestry, peat mining, agriculture, abandonment after such activities) and its intensity, climatic zone, water table depths, and peat type. If the mean annual water table depth in the project area exceeds the depth range for which the emission-vegetation or emission-water table depth relationship determined for the project is valid, a conservative extrapolation must be used. $GHG_{WLbsl\text{-}CH4}$ may be conservatively neglected.

Procedures for the determinations of GHG fluxes and water table depth measurements are provided in Section 9.3.6.

8.2 Project Emissions

8.2.1 General approach

The net CO_2 equivalent emissions in the project scenario may be determined by carbon stock changes in non-peat carbon pools and GHG emissions from rewetted peatland.

GHG emissions from fossil fuel combustion from transport and machinery use in project activities are deemed insignificant.

For the quantification of possible spikes of CH_4 emission during a transient period after rewetting, for which the GEST approach cannot be used, conservative estimates from appropriate literature sources are used.

To demonstrate that N_2O emissions are a) insignificant or b) decrease compared to the baseline scenario, and therefore N_2O emissions need not be accounted for, a) use the CDM A/R methodological tool *Tool for testing significance of GHG emissions in A/R CDM project activities*, or b) refer to peer-reviewed literature, respectively.

For *ex-ante* estimates of GHG emissions in the project scenario use the latest version of the VCS module *VMD0019 Methods to Project Future Conditions*.

The net CO_2 equivalent emissions in the project scenario are estimated as:

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[16] Note that different water levels or water level classes result in different strata. Water levels or water level classes (e.g., 0-10 cm, 11-20 cm, etc.) can be used, depending on data availability.

$$GHG_{WPS} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{WPS}} \left(-\frac{44}{12} \times \Delta C_{WPS-NP,i,t} + GHG_{rewetted,i,t} \right) \quad (28)$$

Where:

GHG_{WPS}	Net CO_2 equivalent emissions in the project scenario up to year t^*; t CO_2e
$\Delta C_{WPS\text{-}NP,i,t}$	Net carbon stock change in non-peat carbon pools in the project scenario in stratum i in year t; t C yr^{-1}
$GHG_{rewetted,i,t}$	Greenhouse gas emissions from the peat after rewetting in the project scenario in stratum i in year t; t CO_2e yr^{-1}
i	1, 2, 3, … M_{BSL} strata in the project scenario
t	1, 2, 3, … t^* years elapsed since the project start

8.2.2 Net carbon stock changes in non-peat carbon pools ($\Delta C_{WPS\text{-}NP,i,t}$)

Under the applicability conditions, the burning of biomass is excluded in the project scenario. This methodology does not provide procedures for estimating GHG emissions from the burning of biomass.

Monitoring procedures for carbon stocks in tree biomass in the project scenario are provided in Section 9.

Net carbon stock changes in non-peat carbon pools in the project scenario will be determined as:

$$\Delta C_{WPS\text{-}NP,i,t} = \Delta C_{WPS\text{-}biomass,i,t} \quad (29)$$

Where:

$\Delta C_{WPS\text{-}NP,i,t}$	Net carbon stock change in non-peat carbon pools in the project scenario in stratum i in year t; t C yr^{-1}
$\Delta C_{WPS\text{-}biomass,i,t}$	Net carbon stock change in tree biomass in the project scenario in stratum i in year t; t C yr^{-1}
i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the project start

$$\Delta C_{WPS\text{-}Biomass,i,t} = A_{WPS,i,t} \times \Delta C_{WPS\text{-}tree,i,t} \quad (30)$$

$$\Delta C_{WPS-tree,i,t} = \sum_{j=1}^{S_{WPS}} \left(\Delta C_{WPS-tree,j,i,t} \right) \quad (31)$$

$$\Delta C_{WPS-tree,j,i,t} = \Delta C_{WPS-tree-AB,j,i,t} + \Delta C_{WPS-tree-BB,j,i,t} \quad (32)$$

$$\Delta C_{WPS-tree-BB,j,i,t} = \Delta C_{WPS-tree-AB,j,i,t} \times R_j \quad \textbf{(33)}$$

Where:

$\Delta C_{WPS\text{-}biomass,i,t}$	Change in carbon stock in biomass in the project scenario in stratum *i* in year *t*; t C yr^{-1}
$A_{WPS,i,t}$	Area of project stratum *i* in year *t*; ha
$\Delta C_{WPS\text{-}tree,i,t}$	Change in carbon stock in tree[17] biomass in the project scenario in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$\Delta C_{WPS\text{-}tree,j,i,t}$	Change in carbon stock in tree biomass in the project scenario for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$\Delta C_{WPS\text{-}tree\text{-}AB,j,i,t}$	Change in carbon stock in above-ground tree biomass in the project scenario for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$\Delta C_{WPS\text{-}tree\text{-}BB,j,i,t}$	Change in carbon stock in below-ground tree biomass in the project scenario for species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
R_j	Root:shoot ratio for tree species *j*; t root t^{-1} shoot d.m.
j	1, 2, 3, … S_{WPS} tree species in the project scenario
i	1, 2, 3, … M_{WPS} strata in the project scenario
t	1, 2, 3, … t^* years elapsed since the project start

Changes in carbon stock in above-ground tree biomass in the project scenario are estimated as:

$$\Delta C_{WPS\text{-}tree\text{-}AB,j,i,t} = (C_{WPS\text{-}tree\text{-}AB,j,i,t} - C_{WPS\text{-}tree\text{-}AB,j,i,(t-T)}) / T \quad \textbf{(34)}$$

Where:

$\Delta C_{WPS\text{-}tree\text{-}AB,j,i,t}$	Net carbon stock change in above-ground tree biomass in the project scenario for tree species *j* in stratum *i* in year *t*; t C $ha^{-1}yr^{-1}$
$C_{WPS\text{-}tree\text{-}AB,j,i,t}$	Carbon stock in above-ground tree biomass in the project scenario for tree species *j* in stratum *i* in year *t*; t C ha^{-1}[18]
t	1, 2, 3 … ***t**** years elapsed since the start of the project activity
i	1, 2, 3, … M_{WPS} strata in the project scenario
j	1, 2, 3, … S_{WPS} tree species
T	Number of years between monitoring times t_m *and* t_{m-1}

The mean carbon stock in above-ground biomass per unit area is estimated on the basis of field

[17] With DBH ≥ 5 cm.
[18] May be conservatively set to zero.

measurements in permanent sample plots. Two methods are available: the biomass expansion factors (*BEF*) method and the allometric equations method.

1) *BEF* method

Step 1: Determine on the basis of available data volume tables (*ex ante*) and measurements (*ex post*) of the diameter at breast height (*DBH,* at typically 1.3 m above-ground level), and also preferably height (*H*), of all the trees above some minimum *DBH* in the permanent sample plots. The exact tree dimensions to be measured will be specified by the information obtained in Step 2.

Step 2: Estimate the stem volume of trees

It is possible to combine Steps 1 and 2 if volume tables allow for deriving average volume of trees, or field instruments (e.g., a relascope) that measure the volume of each tree directly are applied.

Step 3: Choose *BEF*

Step 4: Convert the stem volume of trees into carbon stock in above-ground tree biomass via basic wood density, the *BEF* and the carbon fraction:

$$C_{WPS\text{-}tree\text{-}AB,l,j,i,sp,t} = V_{l,j,i,sp,t} \times D_j \times BEF_{2j} \times CF_j \qquad \textbf{(35)}$$

Where:

$C_{WPS\text{-}tree\text{-}AB,l,j,i,sp,t}$	Carbon stock in above-ground biomass of tree *l* of species *j* in plot *sp* in stratum *i* in year *t*; t C tree^{-1}
$V_{l,j,j,sp,t}$	Stem volume of tree *l* of species *j* in plot *sp* in stratum *i* in year *t*; m^3 tree^{-1}
D_j	Basic wood density of species *j*; t d.m. m^{-3}
BEF_{2j}	Biomass expansion factor for conversion of stem biomass to above-ground tree biomass for species *j*
CF_j	Carbon fraction[19] of dry matter for species *j*; t C t d.m.$^{-1}$
l	1, 2, 3, … $N_{j,i,sp,t}$ individual trees of species *j* in sample plot *sp* in stratum *i* in year *t*
i	1, 2, 3, … M_{WPS} strata in the project scenario
j	1, 2, 3, … S_{WPS} tree species in the project scenario
t	1, 2, 3, … *t** years elapsed since the start of the project activity

Step 5: Calculate carbon stock in above-ground biomass of all tree species *j* present in plot *sp* in stratum *i* at time *t* (i.e., summation over all trees *l* of species *j* present in plot *sp*).

[19] IPCC default = 0.5

$$C_{WPS-tree-AB,j,i,sp,t} = \sum_{l=1}^{N_{j,i,sp,t}} C_{WPS-tree-AB,l,j,i,sp,t} \quad (36)$$

Where:

$C_{WPS\text{-}tree\text{-}AB,j,i,sp,t}$	Carbon stock in above-ground biomass of tree species *j* on plot *sp* of stratum *i* at time *t*; t C
$C_{WPS\text{-}tree\text{-}AB,l,j,i,sp,t}$	Carbon stock in above-ground biomass of tree *l* of species *j* in plot *sp* in stratum *i* at time *t*; t C tree^{-1}
l	1, 2, 3, … $N_{j,i,sp,t}$ individual trees of species *j* in sample plot *sp* in stratum *i* in year *t*
i	1, 2, 3, … M_{WPS} strata in the project scenario
j	1, 2, 3, … S_{WPS} tree species in the project scenario
sp	1, 2, 3, … P_i sample plots in stratum *i* in the project scenario
t	1, 2, 3, … t^* years elapsed since the start of the project activity

Step 6: Estimate the mean carbon stock in above-ground tree biomass for species *j* for each stratum:

$$C_{WPS-tree-AB,j,i,t} = \frac{1}{A_{sp_i}} \sum_{sp=1}^{P_i} C_{WPS-tree-AB,j,i,sp,t} \quad (37)$$

Where:

$C_{WPS\text{-}tree\text{-}AB,j,i,t}$	Above-ground carbon stock in tree species *j* in stratum *i* in year *t*; t C ha^{-1}
$C_{WPS\text{-}tree\text{-}AB,j,i,sp,t}$	Above-ground carbon stock in tree species *j* on plot *sp* of stratum *i* in year *t*; t C
$A_{sp,i}$	Total area of all sample plots in stratum *i*; ha
j	1, 2, 3, … S_{WPS} tree species in the project scenario
i	1, 2, 3, … M_{WPS} strata in the project scenario
sp	1, 2, 3, … P_i sample plots in stratum *i* in the project scenario
t	1, 2, 3, … t^* years elapsed since the start of the project activity

The below-ground tree biomass in the project scenario may be conservatively set to zero. Procedures for including below-ground biomass in total tree biomass estimations are provided in Section 8.1.2.

2) Allometric equations method

Step 1: Same as Step 1 of the *BEF* method.

Step 2: Select or develop an appropriate allometric equation (if possible species-specific, or if not from a similar species) - see Chapter 9 for additional guidance.

Step 3: Estimate carbon stock in above-ground biomass for each individual tree *l* of species *j* in the sample plot *sp* located in stratum *i* using the selected or developed allometric equation applied to the tree dimensions resulting from Step 1, and sum the carbon stocks in the sample plot:

$$C_{WPS-tree-AB,j,i,sp,t} = \sum_{l=1}^{N_{j,i,sp,t}} \left(f_j(X,Y,...)\right) \times CF_j \tag{38}$$

Where:

$C_{WPS\text{-}tree\text{-}AB,j,i,sp,t}$	Carbon stock in above-ground biomass of tree species *j* in sample plot *sp* in stratum *i* in year *t*; t C
$f_j(X, Y, \ldots)$	Allometric equation for species *j* linking measured tree dimension variables (e.g., diameter at breast height (*DBH*) and possibly height (*H*)) to above-ground biomass of living trees; t d.m. tree^{-1}
CF_j	Carbon fraction of dry matter for species *j*; t C t^{-1} d.m.
l	1, 2, 3, … $N_{j,i,sp,t}$ individual trees of species *j* in sample plot *sp* in stratum *i* in year *t*
j	1, 2, 3, … S_{WPS} tree species in the project scenario
i	1, 2, 3, … M_P strata in the project scenario
sp	1, 2, 3, … P_i sample plots in stratum *i* in the project scenario
t	1, 2, 3, … t^* years elapsed since the start of the project activity

Step 4: Proceed with Step 6 of the *BEF* method.

8.2.3 Project greenhouse gas emissions after peat rewetting ($GHG_{rewetted,i,t}$)

The estimation of GHG emissions in rewetted peat follows similar procedures as provided in Section 8.1.3.

For each stratum:

$$GHG_{rewetted,i,t} = GHG_{GESTwps,i,t} \tag{39}$$

Where:

$GHG_{rewetted,i,t}$	Greenhouse gas emissions from soil, lower ground vegetation and litter in the project scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
$GHG_{GESTwps,i,t}$	GHG emissions from GESTs in the project scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
i	1, 2, 3, …M_{BSL} strata in the project scenario
t	1, 2, 3, … *t** years elapsed since the project start

8.2.3.1 Project GHG emissions related to GESTs

This approach builds on the procedure described in Section 8.1.3.1. In addition, the GHG emissions during the transient stage after rewetting (i.e., before new vegetation types have established that are in balance with the rewetted conditions and for from which GESTs can be defined) must be determined.

The GEST approach for the project scenario has the following steps (see Section 9.3.6 for additional guidance on each of these steps):

1) Determine GESTs
2) Assess the spatial distribution of GESTs
3) Define the project scenario for GESTs (*ex ante*) or monitor GESTs (*ex post*)
4) Determine annual GHG emissions per stratum for the entire project crediting period

For the quantification of possible spikes of CH_4 emission during a transient period after rewetting where dying off vegetation may lead to substantial methane emissions, for which the GEST approach cannot be used, conservative estimates from appropriate literature sources must be used. The project proponent must demonstrate applicability of that literature on the basis of similarity with respect to pre-project land use (e.g., forestry, peat mining, agriculture) and land use intensity (especially fertilization), superficial peat types (especially nutrient conditions), and climatic zone.

GHG emissions per stratum of peat after rewetting are estimated as:

$$GHG_{rewetted,i,t} = A_{WPS,i,t} \times (GHG_{GESTwps\text{-}CO2,i,t} + GHG_{GESTwps\text{-}CH4,i,t}) \quad \textbf{(40)}$$

Where:

$GHG_{rewetted,i,t}$	Greenhouse gas emissions from soil, lower ground vegetation and litter in the project scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
$A_{WPS,i,t}$	Total area of project stratum *i*; ha
$GHG_{GESTwps\text{-}CO2,i,t}$	Emission of CO_2 from project GEST in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$

$GHG_{GESTwps\text{-}CH4,i,t}$	Emission of CH_4 from project GEST in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
i	1, 2, 3, …M_{BSL} strata in the project scenario
t	1, 2, 3, … *t** years elapsed since the project start

Ex-ante estimates of $GHG_{rewetted,i,t}$ must be based on *ex-ante* scenario definitions in Step 3.

Ex-post estimates of $GHG_{rewetted,i,t}$ must be based on monitoring results.

If the vegetation composition does not provide a clear indication of GHG emission-related site conditions (e.g., bare peat, transient phases of vegetation development after rewetting) the average annual GHG emissions must be related directly to water table depth. Note that due to a potential hysteresis effect the relationships between water table depth and greenhouse gas emissions in a rewetted peatland can differ from those in a drained peatland.

$$GHG_{GESTwps,i,t} = A_{WPS,i,t} \times (GHG_{WL\text{-}CO2,i,t} + GHG_{WL\text{-}CH4,i,t}) \quad \textbf{(41)}$$

Where:

$GHG_{GESTwps,i,t}$	GHG emissions from GESTs in the project scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
$A_{WPS,i,t}$	Total area of project stratum *i* in year *t*; ha
$GHG_{WLwps\text{-}CO2,i,t}$	Emission of CO_2 related to water table depth in the project scenario in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
$GHG_{WLwps\text{-}CH4,i,t}$	Emission of CH_4 related to water table depth in the project scenario in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
i	1, 2, 3, …M_{BSL} strata[20] in the project scenario
t	1, 2, 3, … *t** years elapsed since the project start

The project may establish project-specific values for $GHG_{WLwps\text{-}CO2}$ and $GHG_{WLwps\text{-}CH4}$ or apply values from appropriate literature sources pertaining to land use classes, water table depths or water table depth classes. For such literature values the accuracy must be defined or conservativeness must be justified. If the mean annual water table depth in the project area exceeds the depth range for which the emission-vegetation or emission-water table depth relationship determined for the project is valid, a conservative extrapolation must be used.

Procedures for the determinations of GHG fluxes and water table depth measurements are provided in Section 9.3.6.

[20] Note that different water levels or water level classes result in different strata. Water levels or water level classes (e.g., 0-10 cm, 11-20 cm, etc.) can be used, depending on data availability

8.2.3.2 Direct estimate approach

GEST conversion assessments may provide direct conservative estimates of emission reductions due to rewetting, rather than providing estimates of baseline and project emissions separately (e.g., a conversion of GEST type a to type b is associated with a given emission reduction with a given uncertainty, or the emission reduction is estimated conservatively).

Table 8.1. Suggested table format for conservative estimates of emission reductions for GEST conversions from drained to rewetted.

Table 8.1: Estimated Emission Reductions for GEST Conversions

GEST t_1	GEST t_2	Emission reduction t CO_2e $ha^{-1}yr^{-1}$
…	…	…
…	…	…

Where this approach is applied, equation 55 in Section 8.5 is amended to:

$$NER_{RDP} = 44/12 \times (\Delta C_{BSL} - \Delta C_{WPS}) + \Delta GHG_{rewetting} + \mathit{Fire\ Reduction\ Premium} - GHG_{LK} \quad \textbf{(42)}$$

The greenhouse gas emission reduction due to rewetting is estimated as:

$$\Delta GHG_{rewetting,i,t} = A_{i,t} \times ((GHG_{GESTbsl\text{-}CO2,i,t} + GHG_{GESTbsl\text{-}CH4,i,t}) - (GHG_{GESTwps\text{-}CO2,i,t} + GHG_{GESTwps\text{-}CH4,i,t})) \quad \textbf{(43)}$$

Where:

$\Delta GHG_{rewetting,i,t}$	Greenhouse gas emission reduction due to rewetting in stratum *i* in year *t*; t CO_2e yr^{-1}
$A_{i,t}$	Total area of stratum *i* in year *t*[21];; ha
$GHG_{GESTbsl\text{-}CO2,i,t}$	Emission of CO_2 from baseline GEST in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
$GHG_{GESTwps\text{-}CO2,i,t}$	Emission of CO_2 from project GEST in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
$GHG_{GESTbsl\text{-}CH4,i,t}$	Emission of CH_4 from baseline GEST in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
$GHG_{GESTwps\text{-}CH4,i,t}$	Emission of CH_4 from project GEST in stratum *i* in year *t*; t CO_2e $ha^{-1}yr^{-1}$
i	1, 2, 3, … M_{BSL} strata in the project scenario
t	1, 2, 3, … *t** years elapsed since the project start

[21] Note that if baseline strata are subdivided in the project scenario, areas $A_{i,t}$ are equal to $A_{WPS,i,t}$ of the relevant strata *i*; if baseline strata are merged in the project scenario, areas $A_{i,t}$ are equal $A_{WPS,i,t}$ of strata that include the merged baseline strata *i*. For unaffected strata $A_{i,t}$ equals $A_{WPS,i,t}$

$$\Delta GHG_{rewetting} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{WPS}} \Delta GHG_{rewetting,i,t} \tag{44}$$

For $t > t_{PDT\text{-}BSL,i}$:

$$GHG_{rewetting,i,t} = 0 \tag{45}$$

Where:

$\Delta GHG_{rewetting}$	Greenhouse gas emission reduction due to rewetting up to year t^*; t CO_2e
$GHG_{rewetting,i,t}$	Greenhouse gas emission reduction due to rewetting in stratum i in year t; t CO_2e yr^{-1}
Fire Reduction Premium	Greenhouse gas emission reduction from peat combustion due to rewetting and fire management up to year t^*; t CO_2e
GHG_{LK}	Net CO_2 equivalent emissions in the project scenario due to leakage up to year t^*; t CO_2e
$t_{PDT\text{-}BSL,i}$	PDT in the baseline scenario in stratum i in years elapsed since the project start; yr
i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the project start

$$\Delta C_{BSL} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{BSL}} \Delta C_{BSL-NP,i,t} \tag{46}$$

Where:

ΔC_{BSL}	Net carbon stock change in non-peat carbon pools in the baseline scenario up to year t^*; t CO_2e
$\Delta C_{BSL\text{-}NP,i,t}$	Net carbon stock change in non-peat carbon pools in the baseline scenario in stratum i in year t; t CO_2e yr^{-1}
i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the project start

$$\Delta C_{WPS} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{BSL}} \Delta C_{WPS-NP,i,t} \tag{47}$$

Where:

ΔC_{WPS}	Net carbon stock change in non-peat carbon pools in the project scenario up to year t^*; t CO_2e

$\Delta C_{WPS\text{-}NP,i,t}$	Net carbon stock change in non-peat carbon pools in the project scenario in stratum *i* in year *t*; t CO_2e yr^{-1}
i	1, 2, 3, … M_{WPS} strata in the project scenario
t	1, 2, 3, … *t** years elapsed since the project start

8.3 Fire Reduction Premium

This methodology addresses anthropogenic peat fires occurring in drained peatland and establishes a conservative default value, based on fire occurrence and extension in the project area in the baseline scenario, so as to avoid the direct assessment of GHG emissions from fire in the baseline and the project scenarios.

The *Fire Reduction Premium* approach is only applicable if anthropogenic peat fires do not occur in the project scenario. The use of fire as a management tool (non-catastrophic fires or human-induced fires) in the project scenario is not allowed in the case that the *Fire Reduction Premium* approach is used to estimate emissions from peat fire.

The 20% Fire Reduction Premium

The 20% fire reduction premium is a rapid and conservative approach to acknowledging fire emission reductions as a result of rewetting without having to develop complex baseline scenarios for peat fires. Emissions from peat fires are, like emissions from microbial peat oxidation, negatively correlated with water table depth (cf. Turetsky *et al*., 2011, Ballhorn *et al.*, 2009). This allows a correlation of emissions from peat fires and microbial peat oxidation. Carbon losses from peat fires[22] are per hectare burned area on average ~10 times larger than the annual carbon emissions from microbial peat oxidation per ha drained peatland (i.e., in temperate and boreal areas; in tropical SE Asia even ~20 times, cf. Ballhorn *et al.*, 2009, Couwenberg *et al.*, 2010, Van der Werf *et al.*, 2008)). If in the baseline scenario at least 25% of the project area would burn at least once every 10 years and if rewetting and fire fighting in the project scenario would stop all carbon losses from microbial peat oxidation and all carbon losses from fire, the peat fire emission reduction would be 25% of the emission reduction from microbial peat oxidation. The 20% default premium is thus a conservative value.

The fire reference period is fixed to a period prior to project start to prevent deliberate fires to meet the eligibility criteria. A minimum period of 10 years must be assessed in order to ensure a representative time period that will reflect frequency of fires in the baseline.

In this procedure, the CO_2 emission reductions from microbial peat oxidation due to rewetting in the project scenario are estimated first (Sections 8.1.3 and 8.2.3 and Equation 48). The default value for reduced emissions from peat fire has a maximum of 20% of the reduced CO_2 emissions from microbial peat oxidation due to rewetting, if the cumulative area[23] burnt in the fire reference period was equal to or exceeded 25% of the project area. This amount of emission reductions

[22] Conservatively assuming that all carbon losses from peat fires occur as CO_2.
[23] The maximum number of times a recurring fire can be counted is 3.

(Equation 48) is denoted '*Fire Reduction Premium*'. The project will only be eligible to claim the premium if the following applies:

1) Over the period of 10 to 15 years, ending 2 years before the project start date, the cumulative area of peat burnt exceeded 10% of the project area (where repeated burning of the same area adds to the percentage). Evidence must be provided using statistics and/or maps in official reports and/or remote sensing data; and,
2) In the baseline scenario the area is now, and in future will be, under risk of anthropogenic peat fires, as demonstrated by current and historic fire statistics and/or fire maps for the project area, in combination with information on current and future land use; and,
3) The fire management plan proposed by the project proponent at validation reflects the best practices available with respect to fire prevention and control as determined by the relevant authorities[24] and takes into account specific project circumstances; and,
4) At each verification, documentation is provided demonstrating that fire management activities have been implemented according to the proposed plan.

If peat fires in the baseline scenario are more frequent than once per 10 years or more extensive than 25% of the project area, the awarded premium is more conservative. If peat fires are less frequent or extensive, the premium is smaller accordingly. If peat fires in the baseline are less extensive than 10% of the project area, the premium is not awarded.

If $(A_{peatburn} / A_P) \geq 0.25$ the emission reduction from peat combustion due to rewetting and fire management is estimated as:

$$Fire\ Reduction\ Premium = 0.20 \times (GHG_{GESTbsl\text{-}CO2} - GHG_{GESTwps\text{-}CO2}) \quad \textbf{(48)}$$

If $(A_{peatburn} / A_P) < 0.1$ then

$$Fire\ Reduction\ Premium = 0 \quad \textbf{(49)}$$

If $(A_{peatburn} / A_P) < 0.25$ and $A_{peatburn} / A_P \geq 0.1$ then

$$Fire\ Reduction\ Premium = (A_{peatburn} / A_P) \times 0.8 \times (GHG_{GESTbsl\text{-}CO2} - GHG_{GESTwps\text{-}CO2}) \quad \textbf{(50)}$$

$$GHG_{GESTbsl\text{-}CO2} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{BSL}} GHG_{GESTbsl\text{-}CO2,i,t} \quad \textbf{(51)}$$

$$GHG_{GESTwps\text{-}CO2} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{BSL}} GHG_{GESTwps\text{-}CO2,i,t} \quad \textbf{(52)}$$

Where:

Fire Reduction Premium Greenhouse gas emission reduction from peat combustion due to

[24] Verifiable evidence must be provided in the project documentation.

	rewetting and fire management up to year t^*; t CO_2e
$GHG_{GESTbsl\text{-}CO2}$	Emission of CO_2 from GESTs in the baseline scenario up to year t^*; t CO_2e
$GHG_{GESTwps\text{-}CO2}$	Emission of CO_2 from GESTs in the project scenario up to year t^*; t CO_2e
$GHG_{GESTbsl\text{-}CO2,i,t}$	Emission of CO_2 from baseline GEST in stratum i in year t; t CO_2e yr^{-1}
$GHG_{GESTwps\text{-}CO2,i,t}$	Emission of CO_2 from project GEST in stratum i in year t; t CO_2e yr^{-1}
$A_{peatburn}$	Cumulative area burnt; ha
A_P	Total project area; ha
i	1, 2, 3, … M_{BSL} strata in the baseline scenario
t	1, 2, 3, … t^* years elapsed since the project start

Fire Reduction Premium may be calculated on a total project basis, which implies that the documentation referred to in requirements 3 and 4 above are provided at the project level. Alternatively, the assessment may be executed at the sub-project level, for example if the project is made up of a number of different peat bogs or fens that have different baseline fire histories, or in case of instances in a Grouped Project.

Ex-ante estimate of *Fire Reduction Premium*: The estimate of $GHG_{GESTwps\text{-}CO2,i,t}$ in Equation 52 must be taken from *ex-ante* calculations (Section 8.2.3.2).

Ex-post estimate of *Fire Reduction Premium*: The estimate of $GHG_{GESTwps\text{-}CO2,i,t}$ in Equation 52 must be taken from monitoring results.

If a) peatland rewetting and b) a best-practices fire management have been implemented, peat fires occurring in the project scenario can be assumed to be catastrophic reversals[25] (i.e. events that would have occurred in the baseline scenario but that would have been unaccounted for). Therefore, provided the above-mentioned two conditions are met, such fire events will not affect the claim to fire emission reduction by the project.

Although rewetting and fire management are aimed at stopping fire in the project scenario, rewetting and fire management may fail, causing peatland fires to occur. Peatland fires inside the project boundary must, therefore, be monitored and – if not catastrophic as defined above – accounted for by cancelling the premium for the entire project or the individual sub-project, as in:

$$\textit{Fire Reduction Premium} = 0 \qquad \textbf{(53)}$$

In case of non-catastrophic fires, adjustments must be made for subsequent changes in carbon store and GHG fluxes (e.g., peat stocks at t=100).

[25] See *VCS Program Definitions* for definition of catastrophic reversal.

8.4 Leakage

Under the applicability conditions of this methodology, market leakage and activity shifting leakage do not occur. Project proponents must demonstrate, based on verifiable information (such as laws and bylaws, management plans, market reports) that in case the pre-project land use is one or a combination of the following:

- Forestry, this forestry is non-commercial in nature;
- Peat extraction, this activity has been abandoned at least 2 years[26] prior to the project start date;
- Agriculture, food, fodder or fiber production has been abandoned at least 2 years prior to the project start date, or will continue in the project scenario, or drainage of additional peatland for new agricultural sites will not occur or is prohibited by law;
- Fuel wood extraction, the activity is non-commercial in nature.

Under the applicability conditions of this methodology, ecological leakage also does not occur, by ensuring that hydrological connectivity with adjacent areas is insignificant (i.e. causing no alteration of mean annual water table depths in such areas). This can be achieved either by an appropriate design (e.g., by establishing an impermeable dam) or by a buffer zone within the project boundary for which conservatively no GHG benefits are accounted. This buffer zone, if employed, must be mapped and is not eligible for carbon crediting. The width of the buffer zone must be determined on the basis of quantitative hydrological modeling, or expert judgment. Procedures for monitoring are provided in Sections 9.3.4 and 9.3.6.

Therefore:

$$GHG_{LK} = 0 \qquad \textbf{(54)}$$

8.5 Summary of GHG Emission Reduction and/or Removals

8.5.1 Calculation of net GHG emissions reductions

The total net GHG emission reductions from the RDP project activity are calculated as follows:

$$NER_{RDP} = GHG_{BSL} - GHG_{WPS} + Fire\ Reduction\ Premium - GHG_{LK} \qquad \textbf{(55)}$$

[26] Agents abandoning peat extraction for the purpose of a rewetting project are unlikely to exist, because the investments in making a new area suitable for peat extraction by far exceed the revenues of a carbon project on the same area.

Where the direct estimate approach in estimating emission reductions due to rewetting (Section 8.2.3.2) is adopted, the total net GHG emission reductions are calculated as follows:

$$NER_{RDP} = 44/12 \times (\Delta C_{BSL} - \Delta C_{WPS}) + \Delta GHG_{rewetting} + \mathit{Fire\ Reduction\ Premium} - GHG_{LK} \quad \textbf{(56)}$$

Where:

NER_{RDP}	Total net CO_2 equivalent emission reductions from the RDP project activity up to year t^*; t CO_2e
GHG_{BSL}	Net CO_2 equivalent emissions in the baseline scenario up to year t^*; t CO_2e
GHG_{WPS}	Net CO_2 equivalent emissions in the project scenario up to year t^*; t CO_2e
ΔC_{BSL}	Net carbon stock change in non-peat carbon pools in the baseline scenario up to year t^*; t C
ΔC_{WPS}	Net carbon stock change in non-peat carbon pools in the project scenario up to year t^*; t C
$\Delta GHG_{rewetting}$	Greenhouse gas emission reduction due to rewetting up to year t^*; t CO_2e
Fire Reduction Premium	Greenhouse gas emission reduction from peat combustion due to rewetting and fire management up to year t^*; t CO_2e
GHG_{LK}	Net CO_2 equivalent emissions in the project scenario due to leakage up to year t^*; t CO_2e

NER_{RDP} must be corrected for uncertainty, by estimating the total uncertainty for the RDP project activity (NER_{RDP_ERROR}) as provided in Section 8.5.2.

8.5.2 Estimation of uncertainty

This procedure allows for estimating uncertainty in the estimation of emissions and carbon stock changes (i.e., a procedure for calculating a precision level and any deduction in credits for lack of precision following project implementation and monitoring, by assessing uncertainty in baseline and project estimations).

This procedure focuses on the following sources of uncertainty:

- Uncertainty associated with estimation of stocks in carbon pools and changes in carbon stocks
- Uncertainty in assessment of project emissions

Where an uncertainty value is not known or cannot be simply calculated, then the project proponent must justify that it is using a conservative number and an uncertainty of 0% may be used for this component.

Guidance on uncertainty – a precision target of a 90% or 95% confidence interval equal to or less than 20% or 30%, respectively, of the recorded value must be targeted. This is especially important in terms of project planning for measurement of carbon stocks where sufficient measurement plots should be included to achieve this precision level across the measured stocks.

Required conditions:

- Levels of uncertainty must be known for all aspects of baseline and project implementation and monitoring. Uncertainty will generally be known as the 90% or 95% confidence interval expressed as a percentage of the mean.
- Where uncertainty is not known it must be demonstrated that the value used is conservative.

Estimated carbon emissions and removals arising from AFOLU activities have uncertainties associated with the measures/estimates of: area or other activity data, carbon stocks, biomass growth rates, expansion factors, and other coefficients. It is assumed that the uncertainties associated with the estimates of the various input data are available, either as default values given in IPCC Guidelines (2006), IPCC GPG-LULUCF (2003), expert judgment, or estimates based of sound statistical sampling.

Alternatively, conservative estimates can also be used instead of uncertainties, provided that they are based on verifiable literature sources or expert judgment. In this case the uncertainty is assumed to be zero. However, this tool provides a procedure to combine uncertainty information and conservative estimates resulting in an overall *ex-post* project uncertainty.

Planning to Diminish Uncertainty

It is important that the process of project planning consider uncertainty. Procedures including stratification and the allocation of sufficient measurement plots can help ensure that low uncertainty in carbon stocks results and ultimately full crediting can result.

It is good practice to apply this procedure at an early stage to identify the data sources with the highest uncertainty to allow the opportunity to conduct further work to diminish uncertainty.

Part 1 – Uncertainty in Baseline Estimates

$$Uncertain_{BSL,i} = \frac{\sqrt{\left(U_{BSL,SS1,i} * E_{BSL,SS1,i}\right)^2 + \left(U_{BSL,SS2,i} * E_{BSL,SS2,i}\right)^2 \cdots + \cdots \left(U_{BSL,SSn,i} * E_{BSL,SSn,i}\right)^2}}{E_{BSL,SS1,i} + E_{BSL,SS2,i} \cdots + \cdots E_{BSL,SSn,i}} \quad \textbf{(57)}$$

Where:

$Uncertain_{BSL,i}$	Percentage uncertainty in the combined carbon stocks and greenhouse gas sources in the baseline case in stratum *i*; %
$U_{BSL,SS,i}$	Percentage uncertainty (expressed as 90% confidence interval as a percentage of the mean where appropriate) for carbon stocks and greenhouse gas sources in the baseline case in stratum *i* (1,2, … n represent different carbon pools and/or GHG sources); %
$E_{BSL,SS,i}$	Carbon stock or GHG sources (e.g., trees, down dead wood, etc.) in stratum *i* (1,2, … n represent different carbon pools and/or GHG sources) in the baseline case; t CO_2e
i	1, 2, 3, … M_{BSL} strata in the baseline scenario

To assess uncertainty across combined strata:

$$Uncertain_{BSL} = \frac{\sqrt{(U_{BSL,1} * A_1)^2 + (U_{BSL,2} * A_2)^2 \ldots + \ldots (U_{BSL,M_{BSL}} * A_{M_{BSL}})^2}}{A_1 + A_2 \ldots + \ldots A_{M_{BSL}}} \tag{58}$$

Where:

$Uncertain_{BSL}$	Total uncertainty in baseline scenario; %
$U_{BSL,i}$	Uncertainty in baseline scenario in stratum *i*; %
A_i	Area of stratum *i*; ha
i	1, 2, 3, … M_{BSL} strata in the baseline scenario

Part 2 – Uncertainty Ex-Post in the Project Scenario

$$Uncertain_{WPS,i} = \frac{\sqrt{(U_{WPS,SS1,i} * E_{WPS,SS1,i})^2 + (U_{WPS,SS2,i} * E_{WPS,SS2,i})^2 \ldots + \ldots (U_{WPS,SSn,i} * E_{WPS,SSn,i})^2}}{E_{WPS,SS1,i} + E_{WPS,SS2,i} \ldots + \ldots E_{WPS,SSn,i}} \tag{59}$$

Where:

$Uncertain_{WPS,i}$	Percentage uncertainty in the combined carbon stocks and greenhouse gas sources in the project case in stratum *i*; %
$U_{WPS,SS,i}$	Percentage uncertainty (expressed as 90% confidence interval as a percentage of the mean where appropriate) for carbon stocks and greenhouse gas sources in the project case in stratum *i* (1,2, … n represent different carbon pools and/or GHG sources); %
$E_{WPS,SS,i}$	Carbon stock or GHG sources (e.g., trees, down dead wood, etc.) in stratum *i* (1,2, … n represent different carbon pools and/or GHG sources) in the project case; t CO_2e

i	1, 2, 3, … M_{WPS} strata in the project scenario

To assess uncertainty across combined strata:

$$Uncertain_{WPS} = \frac{\sqrt{(U_{WPS,1} * A_1)^2 + (U_{WPS,2} * A_2)^2 \ldots + \ldots (U_{WPS,M_{BSL}} * A_{M_{BSL}})^2}}{A_1 + A_2 \ldots + \ldots A_{M_{BSL}}} \quad (60)$$

Where:

$Uncertain_{WPS}$	Total uncertainty in project scenario; %
$U_{WPS,i}$	Uncertainty in project scenario in stratum i; %
A_i	Area of stratum i; ha
i	1, 2, 3, … M_{WPS} strata in the project scenario

Part 3 – Total Error in RDP Project Activity

$$NER_{RDP\_ERROR} = \frac{\sqrt{(Uncertain_{BSL} \times GHG_{BSL})^2 + (Uncertain_{WPS} \times GHG_{WPS})^2}}{GHG_{BSL} + GHG_{WPS}} \quad (61)$$

Where:

NER_{RDP_ERROR}	Total uncertainty for RDP project activity; %
$Uncertain_{BSL}$	Total uncertainty in baseline scenario; %
$Uncertain_{WPS}$	Total uncertainty in the project scenario; %
GHG_{BSL}	Net CO_2 equivalent emissions in the baseline scenario up to year t^*; t CO_2e
GHG_{WPS}	Net CO_2 equivalent emissions in the project scenario up to year t^*; t CO_2e

The allowable uncertainty under this methodology is 20% or 30% of $NER_{RDP,t}$ at a 90% or 95% confidence level, respectively. Where this precision level is met no deduction should result for uncertainty. Where exceeded, the deduction must be equal to the amount that the uncertainty exceeds the allowable level. The adjusted value for $NER_{RDP,t}$ to account for uncertainty must be calculated as:

$$adjusted\_NER_{RDP,t} = NER_{RDP,t} \times (100\% - NER_{RDP\_ERROR} + allowable\_uncert) \quad (62)$$

Where:

$adjusted\_NER_{RDP,t}$	Cumulative total net GHG emission reductions at time t adjusted to account for uncertainty; t CO_2e
$NER_{RDP,t}$	Total net GHG emission reductions from the RDP project activity up to year t; t CO_2e

NER_{RDP_ERROR}	Total uncertainty for RDP project activity; %
allowable_unsert	Allowable uncertainty; 20% or 30% at a 90% or 95% confidence level, respectively; %

8.5.3 Calculation of Verified Carbon Units

The concept of withholding a number of buffer credits in the AFOLU pooled buffer account is based on quantifying the net change in carbon stocks. The proxy for the net change in carbon stocks applied in this methodology is NER (Section 8.5.1). As this proxy includes all net GHG emissions reductions, it provides a conservative (too large) estimate of the buffer withholding.

The number of Verified Carbon Units is calculated as:

$$VCU_{t2} = \left(adjusted\_NER_{RDP,t2} - adjusted\_NER_{RDP,t1}\right) - Bufferw_{t2} \quad \textbf{(63)}$$

Where:

VCU_{t2}	Number of Verified Carbon Units in year *t2*
$NER_{RDP,\ t1}$	Total net GHG emission reductions from the RDP project activity up to year *t1*; t CO_2e
$NER_{RDP,\ t2}$	Total net GHG emission reductions from the RDP project activity up to year *t2*; t CO_2e
NER_{RDP_ERROR}	Total uncertainty for RDP project activity; %
$Bufferw_{t2}$	Number of Verified Carbon Units to be withheld in the VCS Buffer in year *t2*

$$Bufferw_{t2} = \left(NER_{RDP,t2} - NER_{RDP,t1}\right) \times Buffer\%_{t2} \quad \textbf{(64)}$$

Where:

$Bufferw_{t2}$	Number of Verified Carbon Units to be withheld in the VCS Buffer in year *t2*
$NER_{RDP,\ t1}$	Total net GHG emission reductions from the RDP project activity up to year *t1*; t CO_2e
$NER_{RDP,\ t2}$	Total net GHG emission reductions from the RDP project activity up to year *t2*; t CO_2e
$Buffer\%_{t2}$	Percentage of Verified Carbon Units to be withheld in the VCS Buffer in year *t2*; %

The percentage to be withheld in the VCS buffer is to be determined using the latest version of the VCS *AFOLU Non-Permanence Risk Tool*.

The maximum quantity of GHG emission reductions that may be claimed by the project (VCU_{max}) is limited to the difference between project and baseline scenario after a 100-year time frame.

Procedures for estimating the difference between peat carbon stock in the project scenario and baseline scenario in stratum *i* at *t*=100 ($C_{WPS\text{-}BSL,i,t100}$) are provided in Section 5.2.

$$VCU_{max} = \frac{44}{12} \times C_{WPS-BSL,t100} \quad (65)$$

Where:

VCU_{max}	The maximum quantity of GHG emission reductions that may be claimed by the project ; t CO_2e
$C_{WPS\text{-}BSL,t100}$	Difference between peat carbon stock in the project scenario and baseline scenario at *t*=100; t C ha^{-1}

9 MONITORING

9.1 Data and Parameters Available at Validation

Data Unit / Parameter:	$Depth_{peat\text{-}BSL,i}$
Data unit:	m
Description:	Peat depth above the drainage limit in the baseline scenario in stratum *i* at project start
Equations	1, 4, 5
Source of data:	Own measurements and/or literature involving the project area
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Peat depths at project start can be derived from • Own measurements (using peat corers, ground penetrating radar or other techniques laid out in scientific literature or handbooks) • Literature involving the project or similar areas.
Purpose of Data	Calculation of baseline emissions Calculation of the maximum quantity of GHG emission reductions that may be claimed by the project
Comments:	$Depth_{peat\text{-}BSL,i,t0} = Depth_{peat\text{-}WPS,i,t0}$ This parameter must be re-assessed together with the re-assessment of the baseline scenario.

Data Unit / Parameter:	$Depth_{peat\text{-}WPS,i}$

Data unit:	m
Description:	Peat depth above the drainage limit in the project scenario in stratum *i* at project start
Equations	6
Source of data:	As for $Depth_{peat\text{-}BSL,i}$
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	As for $Depth_{peat\text{-}BSL,i}$
Purpose of Data	Calculation of the maximum quantity of GHG emission reductions that may be claimed by the project
Comments:	Only for *ex-ante* assessment $Depth_{peat\text{-}BSL,i,t0} = Depth_{peat\text{-}WPS,i,t0}$

Data Unit / Parameter:	$Rate_{peatloss\text{-}BSL,i}$
Data unit:	m yr^{-1}
Description:	Rate of peat loss due to subsidence and fire in the baseline scenario in stratum *i*
Equations	1, 5, 9
Source of data:	Own measurements, expert judgment, datasets and/or literature of historic subsidence
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	The rate of peat loss due to subsidence must be based on verifiable information and can be derived from 1. Expert judgment, datasets and/or literature of historic subsidence involving the project or similar areas, based on surface height measurements relative to a fixed reference point in m asl (e.g., using poles fixed in the underlying mineral soil or rock, or using LiDAR, or similar). Information used must be verifiable. Or 2. CO_2 emissions derived from the prevalent GESTs (Section 8.1.3), in combination with data on volumetric carbon content of the peat. Divide the annual CO_2 emission (t CO_2 ha^{-1}) by 44/12, then divide by volumetric carbon

	content (g C cm^{-3}) to obtain height loss in m. The average depth of burn scars can be derived from expert judgment, datasets and/or literature of historic burn depths involving the project or similar areas, based on surface height measurements (e.g., using field measurements or LiDAR). When using LiDAR data, projects must use a scientifically robust approach, referring to pertinent scientific literature, ensuring a horizontal accuracy in the meter and a vertical accuracy in the centimeter range. In case of tree cover, scientifically accepted methods must be used to distinguish ground points from non-ground points reflected by the vegetation. Projects may, for example, use the procedures described in Ballhorn *et al*. (2009). Projects may deviate from these procedures provided that the accuracy requirements above are met. The areal extent of burn scars can be obtained from statistics and/or maps in official reports and/or field measurements or remote sensing data (similar materials as required under eligibility criteria 1 and 2 in Section 8.3(*Fire Reduction Premium*), A mean annualized burn depth must be calculated and applied to the entire project area. As only part of the project area is likely to burn in the baseline, this constitutes a conservative approach. The project proponent must demonstrate, using expert judgment, datasets and/or scientific literature that the accuracy of the derived rate of peat loss is sufficient to fulfill the criteria set out in Section 5.2(Stratification). Similarity of areas must be illustrated (by own measurements, literature resources, datasets or a combination of these) addressing peat type, climatic conditions, land use (forestry, agriculture, peat extraction, or abandonment after these activities), and average annual water table depth (±20%). In case of dissimilarity, the project proponent must demonstrate that such difference gives a conservative result for the net GHG benefits of the project. Forecasting peat subsidence rates must be based on the conservative extrapolation of a historic trend, or conservative modeling of proxies such as water table depth and land use type.
Purpose of Data	Calculation of baseline emissions

	Calculation of the maximum quantity of GHG emission reductions that may be claimed by the project
Comments:	The use of a relatively low value for a constant rate of peat loss may not be confused with a relatively high value when determining the need for stratification of peat depth. This parameter must be re-assessed together with the re-assessment of the baseline scenario.

Data Unit / Parameter:	$Rate_{peatloss\text{-}WPS,i}$
Data unit:	m yr^{-1}
Description:	Rate of peat loss due to subsidence in the project scenario in stratum *i*
Equations	6, 10
Source of data:	Own measurements, expert judgment, datasets and/or literature of historic subsidence
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	The rate of peat loss due to subsidence must be based on verifiable information and can be derived from 1. Expert judgment, datasets and/or literature of subsidence involving areas representing conditions similar to the project, based on surface height measurements relative to a fixed reference point in m asl (e.g., using poles fixed in the underlying mineral soil or rock, or by using LiDAR following methods such as those described in Ballhorn *et al*. 2009) or similar. Or 2. CO_2 emissions derived from the prevalent GESTs based on *ex-ante* scenario definitions (Section 8.2.3), in combination with data on volumetric carbon content of the peat. Divide the annual CO_2 emission (t CO_2 ha^{-1}) by 44/12, then divide by volumetric carbon content (g C cm^{-3}) to obtain height loss in m. The project proponent must demonstrate, using expert judgment, datasets and/or scientific literature that the accuracy of the derived rate of peat loss is sufficient to fulfill the criteria set out in Section 5.2(Stratification).

	Similarity of areas must be illustrated (by own measurements, literature resources, datasets or a combination of these) addressing peat type, climatic conditions, land use (forestry, agriculture, peat extraction, or abandonment after these activities), and average annual water table depth (±20%). In case of dissimilarity, the project proponent must demonstrate that such difference gives a conservative result for the net GHG benefits of the project.
Purpose of Data	Calculation of the maximum quantity of GHG emission reductions that may be claimed by the project
Comments:	Only for *ex-ante* assessment

Data Unit / Parameter:	VC_{peat}
Data unit:	t C m^{-3}
Description:	Volumetric carbon content of peat
Equations	3, 4, 9, 10
Source of data:	The volumetric carbon content in peat can be taken from own measurements within the project area or from literature involving the project or similar areas.
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.
Purpose of Data	Calculation of the maximum quantity of GHG emission reductions that may be claimed by the project
Comments:	N/A

Data Unit / Parameter:	$A_{BSL,i,t}$
Data unit:	ha
Description:	Area of baseline stratum *i* in year *t*
Equations	2, 7, 8, 11, 14, 26, 27, 43
Source of data:	Own assessment
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures	Delineation of strata must be done preferably using a geographical information system (GIS), which allows for integrating data from different sources (including GPS

applied:	coordinates and remote sensing data). Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.
Purpose of Data	Calculation of baseline emissions
Comments:	In Equations 2, 7, 8 and 11 the parameter is denoted as $A_{BSL,i,t100}$, which is the area of baseline stratum *i* at *t*=100.

Data Unit / Parameter:	R_j
Data unit:	t root d.m. t^{-1} shoot d.m.
Description:	Root:shoot ratio for tree species *j*
Equations	17, 33
Source of data:	The source of data must be chosen with priority from higher to lower preference as follows: (a) National and species-specific or group of species-specific (e.g., from national GHG inventory); (b) Species-specific or group of species-specific from neighboring countries with similar conditions. Sometimes b) might be preferable to a); (c) Species-specific or group of species-specific from global studies. See also IPCC GPG 2003, Annex 3.A1, Table 3A1.8
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Taken from CDM A/R methodology
Purpose of Data	Calculation of baseline emissions Calculation of project emissions
Comments:	

Data Unit / Parameter:	CF_j
Data unit:	t C t $d.m.^{-1}$
Description:	Carbon fraction of dry matter for species *j*
Equations	19, 22, 23, 31, 34
Source of data:	IPCC default value

Value applied:	0.5
Justification of choice of data or description of measurement methods and procedures applied:	IPCC is a reputable source approved by the VCS
Purpose of Data	Calculation of baseline emissions Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	$I_{v,j,i,t}$
Data unit:	$m^{-3}ha^{-1}yr^{-1}$
Description:	Average annual increment in merchantable volume for species *j* in stratum *i* in year *t*
Equations	20
Source of data:	Based on monitored parameters (species, yield class, age) to be found in regional forest growth tables.
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Common source of data in forestry
Purpose of Data	Calculation of baseline emissions
Comments:	N/A

Data Unit / Parameter:	D_j
Data unit:	t d.m. m^{-3}
Description:	Basic wood density for species *j*
Equations	20, 22, 31
Source of data:	Datasets or literature
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Values for D_j can be taken from tables generally used in the local or regional timber and forest industry, or from peer-reviewed literature applicable to the region. If no species-specific values for D_j are available, the average value across all species can be used, increased by 20% to ensure conservative estimates in the baseline, or decreased by

	20% to ensure conservative estimates in the project scenario. The source of data must be chosen with priority from higher to lower preference as follows: (a) National and species-specific or group of species-specific (e.g., from national GHG inventory); (b) (Group of) Species-specific from neighbouring countries with similar conditions. Sometimes b) might be preferable to a); (c) Globally species-specific or group of species-specific (e.g., IPCC GPG-LULUCF 2003). This is taken from a CDM A/R methodology.
Purpose of Data	Calculation of baseline emissions Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	$BEF_{1,j}$
Data unit:	dimensionless
Description:	Biomass expansion factor for conversion of annual net increment (including bark) in merchantable volume to total above-ground biomass increment for species *j*
Equations	20
Source of data:	The source of data must be chosen with priority from higher to lower preference as follows: a. Existing local and species-specific or group of species-specific; b. National and species-specific or group of species-specific (e.g., from national GHG inventory) c. Species-specific or group of species-specific from neighbouring countries with similar conditions (might be preferable to b under certain conditions) d. Climatic zone and forest type (eg IPCC literature: Table 3A.1.10 of the GPG-LULUCF (IPCC 2003) and Table 4.5 of the AFOLU Guidelines (IPCC 2006)
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures	Taken from CDM A/R methodology

applied:	
Purpose of Data	Calculation of baseline emissions
Comments:	*BEFs* are age dependent, and they are usually large for young stands and quite small for old stands; *BEFs* in IPCC literature and national inventory data are usually applicable to closed canopy forest. If applied to individual trees growing in open field it is recommended that the selected *BEF* be increased by a further 30%.

Data Unit / Parameter:	K_{ph}
Data unit:	dimensionless
Description:	Alexeyev coefficient, converts volumes of above ground growing stock ($m^3 ha^{-1}$) to above, below ground and bark dry biomass (t d.m. ha^{-1})
Equations	-
Source of data:	Alexeyev *et al*. (1995). Carbon in vegetation in Russian forests: methods to estimate storage and geographical distribution. Water, Air Soil Pollution 82: 271-282
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Peer-reviewed literature is a VCS-approved source
Purpose of Data	Calculation of baseline emissions
Comments:	May be used instead of R_j and BEF_j

Data Unit / Parameter:	$V_{j,i,t}$
Data unit:	m^3 ha^{-1}
Description:	Stem volume of tree species *j* in stratum *i* in year *t*
Equations	22
Source of data:	Datasets or literature
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures	Common source of data in forestry

applied:	
Purpose of Data	Calculation of baseline emissions
Comments:	Note that volume tables from which $V_{j,i,t}$ are obtained may or may not include allowance for losses due to harvesting or mortality. Such losses may be conservatively neglected when estimating baseline removals in pre-project trees. Otherwise $C_{BSL\text{-}tree\text{-}AB,j,i,t}$ must be estimated on the basis of credible and transparent information on the rate at which pre-project activities (and mortality, if applicable) are reducing carbon stocks in existing live trees (e.g., due to harvesting for local timber consumption, or for fuelwood).

Data Unit / Parameter:	BEF_{2j}
Data unit:	dimensionless
Description:	Biomass expansion factor for conversion of stem biomass to above-ground tree biomass for species *j*
Equations	22, 31
Source of data:	The source of data must be chosen with priority from higher to lower preference as follows: a. Existing local and species-specific or group of species-specific; b. National and species-specific or group of species-specific (e.g., from national GHG inventory) c. Species-specific or group of species-specific from neighbouring countries with similar conditions (might be preferable to b under certain conditions) d. Climatic zone and forest type (e.g., IPCC literature: Table 3A.1.10 of the GPG-LULUCF (IPCC 2003) and Table 4.5 of the AFOLU Guidelines (IPCC 2006)
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Taken from CDM A/R methodology
Purpose of Data	Calculation of baseline emissions Calculation of project emissions
Comments:	

Data Unit / Parameter:	$nTR_{j,i,t}$
Data unit:	trees ha^{-1}
Description:	Tree stand density of species *j* in stratum *i* in year *t*
Equations	23
Source of data:	Field measurement in sample plots or from forest inventory
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.
Purpose of Data	Calculation of baseline emissions
Comments:	N/A

Data Unit / Parameter:	$f_j(X, Y, …)$
Data unit:	t d.m. tree^{-1}
Description:	Allometric equation for species *j* linking measured tree dimension variables (e.g., diameter at breast height (*DBH*) and possibly height (*H*)) to above-ground biomass of living trees.
Equations	23
Source of data:	Own measurements or literature, or both
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	The allometric equations are preferably locally derived and species specific. When allometric equations developed from a biome-wide database, such as those in Annex 4A.2, Tables 4.A.1 and 4.A.2 of IPCC GPG LULUCF, are used, it is necessary to verify by destructively harvesting, within the project area but outside the sample plots, a few trees of different sizes and estimate their biomass and then compare against a selected equation. If the biomass estimated from the harvested trees is within about □1 by the equation, then it can be assumed that the selected equation is suitable for the project. If this is not the case, it is recommended to develop local allometric equations for the project use. For this, a sample of trees, representing different size classes, is destructively harvested, and its total biomass is determined. The number of trees to be destructively harvested and measured depends on the

	range of size classes and number of species—the greater the heterogeneity the more trees are required.
Purpose of Data	Calculation of baseline emissions Calculation of project emissions
Comments:	Used for trees known at validation

Data Unit / Parameter:	$GHG_{GESTbsl\text{-}CO2,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Emission of CO_2 from baseline GEST in stratum *i* in year *t*
Equations	26, 43
Source of data:	Data can be obtained from peer-reviewed literature or from own measurements.
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	See Section 9.3.6 for procedures to describe and quantify this proxy.
Comments:	This parameter must be re-assessed together with the re-assessment of the baseline scenario.

Data Unit / Parameter:	$GHG_{WLbsl\text{-}CO2,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Emission of CO_2 related to water table depth in the baseline scenario in stratum *i* in year *t*
Equations	27
Source of data:	Data can be obtained from peer-reviewed literature or from own measurements.
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	See Section 9.3.6 for procedures to quantify this proxy. The project may establish project-specific values for $GHG_{WLbsl\text{-}CO2}$ or apply values from appropriate literature sources pertaining to land use classes, or water table depths or water table depth classes and similar project circumstances. For such literature values the accuracy must be defined or conservativeness must be justified. Project circumstances are defined by pre-project land use (e.g., forestry, peat mining, agriculture, abandonment after such

	activities) and its intensity, climatic zone, water table depths, and peat type. If the mean annual water table depth in the project area exceeds the depth range for which the emission-vegetation or emission-water table depth relationship determined for the project is valid, a conservative extrapolation must be used.
Purpose of Data	Calculation of baseline emissions
Comments:	This parameter must be re-assessed together with the re-assessment of the baseline scenario.

Data Unit / Parameter:	$GHG_{GESTbsl\text{-}CH4,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Emission of CH_4 from baseline GEST in stratum *i* in year *t*
Equations	26, 43
Source of data:	Data can be obtained from peer-reviewed literature or from own measurements.
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	See Section 9.3.6 for procedures to describe and quantify this proxy.
Purpose of Data	Calculation of baseline emissions
Comments:	This parameter must be re-assessed together with the re-assessment of the baseline scenario.

Data Unit / Parameter:	$GHG_{WLbsl\text{-}CH4,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Emission of CH_4 related to water table depth in the baseline scenario in stratum *i* in year *t*
Equations	27
Source of data:	Data can be obtained from peer-reviewed literature or from own measurements.
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	See Section 9.3.6 for procedures to quantify this proxy. The project may establish project-specific values for $GHG_{WLbsl\text{-}CH4}$ or apply values from appropriate literature sources pertaining to land use classes, or water table

	depths or water table depth classes and similar project circumstances. For such literature values the accuracy must be defined or conservativeness must be justified. Project circumstances are defined by pre-project land use (e.g., forestry, peat mining, agriculture, abandonment after such activities) and its intensity, climatic zone, water table depths, and peat type. If the mean annual water table depth in the project area exceeds the depth range for which the emission-vegetation or emission-water table depth relationship determined for the project is valid, a conservative extrapolation must be used. $GHG_{WLbsl\text{-}CH4}$ may be conservatively neglected.
Purpose of Data	Calculation of baseline emissions
Comments:	This parameter must be re-assessed together with the re-assessment of the baseline scenario.

Data Unit / Parameter:	$V_{l,j,i,sp,t}$
Data unit:	m^3 $tree^{-1}$
Description:	Stem volume of tree *l* of species *j* in plot *sp* in stratum *i* in year *t*
Equations	35
Source of data:	$V_{l,j,i,sp,t}$ is based on available equations or yield tables (if locally derived equations or yield tables are not available use relevant regional, national or default data as appropriate).
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Common source of data in forestry
Purpose of Data	Calculation of baseline emissions
Comments:	N/A

Data Unit / Parameter:	$A_{peatburn}$
Data unit:	ha

Description:	Cumulative area burnt
Equations	50
Source of data:	Statistics and/or maps in official reports and/or remotes sensing data
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	The cumulative area burnt must be provided using statistics and/or maps in official reports and/or remotes sensing data. Repeated burning of the same area adds to the cumulative area. Delineation of the project area must be done preferably using a Geographical Information System (GIS), which allows for integrating data from different sources (including GPS coordinates and Remote Sensing data). Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.
Purpose of Data	Calculation of baseline emissions
Comments:	N/A

Data Unit / Parameter:	A_P
Data unit:	ha
Description:	Total project area
Equations	49, 50
Source of data:	Own assessment
Value applied:	n/a
Justification of choice of data or description of measurement methods and procedures applied:	Delineation of the project area must be done preferably using a Geographical Information System (GIS), which allows for integrating data from different sources (including GPS coordinates and Remote Sensing data). Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.
Purpose of Data	Calculation of baseline emissions
Comments:	N/A

9.2 Data and Parameters Monitored

Data Unit / Parameter:	$A_{WPS,i,t}$
Data unit:	ha
Description:	Area of project stratum *i* in year *t*
Equations:	2, 7, 8, 11, 30, 40, 43
Source of data:	Own assessment
Value applied:	n/a
Description of measurement methods and procedures to be applied:	Delineation of strata must be done preferably using a Geographical Information System (GIS), which allows for integrating data from different sources (including GPS coordinates and Remote Sensing data). Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.
Frequency of monitoring/recording:	Determined at each monitoring period
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	In Equations 2, 7, 8 and 11 the parameter is denoted as $A_{WPS,i,t100}$, which is the area of project stratum *i* at *t*=100.

Data Unit / Parameter:	$A_{sp,i}$
Data unit:	ha
Description:	Total area of all sample plots in stratum *i*
Equations:	37
Source of data:	Field measurements
Value applied:	n/a
Description of measurement methods and procedures to be applied:	Sample plots may be delineated on a map using a Geographical Information System (GIS). Alternatively, coordinates of sample plots map be stored in a GIS. The database must contain information on plot size and orientation. Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.

Frequency of monitoring/recording:	Determined at first monitoring period
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	$f_j(X, Y, \ldots)$
Data unit:	t d.m. tree^{-1}
Description:	Allometric equation for species *j* linking measured tree dimension variables (e.g., diameter at breast height (*DBH*) and possibly height (*H*)) to above-ground biomass of living trees.
Equations:	38
Source of data:	Own measurements or literature, or both
Value applied:	n/a
Description of measurement methods and procedures to be applied:	The allometric equations are preferably locally derived and species specific. When allometric equations developed from a biome-wide database, such as those in Annex 4A.2, Tables 4.A.1 and 4.A.2 of IPCC GPG LULUCF, are used, it is necessary to verify by destructively harvesting, within the project area but outside the sample plots, a few trees of different sizes and estimate their biomass and then compare against a selected equation. If the biomass estimated from the harvested trees is within about 10% of that predicted by the equation, then it can be assumed that the selected equation is suitable for the project. If this is not the case, it is recommended to develop local allometric equations for the project use. For this, a sample of trees, representing different size classes, is destructively harvested, and its total biomass is determined. The number of trees to be destructively harvested and measured depends on the range of size classes and number of species—the greater the heterogeneity the more trees are required.
Frequency of monitoring/recording:	Determined at first monitoring period
QA/QC procedures to be applied:	See Section 9.3.2

Purpose of Data:	Calculation of project emissions
Comments:	Used for trees monitored

Data Unit / Parameter:	*DBH*
Data unit:	cm
Description:	Diameter at breast height of tree
Equations:	38
Source of data:	Field measurement in sample plots
Value applied:	n/a
Description of measurement methods and procedures to be applied:	Measure all the trees above 5 cm DBH at typically 1.3 m above-ground level in the permanent sample plots. Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.
Frequency of monitoring/recording:	Determined at each monitoring period
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	*H*
Data unit:	m
Description:	Height of tree
Equations:	38
Source of data:	Field measurement in sample plots
Value applied:	n/a
Description of measurement methods and procedures to be applied:	Applied techniques shall follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.
Frequency of	Determined at each monitoring period

monitoring/recording:	
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	$GHG_{GESTwps-CO2,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Emission of CO_2 from project GEST in stratum *i* in year *t*
Equations:	40, 43
Source of data:	Data can be obtained from peer-reviewed literature or from own measurements.
Value applied:	n/a
Description of measurement methods and procedures to be applied:	See Section 9.3.6 for procedures to quantify this proxy.
Frequency of monitoring/recording:	See Section 9.3.6
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	$GHG_{GESTwps-CH4,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Emission of CH_4 from project GEST in stratum *i* in year *t*
Equations:	40, 43
Source of data:	Data can be obtained from peer-reviewed literature or from own measurements.
Value applied:	n/a
Description of measurement methods and procedures to be applied:	See Section 9.3.6 for procedures to quantify this proxy.
Frequency of monitoring/recording:	See Section 9.3.6

QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	$GHG_{WLwps\text{-}CO2,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Emission of CO_2 related to water table depth in the project scenario in stratum *i* in year *t*
Equations:	41
Source of data:	Data can be obtained from peer-reviewed literature or from own measurements.
Value applied:	n/a
Description of measurement methods and procedures to be applied:	See Section 9.3for procedures to quantify this proxy. The project may establish project-specific values for $GHG_{WLwps\text{-}CO2}$ or apply values from appropriate literature sources pertaining to land use classes, or water table depths or water table depth classes. For such literature values the accuracy must be defined or conservativeness must be justified. If the mean annual water table depth in the project area exceeds the depth range for which the emission-vegetation or emission-water table depth relationship determined for the project is valid, a conservative extrapolation must be used.
Frequency of monitoring/recording:	See Section 9.3.5
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	$GHG_{WLwps\text{-}CH4,i,t}$
Data unit:	t CO_2e $ha^{-1}yr^{-1}$
Description:	Emission of CH_4 related to water table depth in the project scenario in stratum *i* in year *t*
Equations:	41

Source of data:	Data can be obtained from peer-reviewed literature or from own measurements.
Value applied:	n/a
Description of measurement methods and procedures to be applied:	See Section 9.3.6 for procedures to quantify this proxy. The project may establish project-specific values for $GHG_{WLwps-CH4}$ or apply values from appropriate literature sources pertaining to land use classes, or water table depths or water table depth classes. For such literature values the accuracy must be defined or conservativeness must be justified. If the mean annual water table depth in the project area exceeds the depth range for which the emission-vegetation or emission-water table depth relationship determined for the project is valid, a conservative extrapolation must be used.
Frequency of monitoring/recording:	See Section 9.3.6
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	N/A

Data Unit / Parameter:	Water table depth
Data unit:	cm
Description:	Sub-soil or above soil surface of water, relative to the soil surface
Equations:	-
Source of data:	Own measurements
Value applied:	n/a
Description of measurement methods and procedures to be applied:	Procedures for water table depth measurements are provided in Section 9.3.6.
Frequency of monitoring/recording:	See Section 9.3.6
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	Used in Section 9.3.4

Data Unit / Parameter:	*t2* and *t1*
Data unit:	yr
Description:	Years of the monitoring activity
Equations:	63, 64
Source of data:	Field measurement in sample plots
Value applied:	n/a
Description of measurement methods and procedures to be applied:	N/A
Frequency of monitoring/recording:	Determined at each monitoring period
QA/QC procedures to be applied:	See Section 9.3.2
Purpose of Data:	Calculation of project emissions
Comments:	$T = t2 - t1$

9.3 Description of the Monitoring Plan

9.3.1 General

The main objective of project monitoring is to reliably quantify carbon stocks and GHG emissions in the project scenario during the project crediting period, prior to each verification, with the following main tasks:

- Monitoring of project carbon stock changes and GHG emissions
- Estimation of ex-post total net carbon stock changes and greenhouse gas emissions, and GHG emissions reductions

The monitoring plan must contain at least the following sections:

- A description of each monitoring task to be undertaken, and the technical requirements
- Parameters to be measured
- Data to be collected and data collection techniques
- Frequency of monitoring
- Quality Assurance and Quality Control (QA/QC) procedures
- Data archiving procedures
- Roles, responsibilities and capacity of monitoring team and management

9.3.2 Uncertainty and quality management

Quality management procedures are required for the management of data and information, including the assessment of uncertainty, relevant to the project and baseline scenarios. As far as practical, uncertainties related to the quantification of GHG emission reductions and removals by sinks should be reduced.

To help reduce uncertainties in the accounting of emissions and removals, this methodology uses whenever possible the proven methods from the GPG-LULUCF, GPG-2000, the IPCC's Revised 2006 Guidelines and peer-reviewed literature. Despite this, potential uncertainties still arise from the choice of parameters to be used. Uncertainties arising from input parameters would result in uncertainties in the estimation of both baseline net GHG emissions and project net GHG emissions - especially when global default values are used. The project proponent must identify key parameters that would significantly influence the accuracy of estimates. Local values that are specific to the project circumstances must then be obtained for these key parameters, whenever possible. These values should be based on:

- Data from well-referenced peer-reviewed literature or other well-established published sources[27]; or,
- National inventory data or default data from IPCC literature that has, whenever possible and necessary, been checked for consistency against available local data specific to the project circumstances; or
- In the absence of the above sources of information, expert opinion (see Section 9.3.3) may be used to assist with data selection. Experts will often provide a range of data, as well as a most probable value for the data. The rationale for selecting a particular data value must be briefly noted in the project documentation.

In choosing key parameters, or making important assumptions based on information that is not specific to the project circumstances, such as in use of default data, project proponents must select values that will lead to an accurate estimation of net GHG emission reductions, taking into account uncertainties.

If uncertainty is significant, project proponents must choose data such that it indisputably tends to under-estimate, rather than over-estimate, net GHG project benefits. For example, conservativeness in GHG emission reductions based on GESTs could be established by applying too low flux values to GESTs in the baseline. The conservativeness of the value (e.g., applying the value of the next wetter GEST), or any alternative way of ensuring conservativeness, must be demonstrated.

To ensure that carbon stocks are estimated in a way that is accurate, verifiable, transparent, and consistent across measurement periods, the project proponent must establish and document

[27] Typically, citations for sources of data used should include: the report or paper title, publisher, page numbers, publication date etc (or a detailed web address). If web-based reports are cited, hardcopies should be included as annexes in the project documentation if there is any likelihood such reports may not be permanently available.

clear standard operating procedures and procedures for ensuring data quality. At a minimum, these procedures must include:

- Comprehensive documentation of all field measurements carried out in the project area. This document must be detailed enough to allow replication of sampling in the event of staff turnover between monitoring periods.
- Training procedures for all persons involved in field measurement or data analysis. The scope and date of all training must be documented.
- A protocol for assessing the accuracy of plot measurements using a check cruise and a plan for correcting the inventory if errors are discovered.
- Protocols for assessing data for outliers, transcription errors, and consistency across measurement periods.
- Data sheets must be safely archived for the life of the project. Data stored in electronic formats must be backed up.

9.3.3 Expert judgment

Expert judgment on methodological choice and choice of input data and to fill gaps in the available data, to select data from a range of possible values or on uncertainty ranges is well established in the IPCC 2006 good practice guidance. Obtaining well-informed judgments from domain experts regarding best estimates and uncertainties of inputs to the quantification of emission reductions is an important aspect in various procedures throughout this methodology. Project proponents must use the guidance provided in Chapter 2, Volume 1 (Approaches to Data Collection), in particular, Section 2.2 and Annex 2A.1 of the IPCC 2006 Guidelines for National Greenhouse Gas Inventories.

9.3.4 Monitoring of project implementation

Information must be provided, and recorded in the project documentation to establish that:

a) The geographic position of the project boundary is recorded for all areas of land. The geographic coordinates of the project boundary (and any stratification or buffer zones inside the boundary) are established, recorded and archived. This can be achieved by field survey (e.g., using GPS), or by using georeferenced spatial data (e.g., maps, GIS datasets, orthorectified aerial photography or georeferenced remote sensing images).

   The above also applies to the recording of strata, including strata resulting from peatland fires in the project scenario (Section 8.3).

b) Commonly accepted principles of land use inventory and management are implemented such as the following:

   - Standard operating procedures (SOPs) and quality control/quality assurance (QA/QC) procedures for inventories including field data collection and data management must be applied. Use or adaptation of SOPs already applied in national land use monitoring, or available from published handbooks, or from the IPCC GPG LULUCF 2003, is recommended;

- Apply SOPs, especially, for actions likely to cause peat disturbances;
- The project plan, together with a record of the plan as actually implemented during the project must be available for validation or verification, as appropriate.

Continued compliance with the applicability conditions of this methodology must be ensured by monitoring that:

- Burning of biomass within the project boundary in the project scenario does not occur. Small and isolated events (with *de minimis* effects on GHG emissions'), although not permitted, do not fail the project.
- Peatland fires within the project boundary do not occur in the project scenario. If they occur as non-catastrophic events as defined in this methodology, they are accounted for by cancelling the *Fire Reduction Premium* for the entire project or the individual sub-project.
- Water leakage, if occurring, is limited to accidents that can be repaired (e.g., the breaching of a dam). Such accidents and their remediation must be monitored together with justifications that the effect has been temporal and insignificant and has not caused the dieback of woody vegetation in adjacent areas.
- N-fertilizers are not used within the project boundary in the project scenario.

The effectiveness of buffer zones must be demonstrated. This must be done using water level gauges or vegetation assessments (see Section 9.3.6 for procedures), or a combination of these.

a) If a buffer zone has been established, water level gauges must be installed at the boundary of the buffer zone (outer boundary if used against leakage, inner boundary if used against drainage activities outside the project area) and readings must be compared with the hydrological modeling results or expert judgment on which the establishment of the buffer zone was based. The number and spacing of water level gauges must be based on hydrological modeling or expert judgment. Alternatively, a GEST vegetation assessment must be performed in the buffer zone. Results for vegetation types adjacent to the project boundary are compared with the vegetation composition in the same area at project start.

b) In the case of an impermeable dam, to demonstrate its effectiveness, water level gauges must be located outside the dam (if used against leakage) or inside the dam (if used against effects of drainage outside the project boundary). Placing gauges outside the boundary may require agreements with adjacent landowners if the dam is located on the project boundary. Alternatively, a vegetation assessment must be performed in a strip adjacent to and outside the project boundary (leakage) or inside the boundary (outside drainage effects). The width of this strip is determined by the size of the area with homogeneous GEST characteristics nearest to the boundary. Results are compared with the vegetation composition in the same zone at project start.

c) In absence of a buffer zone or an impermeable dam (e.g., in case pump-drained systems are rewetted), water level gauges must be installed or vegetation assessed as described in (a) above, or the proponent must justify in the project documentation that such measurements can be omitted.

9.3.5 Stratification and sampling framework

Stratification of the Project Area into relatively homogeneous units can either increase the measuring precision without increasing the cost unduly, or reduce the cost without reducing measuring precision because of the lower variance within each homogeneous unit. Project proponents must present in the project documentation an *ex-ante* stratification of the Project Area or justify the lack of it. The number and boundaries of the strata defined *ex ante* may change during the project crediting period (*ex post*).

The *ex-post* stratification must be updated because of the following reasons:

- Unexpected disturbances occurring during the project crediting period (e.g., due to changes in the hydrology, fire, pests or disease outbreaks), affecting differently various parts of an originally homogeneous stratum;
- Management activities (forestry, agriculture, hydrology) that are implemented in a way that affects the existing stratification.

  Established strata may be merged if the reasons for their establishment have disappeared.

The sampling framework, including sample size, plot size, plot shape, and determination of plot location must be specified in the project documentation. Where changes in carbon stocks are to be monitored (i.e., in trees), permanent sampling plots are used, noting the following:

1) To determine the sample size and allocation among strata, this methodology uses the procedures in Section 9.3.5 and the latest version of the tool for the “Calculation of the number of sample plots for measurements within A/R CDM project activities”, approved by the CDM Executive Board. The targeted confidence interval must be 90% or 95%. Where a 90% confidence interval is adopted and the width of the confidence interval exceeds 20% of the estimated value or where a 95% confidence interval is adopted and the width of the confidence interval exceeds 30% of the estimated value, an appropriate confidence deduction must be applied, as outlined in Section 8.5.2.
2) In order to avoid bias, sample plots should be marked inconspicuously.
3) The sample plot size must be established according to common practice in forest and vegetation inventories.
4) To avoid subjective choice of plot locations, the permanent sample plots must be located either systematically with a random start or completely randomly inside each defined stratum. The geographical position (GPS coordinate), administrative location, stratum and stand, series number of each plot, as well as the procedure used for locating them

must be recorded and archived. The sampling plots are to be as evenly distributed as possible, where larger strata have more plots than smaller strata. However, remote areas and areas with poor accessibility may be excluded for the location of sampling plots. Such areas must be mapped as separate strata and for these strata accounting of carbon stocks in tree biomass in the project scenario is conservatively omitted (Section 8.2.2).

Guidance on plot size for GEST assessments is provided under "Assessing the spatial distribution of GESTs" in Section 9.3.6.

The choice of monitoring frequency must be justified in the project documentation.

9.3.6 Estimating GHG emissions on the basis of GESTs and water table depth

A GEST-indication system is based on a meta-analysis of published and other data of GHG fluxes (emissions or removals) in relation to site characteristics of a wide range of sites in a specific biogeographic and climatic region (Couwenberg *et al.*, 2011). For the analysis of GHG fluxes, only data on yearly net fluxes, based on year-round measurements or on sound model extrapolations are used. With respect to CO_2 fluxes, care has to be taken to include only net CO_2 balances (NEE or NEP) from reliable models using light and dark fluxes as input. The meta-analysis of data is used for the following:

- Classify vegetation data and GHG flux characteristics in a way that the distinguished vegetation types optimally indicate GHG fluxes;
- Develop regression models between GHG fluxes and mean annual water table depth (as this is the prime explanatory variable for annual GHG fluxes from peatland) in order to allow a triangular verification crosscheck between independent datasets: (i) flux data related to the vegetation types, (ii) flux data related to water table depths and (iii) vegetation types related to water table depths.

<u>Determining CO_2 and CH_4 emissions</u>

For project-specific flux values the project proponent may carry out direct measurements of GHG fluxes, such as closed chamber and eddy covariance measurements. Applied techniques must follow international standards of application as laid out in pertinent scientific literature (e.g., Matson & Harriss, 1995, Pattey *et al*. 2006, Alm *et al*. 2007, Evans *et al*. 2011).

<u>Determining GESTs</u>

GESTs can be classified and specified with respect to their GHG flux values using the following step-wise protocol for meta-analysis of collected data (cf. Couwenberg *et al.*, 2011):

1) Develop regression models between GHG fluxes and mean annual water table depth on the basis of all available data from the relevant biogeographic and climatic region;
2) Classify relevant vegetation types that are actually found and potentially expected in the region on the basis of plant species or species groups indicative for water table depth,

using for example the bio-indication data of Ellenberg *et al.* (1992) and Koska *et al.* (2001);

3) Compare the distinguished vegetation types with the vegetation data from sites in the relevant region for which reliable GHG flux data are available. If vegetation of a type is sufficiently similar (e.g., with respect to presence and absence of species groups (Koska, 2007; Koska *et al.* 2001); similarity is defined on the basis of floristic composition or plant functional types and expert judgment and must be justified) to vegetation for which the GHG flux values are reported in literature, the range of GHG values from literature is ascribed to the type;

4) The results of step 3 may be verified and refined by comparing the water table depth data (acquired from field observation, vegetation form indication (Koska *et al.* 2001) and/or Ellenberg values) of the sites used under Step 3 above with the regression models from Step 1 above to verify and refine the flux values found under Step 3 above. After verification and refinement of the flux values, the vegetation type is a GEST.

5) In case a distinguished vegetation type does not have sufficient similarity (see above) with vegetation described in GHG literature, use the mean annual water table depth data and the regression models to establish its preliminary flux values.

6) Optimize the GHG flux value of the vegetation type by expert judgment using the matrix of all distinguished vegetation types and taking into account the emission-relevant site characteristics of the vegetation type (incl. the proportion of shunt species in case mean water table depths are higher than 20 cm below surface; water table depth, soil reaction, C/N of the peat, type and intensity of land use) and the emission and site characteristics of related vegetation types. As soon as the GHG flux values of a type can be consistently and unequivocally defined, the type is considered a GEST (Table 3), independent from the deduced range of GHG fluxes. Later expansion of the GHG flux/vegetation dataset may lead to further refining the GESTs and to narrowing GHG flux ranges.

7) Flux values associated with vegetation types must comply with QA/QC requirements outlined in Section 9.3.2 and are subject to the uncertainty assessment. Where an uncertainty value is not known or cannot be simply calculated the project proponent must justify that a conservative value is used.

The results of this procedure must be described in the project documentation. An example of this can be found in Table 9.1 below.

Table 9.1: Example of GESTs Related to Water Table Depth Class and CH_4 and CO_2 Emission Values (after Couwenberg *et al.* 2008, 2011).

GEST	Typical/differentiating species	Water table depth class	CO_2 emission t CO_2e $ha^{-1}yr^{-1}$	CH_4 emission t CO_2e $ha^{-1}yr^{-1}$	Reference
Moist bog heath	*Calluna, Vaccinium myrt., Ledum + Dicranum scop., Pleurozium* (+ *Molinia*)	Moist	12.5	0	Couwenberg et al. 2008, 2011
Wet reeds and sedge fens	*Carex paniculata, Epilobium hirsutum, Lycopus, Lythrum, Berula erecta*	Wet	-4	12.5	Couwenberg et al. 2008, 2011

Water table depth classes refer to water supply: +: wetlands and aquatic habitats; -: non-hydric terrestrial habitats. They are characterised by: WLw: long-term median water table depth wet season; WLd: long term median water table depth dry season; and WD: water supply deficiency. Seasonally alternating wetness is indicated by a combination of different water table depth classes (e.g., 5+/4+ refers to a WLw within 5+ range and a WLd within 4+ range). Strongly alternating wetness is indicated by a tilde-sign (e.g., 3~ refers to a WLw within 4+ range and a WLd within 2+ range).

Class		Water table depth related to surface (+ above, - below)
7+	Upper sublitoral	WLm: +250 to +140 cm
6+	Lower eulitoral	WLm: +140 to +20 cm
5+	Wet (upper eulitoral)	WLm: +20 to 0 cm
4+	Very moist	WLm: 0 to -20 cm
3+	Moist	WLm: -20 to -45 cm
2+	Moderately moist	WLm: -45 to -80 cm
2-	Moderately dry	WD: < 60 l/m²
3-	Dry	WD: 60 – 100 l/m²
4-	Very dry	WD: 100 – 140 l/m²
5-	Extremely dry	WD: > 140 l/m²

Assessing the spatial distribution of GESTs

For assessing the spatial distribution of GESTs in the field, project proponents must apply the following procedure:

1) Map units of more or less homogenous vegetation using common approaches (incl. remote sensing, see Box) and specify mapping resolution. Use units larger than 3000 m^2. Include areas < 3000 m^2 with deviating vegetation in an adjacent mapping unit, when the water table depth is identical and the soil relief differences smaller than 1 dm. Map strongly deviant units (much higher, much lower, forested, open spots in forest) > 1000 m^2 but < 3000 m^2 separately. Include deviant areas < 1000 m^2 in the adjacent mapping unit to which it is most related.

2) Map vegetation units < 3000 m^2 with soil relief differences of more than 1 decimeter (fine-scaled peat extraction sites, string/flark and hummock-hollow complexes) to mosaic mapping units > 3000 m^2. Describe their relief pattern (i.e. proportion, extent and height of various elements).

3) Assess within each mapping unit the cover of the living parts of “shunt species” (see Box) in five cover classes: 0-20%, 20-40%, 40-60%, 60-80%, 80-100%.

4) Mark the borders of the mapping units with GPS waypoints or track-routes or depict borders directly on a topographical map or aerial picture (with GPS reference points).

5) Record relevés (5 m × 5 m) of characteristic homogenous vegetation in each mapping unit to facilitate later (a posteriori) identification of the GESTs.

6) Assign the herb layer of shrub or tree-dominated peatland to non-forested vegetations types.

This procedure must be applied for both the pre-project spatial distribution of GESTs and monitoring. When monitoring, assess whether the range of GESTs with their specific GHG emission levels as obtained in Section 8.1.3.1sufficiently covers the vegetation types expected in the project scenario. If not, expand the system using the same procedure by collecting more literature or field data

Shunt species

Shunt species are species with aerenchyma (open stem and root tissue) that pump air into the rhizosphere and transport methane from the anaerobic soil layer directly into the atmosphere. As a consequence, an area with many shunt species may have a two times higher methane emission than other areas with a similar water table depth. Important shunt species are: *Blysmus* species, *Bolboschoenus* species, *Carex* species (tall and small sedges), *Cladium mariscus*, *Eleocharis* species, *Eriophorum angustifolium*, *Eriophorum vaginatum*, *Juncus* species, *Scheuchzeria palustris*, *Schoenoplectus* species, *Scirpus* species.

Vegetation mapping with high spatial resolution satellite imagery, for example:

- Use satellite imagery with a minimum spatial resolution of 5 m × 5 m and a minimum of four spectral channels, which includes visible and at least one infrared band.
- Derive the mapping units by vegetation indexes analysis or a simple unsupervised classification.

- Select in every mapping unit three random points for vegetation analysis (e.g., ISODATA classification).
- In each clearly distinguished mapping unit select three centrally located points for vegetation analysis.
- Visit these points and record representative vegetation relevés (using high accuracy GPS devices and record water table depth).
- Conduct a supervised classification (e.g., a maximum likelihood classification of 90%), minimum distance classifier or spectral angle mapper, if necessary include vegetation indexes.
- To improve the classification result, high quality geo-referencing is favourable and training areas can be added/removed on the base of site knowledge; the training areas or regions of interest based on groundtruthing data should be outlined on minimum 5 pixels
- Relate the classes to vegetation forms or additional vegetation types based on relevés and site knowledge.
- Conduct an accuracy assessment, by checking the classification result via visiting additional ground control points. These additional points must be selected so that each class is represented by more than one point. Accuracy must be at least 60%, any activities to increase the accuracy are recommended.

Deriving time series of GEST development for each stratum for the entire project crediting period

Predict (*ex ante*), based on vegetation succession schemes in drained and rewetted peatlands from scientific literature or expert judgment, or monitor GESTs (*ex post*), for each stratum and for the entire project crediting period, the development of GESTs over time by defining a time series of GESTs, with time steps of a reasonable time period (e.g., 5 years) to allow for the inherent discrete character of the GESTs.

Determining annual GHG emissions per stratum for the entire project crediting period

Obtain annual GHG emissions per stratum by extrapolation between the typical emissions of two subsequent GESTs in a time series. Extrapolation can be linear, skewed, or conservative. If the chosen interpolation method is not inherently conservative, the project proponent must provide conclusive argumentation why the chosen method would apply.

For each stratum, the annual results can be reported in the formatting of Table 9.2. Italics indicate interpolated values.

Table 9.2: Time Series of Emissions from GESTs.

Year	Stratum 1	Total emissions t $CO_2e\ yr^{-1}$
1	GEST1	15
2		*16*
3		*17*

4		*18*
5	GEST2	19
…		…
…		…
15	GEST3 | GEST4	22*
…		…

* Area-weighted average of GEST 3 and GEST 4 emissions. Stratum 1 is subdivided into 1a and 1b.

For areas for which the vegetation composition does not provide a clear indication of GHG emissions (bare peat, transient phases of vegetation development after rewetting) water table depth measurements must be used as additional input to assess GHG fluxes. However, project proponents may also opt to choose water table depth as a proxy for the entire project area.

Strata can be defined on the basis of (amongst others) water table depth (e.g., at 0 cm defining a level of zero emissions, a deep water table depth defining the high end of emissions, and arbitrary levels in between, or expected changes in these). Water table depths or water table depth classes (e.g., 0-10 cm, 11-20 cm, etc.) can be used, depending on data availability.

Water table depth measurements can be continuous with data loggers and using min-max devices (Bragg *et al*., 1994) or simple water level gauges.

Normally, the vegetation mapping can be conducted during the entire vegetation period. The water table depth measurements must be done at least throughout the seasons (spring to winter) to capture seasonal variation. The frequency of monitoring vegetation changes must be based on expert judgment, taking into account expected and observed changes in vegetation composition upon rewetting. A recommended monitoring schedule for temperate climate zones is provided below:

- Mapping vegetation types: before rewetting, 2nd year after rewetting, 5th year after rewetting, then every 5th year after rewetting
- Monitoring water table depth: continuously from 1 year before rewetting, to the end of the project crediting period.

9.3.7 Monitoring of fire events in the project scenario

As laid out in Section 8.3, if peatland rewetting and a best-practices fire management have been implemented, peat fires occurring in the project scenario can be assumed to be catastrophic events. If such fires occur, the project proponent must demonstrate that rewetting and fire management have been carried out as proposed at validation. Peat losses associated with such fires must be added to the *ex-ante* estimate of peat loss in the project scenario as they may affect the number of eligible credits (Section 5.2 – Peatland areas eligible for carbon crediting). The assessment of peat losses must follow the fire-specific procedures and criteria used to derive $Rate_{peatloss\text{-}BSL}$ (Section 9.1).

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DOCUMENT HISTORY

Version	Date	Comment
v1.0	17 July 2017	Initial version released.

VCS Methodology

VM0037

Methodology for Implementation of REDD+ Activities in Landscapes Affected By Mosaic Deforestation and Degradation

Version 1.0

3 November 2017

Sectoral Scope 14

This methodology was developed by:

GIZ India
Deutsche Gesellschaft für Internationale Zusammenarbeit

IORA Ecological Solutions

Authors:

Mr. Ashwin A. S., IORA Ecological Solutions

Mr. Kundan Burnwal, GIZ India

Ms. Zainab Hassan, IORA Ecological Solutions

Mr. Swapan Mehra, IORA Ecological Solutions

Dr. Santanu Basu, IORA Ecological Solutions

Mr. Ankit Rawat, IORA Ecological Solutions

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Table of Contents

1 SOURCES

This methodology refers to the latest version of the following approved methodologies:

- CDM methodology *AR-AMS0007 Afforestation And Reforestation Project Activities Implemented On Lands Other Than Wetlands*
- VCS methodology *VM0006 Carbon Accounting for Mosaic and Landscape-scale REDD Projects*
- VCS methodology *VM0009 Methodology for Avoided Ecosystem Conversion*

This methodology also refers to the latest version of the following approved tools and modules:

- CDM tool *Tool for testing significance of GHG emissions in A/R CDM project activities*
- CDM tool *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*
- CDM tool *Estimation of non-CO_2 GHG emissions resulting from burning of biomass attributable to an A/R CDM project activity*
- CDM tool *Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities*
- CDM tool *Procedure to determine when accounting of the soil organic carbon pool may be conservatively neglected in CDM A/R project activities*
- CDM tool *Calculation of the number of sample plots for measurements within A/R CDM project activities*
- CDM tool *A/R Methodology Tool, Estimation of direct nitrous oxide emission from nitrogen fertilization*
- CDM tool *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion*
- CDM tool *Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity*
- VCS tool *VT0001 Tool for the demonstration and assessment of additionality in VCS AFOLU project activities*
- VCS module *VMD0010 Estimation of emissions from activity shifting for avoided unplanned deforestation (LK-ASU)*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

This methodology is applicable to project activities that reduce greenhouse gas (GHG) emissions from mosaic unplanned deforestation and forest degradation, and that enhance GHG sequestration through afforestation, reforestation and revegetation (ARR) activities. This methodology was developed with the intended use in India, but is globally applicable.

Mosaic degradation of forest lands may be the result of many drivers, such as unsustainable fuelwood extraction and uncontrolled grazing. Reduction of these activities is important since their continuation may lead to deforestation.

This methodology was developed with a focus on the specific drivers listed in Table 1 below. For the purposes of this methodology, these drivers are categorized as either a deforestation or forest degradation activity.

Table 1: List of Drivers Considered

Drivers and activities considered under this methodology	Deforestation or degradation
Unsustainable extraction of fuel wood	Degradation
Unsustainable extraction of non-timber forest produce (NTFP)	Degradation
Unplanned timber harvesting	Degradation
Uncontrolled grazing and fodder collection	Degradation
Anthropogenic forest fire	Deforestation
Unplanned mining and quarrying	Deforestation
Expansion of subsistence agriculture by conversion of forest lands	Deforestation
Encroachment	Deforestation

The drivers listed in Table 1 were identified, based on observed practices in India,[1] as the most impactful in terms of their contribution to emissions from deforestation and degradation.

[1] Drivers and localized agents that are active in forest areas facing pressure were shortlisted based on literature review, focal group interviews and stakeholder consultation. Different landscapes in India were chosen as pilot study sites for analyzing driver dynamics. Choosing Indian sites for the study was important due to the following:

The main elements of this methodology include:

- A project method for demonstrating both additionality and the crediting baseline.
- Separate quantification methods for REDD and ARR project activities.
- An optional method for monitoring the project area with the help of local communities.
- Options to use secondary data from sources already available, such as censuses, working plans, and existing participatory rural appraisals (PRAs)[2] to form detailed references of active drivers and their physical extent.

3 DEFINITIONS & ACRONYMS

3.1 Definitions

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions apply to this methodology:

Activity-shifting Leakage
Leakage caused by the application of conservation practices in the project area which leads to undesirable and unintended movement of Drivers of Forest Change (DoFC) outside the project area, leading to GHG emissions due to deforestation and forest degradation in those other areas. Where the shifting of activities increases the rate of DoFC, the related land use change, carbon stock/density changes and non-CO_2 emissions must be estimated and accounted for as leakage.

Anthropogenic Forest Fires
Forest fires which originate due to human activity

Avoiding Planned Deforestation and/or Degradation (APDD)
Activities that stop planned deforestation and/or degradation of forest lands

Avoiding Unplanned Deforestation and/or Degradation (AUDD)
Activities that stop unplanned deforestation and/or degradation of forest lands

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1) India, having a large geographical area, a forest cover of 21.34% (ISFR 2015 http://fsi.nic.in/isfr-2015/isfr-2015-executive-summary.pdf),and more than 300 million forest dependent people (including around 87 million tribal peoples), is an ideal candidate to study mosaic deforestation and degradation of forest lands under varied drivers.
2) Management regime and land tenure is different from state to state, and so the country is a good candidate to study jurisdictional aspects of baseline development.
3) No large scale deforestation has occurred in recent years, and so few cases of frontier deforestation are observed. This helps in better understanding the dynamics of deforestation and degradation caused due to drivers in mosaic deforestation and degradation.

[2] Note that existing PRAs can be used only for data comparison where a new PRA has been conducted.

Baseline Validation Period

The 10 year period for which the baseline remains valid. The baseline must be reassessed every 10 years throughout the project crediting period in accordance with the VCS rules.

Deforestation

Direct human-induced conversion of forest land to non-forest land. Deforestation implies the long-term or permanent loss of forest cover. For this methodology, the change in land use from forest land to non-forest land must not be less than three years.

Degradation

The persistent reduction of canopy cover and/or carbon stocks in a forest due to human activities such as animal grazing, fuelwood extraction, timber removal or other such activities, but that does not result in the conversion of forest to non-forest land, and falls under the *IPCC 2003 Good Practice Guidance* land category of *forest remaining forest*. For this methodology, continued loss of carbon stock from forest land for at least three years qualifies as degradation.

Drivers of Forest Change (DoFC)

Activities that lead to losses in forest carbon

Historical Reference Period

The period during which the selected reference region transitions from forest land to non-forest land, or in the case of degradation, the period during which degradation occurs

Land Use and Land Cover (LULC) Classes

The six LULC classes as specified by IPCC, or LULC classes which the host country has specified, provided that all the land classes under IPCC are covered by the latter

Leakage Area

An area outside the project area to where the drivers of deforestation and degradation of forest lands are displaced in the case of REDD activities.

Leakage Management Zone (LMZ)

An area earmarked as an area which is intended to reduce leakage

Logging Slash

Dead wood residues (including foliage) left on the forest floor after timber removal

Market Leakage

Leakage caused by conservation practices inside the project area such that there is impact on the supply chain of forest products which result in a shift of production of forest product elsewhere to fulfill demand

Minimum Mapping Unit (MMU)
The minimum unit that is used in classification and RS analysis, and is fixed as 1 ha

Project Area (PA)
The geographical area where REDD activities (with or without ARR activities) are implemented. ARR and REDD areas must be separately mapped and must not share the same area. The project area must be forest land for a minimum of 10 years prior to the project start date.

Reference Region (RR)
The region from which the historical trends of changes in forest land are modeled. From these trends, the change that is expected to occur within the project area in the baseline scenario is predicted.

3.2 Acronyms

ACoGS	Avoided Conversion of Grasslands and Shrublands
AFOLU	Agriculture, Forestry and Other Land Use
AGB	Above Ground Biomass
BGB	Below Ground Biomass
CIFOR	Center for International Forestry Research
DBH	Diameter at Breast Height
FGD	Focal Group Discussion
GOFC-GOLD	Global Observation of Forest and Land Cover Dynamics
IFM	Improved Forest Management
KML	Keyhole Markup Language
LIDAR	Light Detection and Ranging
LMZ	Leakage Management Zone
LULC	Land Use Land Cover
NTFP	Non Timber Forest Produce
PA	Project Area
PRA	Participatory Rural Appraisal
RR	Reference Region
RS	Remote Sensing
SAR	Synthetic Aperture Radar
SOC	Soil Organic Carbon
SOP	Standard Operating Procedures

4 APPLICABILITY CONDITIONS

This methodology is globally applicable under the following conditions:

1) The project activities include AUDD[3] or a combination of AUDD and ARR.
2) The project area must meet the definition of forest land for at least 10 years prior to the start date of any REDD activities.
3) The project area must not be forest land for at least 10 years prior to the start date of any ARR activities and must not convert native ecosystems.
4) Biofuel crop production is allowed in ARR activities.

This methodology is not applicable under the following conditions:

1) The project activities include APDD.
2) The project activities only include ARR.
3) ARR activities displace more than 50 percent of agricultural lands from the project area.
4) The project activities take place on wetlands or peatlands.
5) The project activities include ACoGS.

5 PROJECT BOUNDARY

5.1 Reference Region

A reference region (RR) must be identified and analyzed in order to effectively capture the trends of deforestation and degradation of forest lands that would occur in the baseline scenario within the project area (PA). There are two approaches to assess the historical rate of deforestation and forest degradation within the reference region. Approach 2 may be employed only when the project area is equal to, or is less than, 1000 ha and in proximity to the reference region. In all other cases, approach 1 must be applied. Further requirements for the RR and PA are as follows:

- The area of the RR must not be less than that of the PA.
- The RR need not share a boundary with the PA.
- The RR need not be contiguous, and may be formed by distinct parcels.
- REDD components and ARR components of the project must be distinctly mapped.

[3] AUDD activities will be referred to as REDD activities for the remainder of the methodology.

Approach 1: When selecting a RR, the project proponent must satisfy all points of comparison between the RR and PA mentioned in Table 2 below.

Table 2: Comparison between Project Area and Reference Region

Factor	Points of Comparison
Forest types and landscape factors	The forest types and landscape factors within the RR must be similar to the forest types and landscape factors within the PA. With respect to forest types, a list of all the forest types within the PA and RR must be prepared, and the RR must be comparable in proportion (within ±20%) to those present in the PA. The forest classification (e.g., revised Champion and Seth Forest Classification by ICFRE)[4] used in the host country may be used for this exercise. Any forest type that composes at least 5% of the PA must be present within the RR, and any forest type composing more than 5% of the RR that is not present in the PA must be removed from any LULC analysis. With respect to landscape factors, a comparison of elevation, slope, and climactic conditions (e.g., temperature and rainfall) must be undertaken between the PA and RR, and each factor must be demonstrated to be similar in proportion.
Drivers	The types of prevalent drivers (e.g., extraction of fuel wood and other drivers listed in Table 1) must be the same between the RR and PA. To determine this, two lists of all possible drivers must be prepared, one for RR and one for PA. All the drivers in the respective region are marked and selected for comparison. All the drivers which are present in the RR, but absent in the PA must be identified, and the areas which are affected by such drivers must be identified. RR is again modified by removing such areas, and conducting the exercise once again until all such areas are removed from the RR. A similar comparison of agents of forest change also must be conducted after finalizing the list of drivers. Any agent not active in the PA must be excluded from RR. The requirements for analysis of drivers of forest change (DoFC) are discussed more in detail in Section 8.1.7 below.
Land tenure and management	The land tenure system and management practices

[4] This is just an indicative method, where the Indian case is taken as an example. Every country will have the freedom to choose the forest classification that they want to use.

Factor	Points of Comparison
practices	prevalent in the RR must be demonstrated to be similar to the land tenure system and management practices in the PA, as demonstrated through reference to peer-reviewed literature, reports, or expert opinion. Such must be demonstrated even if RR does not share a boundary with the PA, and is comprised of discrete parcels. Therefore, RR and PA may not be subject to two completely different land tenure and management practices, either partially or for the whole area.
Policies and regulations	Policies and regulations having an impact on land-use change patterns within the RR and the PA must be of the same type, or have an equivalent effect, taking into account the current level of enforcement.
Population factors and transportation infrastructure	Where navigable rivers are present in the PA, navigable river/stream density must be similar in proportion in the RR. In addition, proximity and/or potential of the proximity to the transportation infrastructure (e.g., roads) must be similar between the RR at the start of the historical reference period and PA. Finally, proximity to population centers with similar population density must also be similar in proportion between the RR at the start of the historical reference period and PA.

If no area exists within the country that satisfies all points of comparison, the project proponent must justify use of a reference region that satisfies the requirements for forest type and drivers, and is justified to be conservative for other points of comparison, or a conservative deduction is applied for uncertainty when analyzing LULC change.

Examples of different spatial configurations of the RR and PA are given in Figures 1, 2 and 3 below.

Figure 1: Project Area Inside the Reference Region

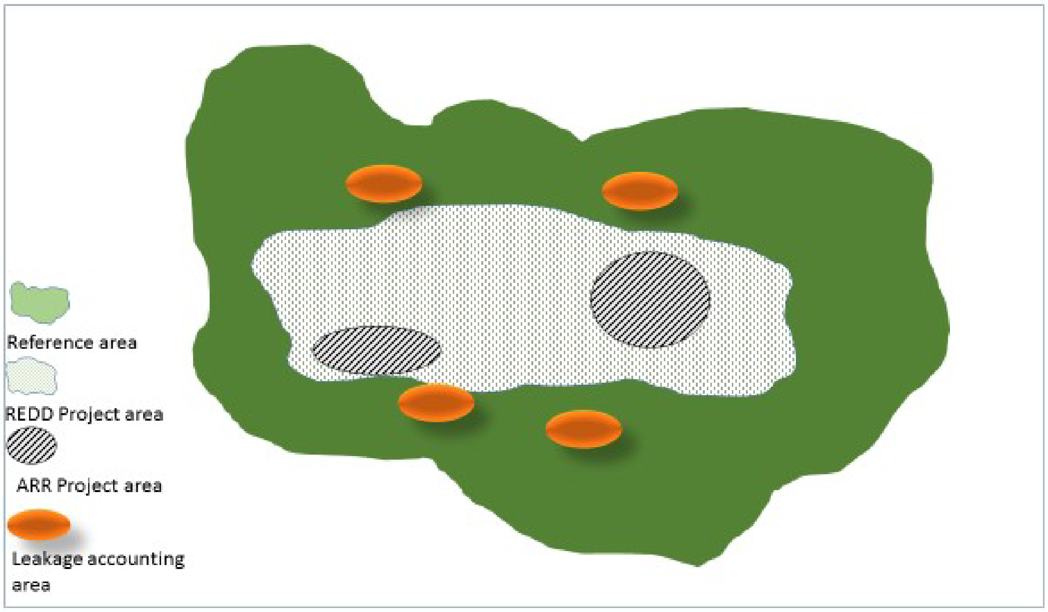


Figure 2: Project Area and Reference Region Not Sharing Boundary

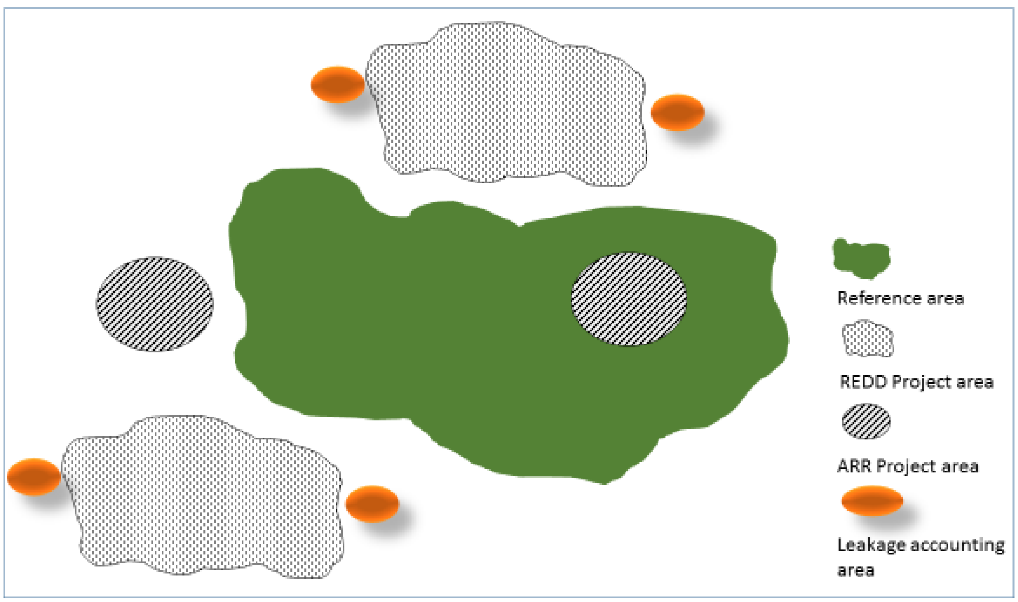
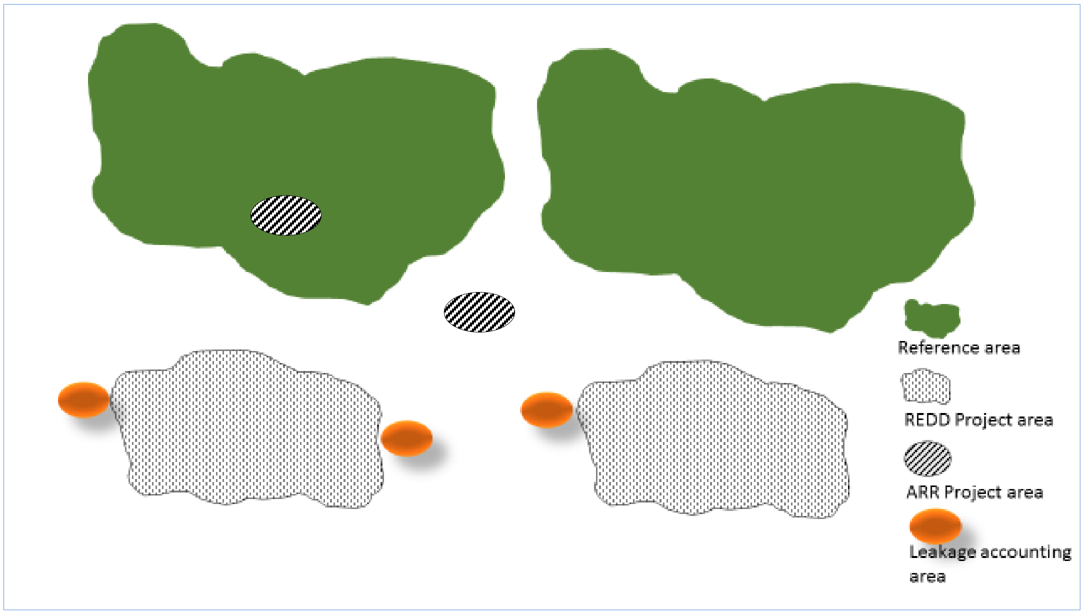


Figure 3: Discrete Parcels of Project Area and Reference Region



Approach 2: This approach is applicable only under the following conditions:

1) Each project parcel is demonstrated to be equal to, or less than, 1000 ha.

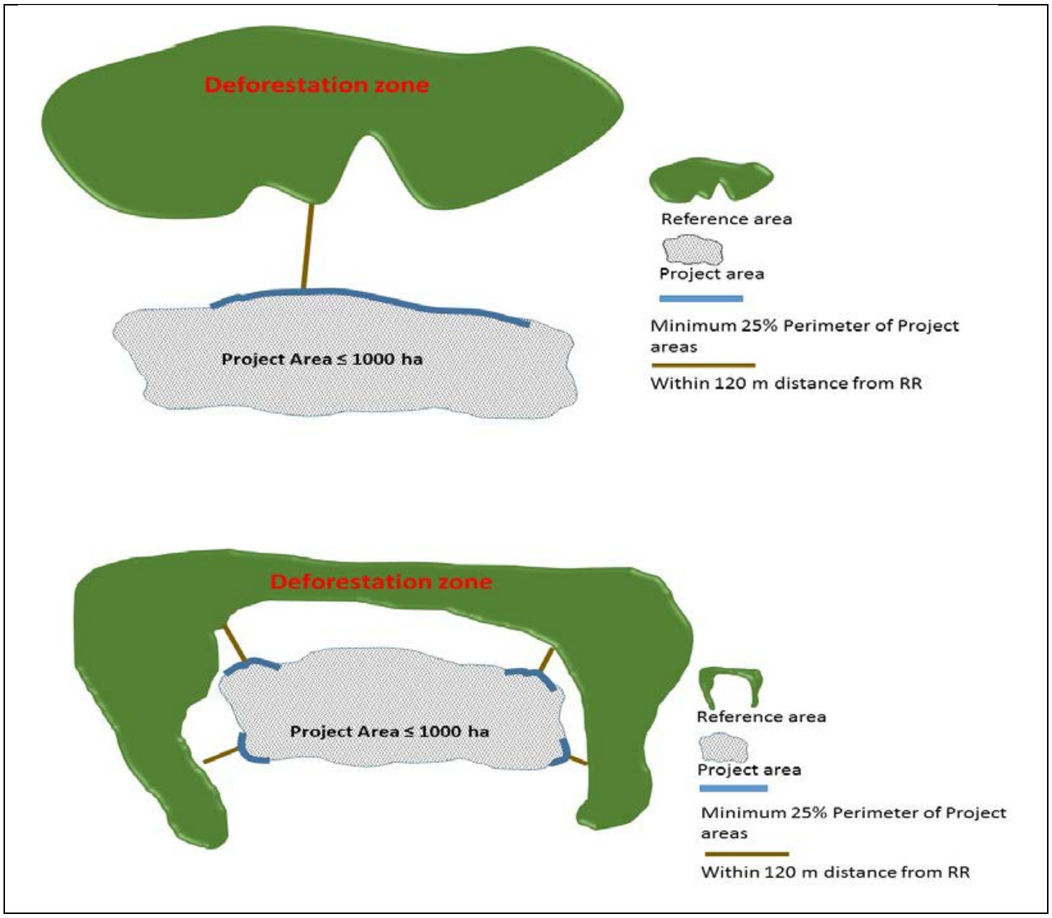
2) Project parcels must lie within 120 meters of an anthropogenic deforested area where it can be demonstrated that such deforestation occurred within 10 years prior to the project start date.

3) It is demonstrated that at least 25 percent of the perimeter of the project parcel lies within 120 meters of the deforested area identified (2) above.

The above must be demonstrated by applying different social and geographical survey tools and techniques, which include, *inter alia*, land survey reports/records, PRA, FGD, official LULC records and revenue department records. Peer reviewed and published papers may be referenced where they were published within 10 years prior to the project start date. Scalable maps that clearly demarcate project areas and reference region(s) must be available at the time of validation.

It is anticipated that if immediate intervention activities are not initiated in approach 2 scenarios, that the agents active in the reference region will imminently affect the project parcel. Examples of such configurations are shown in Figure 4 below.'

Figure 4: Approach 2 Scenarios



5.2 Leakage Management Zone (LMZ)

The LMZ is the area designated to manage potential leakage. An LMZ must be developed for all project areas where the same amount of goods and services from forests will be extracted in the project scenario as compared to the baseline scenario. It must be established that LMZs are within the maximum distance the agent is willing to travel to avail the specific goods and services that has been availed in the baseline scenario. The maximum distance the agent is willing to travel may be ascertained by using tools such as PRA, RRA, key informant interview, FGD, survey and expert opinion.

Where an LMZ is not developed, the project proponent must map the sources from where these goods and services will be availed/procured for the first 10 years from the start date of the project activity. These sources must be considered as potential points of leakage, and must be spatially mapped. This must be updated every 10 years along with the baseline reassessment. In those instances where there is a decrease in the goods and services availed due to project activities, such LMZs are not mandated[5].

5.3 Carbon Pools

The carbon pools included in or excluded from the project boundary are shown in Tables 3 and 4 below.

Table 3: Carbon Pools Included In or Excluded From the Project Boundary for REDD Activities

REDD Activity	Carbon Pool	Included?	Justification/Explanation
REDD with annual crop as the land cover in the baseline scenario	Aboveground tree biomass	Yes	Carbon stock will increase and is one of the major carbon pools
	Aboveground non-tree Biomass	Optional	May be conservatively excluded
	Below ground biomass	Optional	May be conservatively excluded
	Dead wood	Optional	May be conservatively excluded
	Litter	No	Excluded as per the VCS *AFOLU Requirements*
	Wood products	Yes	Major carbon pool affected by the project activities and must be included
	Soil Organic carbon	Optional	May be conservatively excluded
REDD with pasture grass as the land cover in the baseline scenario	Aboveground tree biomass	Yes	Carbon stocks will increase and is one of the major carbon pools
	Aboveground non-tree Biomass	Optional	May be conservatively excluded
	Below ground biomass	Optional	May be conservatively excluded
	Dead wood	Optional	May be conservatively

[5] For example, if improved cook stoves are designed as intervention, then there is a drop in the resources used from forests. LMZ is still desirable, but not mandated in such instances.

			excluded
	Litter	No	Excluded as per the VCS *AFOLU Requirements*
	Wood products	Yes	Major carbon pool affected by the project activities and must be included
	Soil Organic carbon	No	Excluded as per the VCS *AFOLU Requirements*
REDD with perennial tree crop as the land cover in the baseline scenario	Aboveground tree biomass	Yes	Carbon stock will increase and is one of the major carbon pools
	Aboveground non-tree Biomass	Yes	May be conservatively excluded
	Below ground biomass	Optional	May be conservatively excluded
	Dead wood	Optional	May be conservatively excluded
	Litter	No	Excluded as per the VCS *AFOLU Requirements*
	Wood products	Yes	Major carbon pool affected by the project activities and must be included
	Soil organic carbon	No	Excluded as per the VCS *AFOLU Requirements*

Table 4: Carbon Pools Included In or Excluded From the Project Boundary for ARR Activities

ARR	Included?	Justification/Explanation
Aboveground woody biomass	Yes	One of the major carbon pools
Aboveground non-woody biomass	Optional	May be conservatively excluded
Below ground biomass	Yes	One of the major carbon pools
Dead wood	Optional	May be conservatively excluded
Litter	Optional	May be conservatively excluded
Wood products	Optional	May be conservatively excluded

Soil Organic Carbon	Optional	May be conservatively excluded

Carbon pools may be excluded if they are determined to be *de minimis*. To determine if a carbon pool is *de minimis*, the project proponent may use peer reviewed literature, or the latest version of CDM tool *Tool for testing significance of GHG emissions in A/R CDM*, or use primary data collected from the project site or reference site(s).

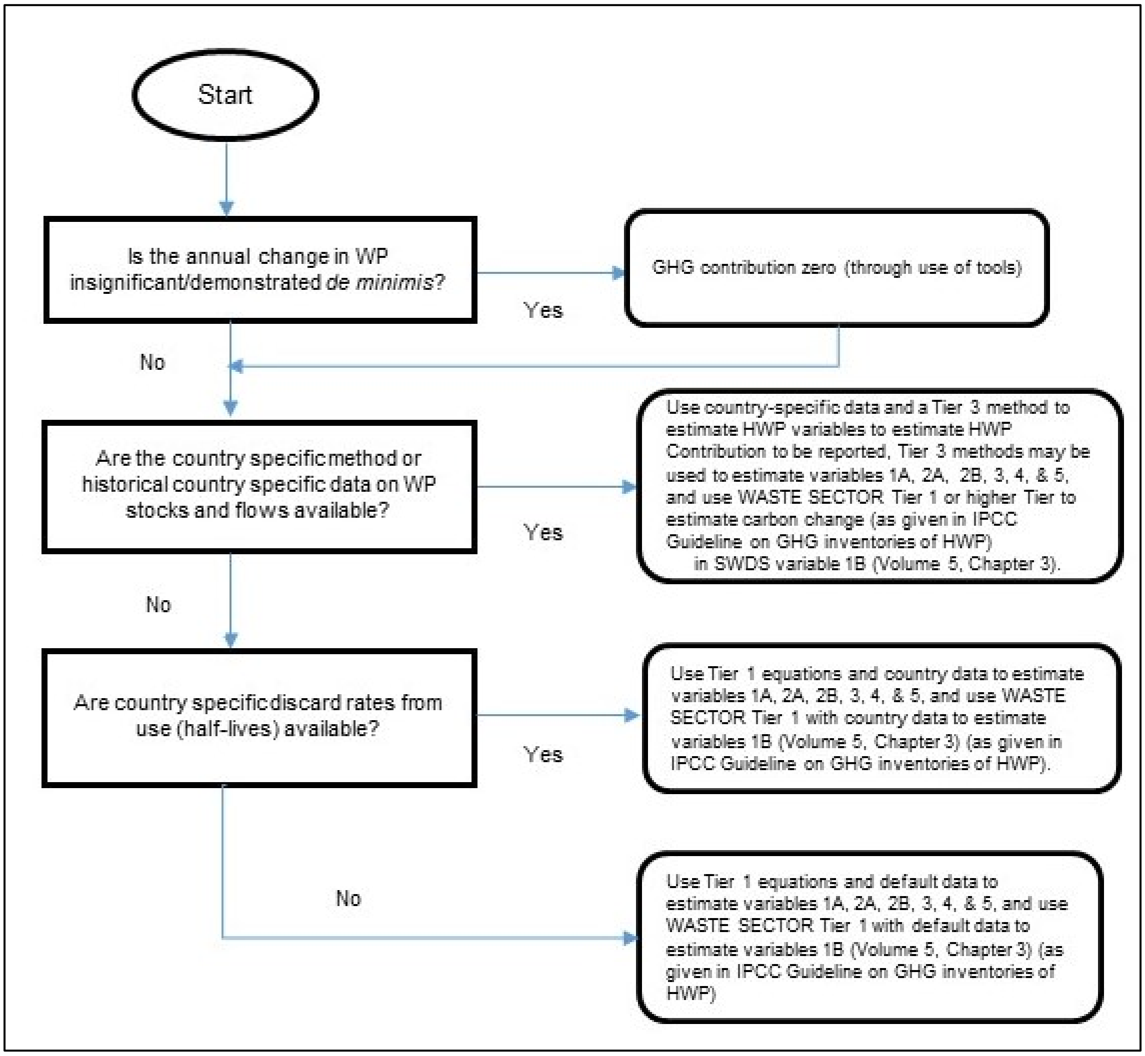
When below ground biomass and dead wood carbon pools are included as part of the project boundary, dead wood must be modeled using a 10- year linear decay function and soil carbon loss must be modeled based upon a 20-year linear decay function, taking into account the depth of affected soil layers and the total portion of the pool that would have been lost and affected.

When wood products are included, carbon loss must be modelled as follows:

- For short-term wood products and wood waste (i.e., decay within 3 years), all carbon must be assumed to be lost immediately.
- For medium-term wood products (i.e., decay between 3 and 100 years), a 20-year linear decay function must be applied.
- For long-term wood products that are considered permanent (i.e., carbon is stored for 100 years or more), no carbon released may be considered.

A decision tree for determining whether wood product pools must be accounted for is described in Figure 5 below and equations for calculating wood products may be derived from *IPCC Guideline on GHG Inventories of Harvested Wood Products*.

Figure 5 : Decision Tree of Reporting Wood Products[6]



5.4 GHG Sources

The greenhouse gases included in or excluded from the project boundary are shown in Table 5 below.

Table 4: GHG Sources Included In or Excluded From the Project Boundary

Source		Gas	Included?	Justification/Explanation
Baseline	Baseline Deforestation and Forest Degradation	CO_2	Yes	Emissions are related to changes in carbon pools.
		CH_4	Yes	Included only in the case of certain intervention activities such as cook stove and fuel efficiency activities

[6] Adapted from IPCC Guideline on GHG Inventories of HWP

Source		Gas	Included?	Justification/Explanation
				(CFE). In the baseline scenario, if biomass is burnt during land preparation in the case of ARR, CH_4 is included. In the baseline scenario, if grazing and animal management is involved, CH_4 is not included for reasons of conservativeness.
		N_2O	Yes	Included where cook stove and fuel efficiency activities (CFE) are involved. If biomass is burnt in the baseline or project scenarios, N_2O is included. If the baseline scenario involves application of fertilizers, N_2O is not included for reasons of conservativeness.
	Baseline ARR	CO_2	Yes	Emissions are related to changes in carbon pools.
		CH_4	No	Emissions are expected to be negligible and are therefore excluded.
		N_2O	No	Emissions are expected to be negligible and are therefore excluded.
Project	Biomass burning from unplanned large and small scale fires	CO_2	No	Emissions are excluded as they are a part of the changes in carbon pools.
		CH_4	Yes	CH_4 emissions of burning woody biomass from unplanned fires must be included. If the fires are catastrophic, CH_4 emissions must be estimated and demonstrated negligible, or otherwise accounted for.
		N_2O	Yes	N_2O emissions of burning woody biomass from unplanned fires are to be accounted. If the fires are catastrophic, N_2O emissions must be estimated and demonstrated negligible, or otherwise accounted

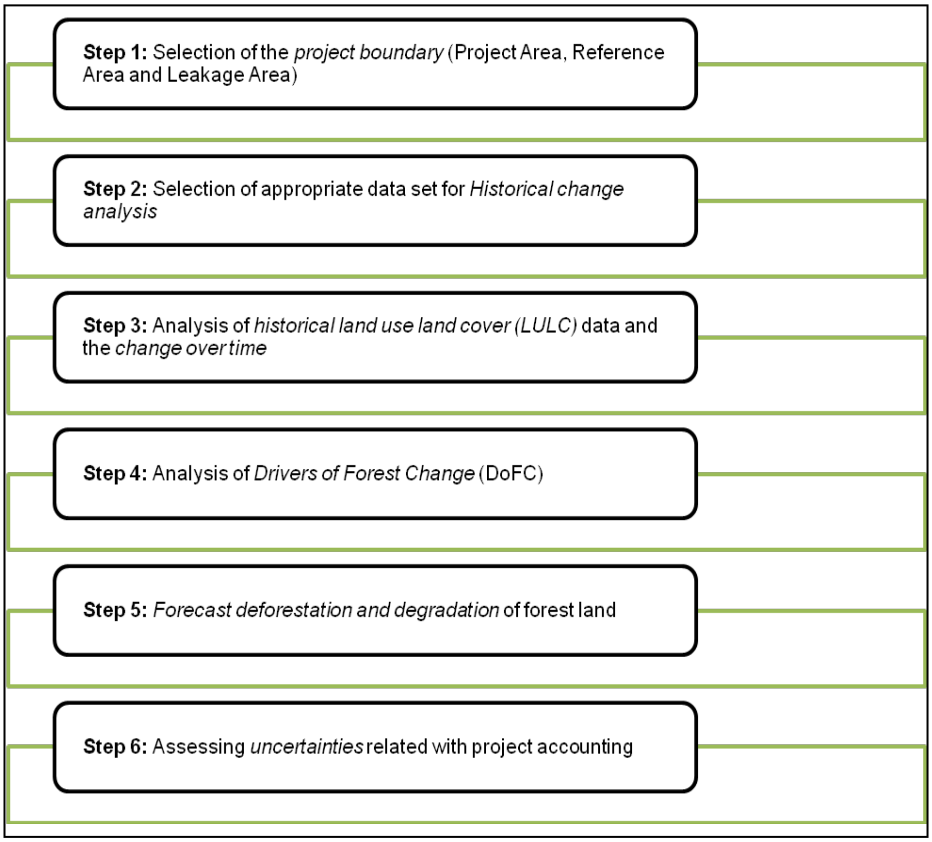
Source		Gas	Included?	Justification/Explanation
				for.
	Fossil fuel used during operations	CO_2	No	Emissions from fossil fuel combustion is considered *de minimis* for REDD and ARR, and is therefore excluded.
		CH_4	No	Insignificant
		N_2O	No	Insignificant
	Removal of woody biomass during assisted natural regeneration (ANR and ARR) activities	CO_2	Yes	Emissions related to changes in carbon pools are taken into account.
		CH_4	Yes	CH_4 emissions from removal of woody biomass are significant when fire is used in preparing the land for ANR activities.
		N_2O	No	N_2O emissions from burning woody biomass during ANR activities are assumed negligible and are therefore conservatively excluded.
	Fertilizer used during enrichment planting for assisting natural regeneration and ARR	CO_2	No	Assumed negligible
		CH_4	No	Assumed negligible
		N_2O	No	Assumed negligible
	Increased fertilizer use	CO_2	No	Not applicable
		CH_4	No	Not applicable
		N_2O	No	N2O emissions related to increased fertilizer use are *de minimis*.

6 BASELINE SCENARIO

The baseline scenario for this methodology is the historic and/or continued LULC and the changes in associated carbon stocks in all selected carbon pools within the project boundary. This is the case for both REDD and ARR components of the project. A step-by-step procedure for determining the baseline scenario is given below in Figure 6 below. Each step is expanded upon in Section 8.

Where a jurisdictional baseline has been developed and reference emission levels have been published by an appropriate entity (e.g., national or sub-national government agencies), the available jurisdictional baseline data must inform the development of the project-specific baseline.

Figure 6: Procedure to Determine Baseline Scenario and Emissions



The sources and sinks of the identified baseline scenario must be determined ex-ante for each year in the baseline validation period. Reassessment of the baseline must be conducted as per the VCS rules.

7 ADDITIONALITY

To demonstrate additionality, the project proponent must apply the steps given below:

Step 1: Regulatory Surplus

Project proponents must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in latest version of the *VCS Standard*.

Step 2: VT0001 AFOLU Additionality Tool

After ensuring that the project meets the conditions of regulatory surplus, the project proponent must determine additionality by applying the latest version of VCS tool *VT0001 Tool for the Demonstration and Assessment of Additionality in VCS AFOLU Project Activities*.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions (BE)

Baseline emissions include all emissions that would have happened in the project area in the absence of the implementation of the project. This is the case for both REDD and ARR components of the project. Baseline emissions are quantified based on the requirements in the sections that follow.

8.1.1 Select Project Area

The project area must be selected and clearly defined. The project boundary must not be finalized until due consideration of inputs from local stakeholder consultations have been taken into account.

The project area may coincide with a combination of natural boundaries and geopolitical or administrative boundaries (e.g., forest management and administration units such as beat boundaries, range boundaries, or revenue administration boundaries such as revenue districts). This will assist the management of projects and boundaries, and avoid duplication of boundaries. Discrete parcels of the project area are permitted.

8.1.2 Select Reference Region

The reference region must meet the conditions detailed in Section 5.1 above. The Land Use Land Cover (LULC) changes within the reference region are analyzed to develop the baseline of the project area. It must be demonstrated that the drivers causing changes in forest lands within the reference region are also active in the project area. The same reference region used for REDD activities must also be used to validate the baseline of any ARR activities.

8.1.3 Select Data Set for Historical Change Analysis

Appropriate data sets are to be selected for analyzing historical change in the reference region. The selected datasets must be of the same season, or of the same expected phenological variations in order to maintain uniformity.

Data sets must meet the following requirements:

- The change analysis must start no more than 30 years prior to the project start date.
- The change analysis must start no less than 10 years before the project start date.
- The change analysis must include at least 3 points to consider the historical LULC change analysis.
- The time points must be at least 4 years apart.
- At least one dataset must be within 2 years of the project start date.

The time horizon of the change analysis must be selected after taking into consideration all local, provincial, and national policies, laws, and trends that may have a general impact on forest carbon.

During validation, special care must be taken by the VVB to assess that the time horizon was not artificially expanded to account for more changes in carbon stocks. This may be done by analyzing the detailed policy changes and impact assessment that the project proponent must conduct and present to the VVB.

8.1.4 Land Use Land Cover Stratification Scheme

The project proponent must identify and describe the land-use and land-cover (LULC) strata present in the reference region at the project start date. The sampling and stratification strategy must follow regional/national strategies, or one that is in line with IPCC and international guidelines. Stratification must consider LULC classification as per the national classification scheme, and should consider all six IPCC classes (forest, cropland, grassland, wetlands, settlements, and other land). All forest types within the project area must also be considered. Any other significant sub-strata must be considered based on established scientific principles.

Forest land must therefore be further stratified based on forest types and density. This methodology allows the project proponent the use of nationally accepted canopy density classes with proper justifications. These classes may be further optionally subdivided based on spatial and spectral classification technique as found suitable by the project proponent.

Non-forest land may be further stratified in strata representing different non-forest classes. IPCC land classes used for national GHG inventories may be used to define such classes. However, where appropriate, additional or different sub-classes may be specified. Croplands may be further classified into smaller strata, as it is possible that cropping systems/plantations and associated practices directly or indirectly act as drivers of deforestation and forest degradation. This will provide for loss of forest carbon in each such stratum during the transition from forest lands. However, such a classification is not deemed mandatory.

The description of a LULC class must include criteria and thresholds that are relevant for the discrimination of that class from all other classes. Such criteria may include different kinds of information such as elevation above mean sea level, aspect, soil type, distance to roads and villages, and forest management category. Land with temporary unstocking of forest will not be considered under this methodology.

The minimum mapping unit (MMU) must be equal to, or less than, 1 ha.

8.1.5 Geo-spatial Analysis and Techniques

The stratification of forest and non-forest components is achieved using either digital classification algorithms such as maximum likelihood, decision trees, knowledge classifier, support vector machines or nationally approved forest/non-forest maps. The stratification approach also allows the project proponent to generate forest/non-forest masks using different vegetation indices and classification algorithms to ease the image classification process (P. Bholanatha, K. Cort, 2015) and (R. Suraj Reddy, 2014[7]).

The final classification map must include a minimum of six IPCC LULC classes to quantify deforestation. In case of heterogeneous forest types in the reference area, the classified map must also contain major forest types available in the landscape (see detailed workflow in Figure 7 below). The project proponent may use the existing administrative forest/non-forest boundaries or land use dynamics studies in or around the landscape to improve classification accuracy. The methodology also allows the project proponent to use any nationally or sub-nationally approved data. In such cases, further classification by the project proponent is not required.

8.1.5.1 Vegetation Index Model

A vegetation index model must be determined. The model must be based on satellite derived temporal vegetation indices images. Using these indices-based images, a vegetation fraction map or forest canopy density must be generated using spectral un-mixing or machine learning algorithms (Matricardi et al 2010).

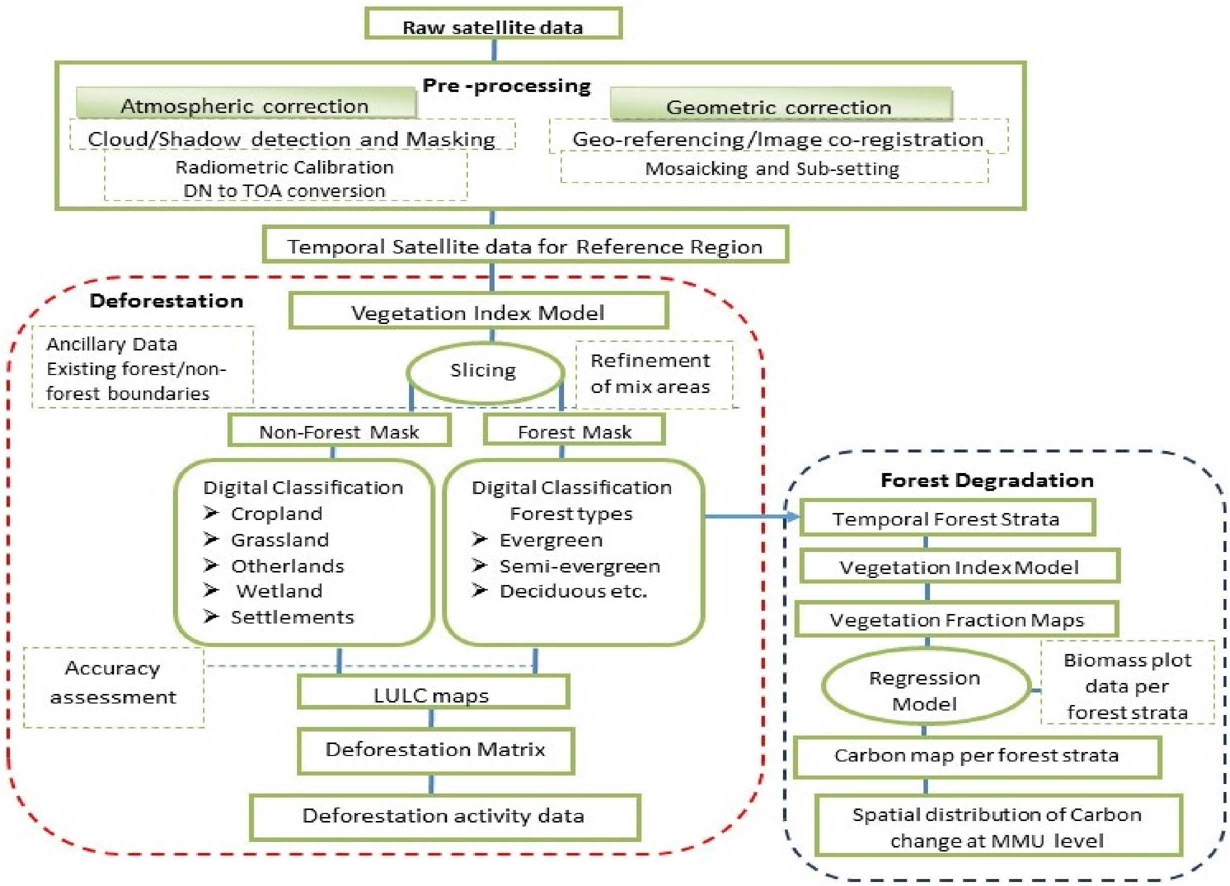
The vegetation fraction map/density map must be divided as per the forest types present in the landscape to form the forest strata. The project proponent may use strata based on forest type or density or a combination of both. In order to assess forest degradation, a transition matrix must be developed between the changes in area among the fractional cover/density classes in a particular forest type.

The basis of applicability of forest degradation mapping is the integration of temporal vegetative fraction or canopy density with field carbon data (emission factor), which may be done separately for each forest stratum. Nationally accepted sampling strategies for forest inventory may be used in this process. In the absence of such sampling designs, the project proponent may use a peer reviewed sampling technique. In such scenarios, in order to decide the number of sample plots per strata, refer to the equations in CDM methodological tool *Calculation of the number of sample plots for measurements within A/R CDM project activities*.

An example of a detailed workflow is shown in Figure 7 below.

[7] Decadal forest cover loss analysis over Indian forests using MODIS 250m imagery, Conference: ISPRS Technical Commission VIII Symposium, 09 – 12 December 2014, Hyderabad, India, At Hyderabad, India, Volume: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-8, 2014

Figure 7: Workflow of Remote Sensing Approach for Baseline Emissions Estimation



8.1.5.2 Analyze LULC Change

Based on the remote sensing analysis, the historical LULC in the reference region must be analyzed for assessing the baseline scenario and quantifying the rates of deforestation and forest degradation. Analysis of the RS data provides the historical changes and current status of LULC dynamics within the reference region.

8.1.5.3 Accuracy Assessment of LULC Maps

Reporting accuracy and verification of results are essential components of a monitoring system. Accuracy may be quantified following recommendations of Section 5 of IPCC *Good Practice Guidance 2003, Chapter 3A.2.4 of IPPC 2006 Guidelines for AFOLU*, and the most recent version of the *GOFC-GOLD Sourcebook* on monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation.

Complete cloud-free satellite maps must be used where available. However, multiple images of the same year may be used so that the cumulative impact of cloud cover for all time points is ≤ 10% of the RR (e.g., in t1, t2 and t3, percent cloud covers are x, y & z, where x+y+z ≤10). Cloud cover and cloud shadow areas must be removed from the baseline calculation. The project proponent may also refer to VCS tool *VT0006 Tool for Calculating LULC Transitions and Deforestation Rates Using Incomplete Remote Sensing Images* for guidance. As an alternative option, project proponents may also use a hybrid approach of Synthetic Aperture Radar (SAR) techniques in areas where heavy cloud cover exists most of the year. In that scenario, combined carbon stock maps must be prepared from both optical and SAR datasets and merged to create a seamless dataset of any year.

With reference to the above, accuracy must be estimated on a class-by-class (LULC map) basis and, where applicable, category-by-category (LULC-change map) basis, respectively. At least 25 validation points for each strata of the area being analyzed must be selected and an error matrix must be presented. The diagonal must show the proportion of correct classification and the off-diagonal cells must show the relative proportion of misclassification of each class or category into the other class or, respectively, categories. Based on the error matrix (or confusion matrix), a number of accuracy indices may be derived.

The minimum accuracy for the forest to non-forest map must be 85 percent. The minimum classification accuracy of each class or category in the Land-Use and Land-Cover Map and Land-Use and Land-Cover Change Map, respectively, must be 80 percent. Where the classification of a class or category is lower than 80 percent, the project proponent should consider merging the class/category with other classes/categories, or excluding the forest-classes from the Forest Cover Benchmark Map that are causing the greatest confusion with non-forest classes according to the error matrix (e.g., initial secondary succession and heavily degraded forest may be difficult to distinguish from certain types of grassland or cropland, such as agro-forestry and silvopastoral systems not meeting the definition of forest).

Both commission errors (false detection of a class/category, such as deforestation) and omission errors (non-detection of actual class/category, such as deforestation) must be estimated and reported.

In order to assess the accuracy of forest degradation mapping, the vegetation fraction/forest cover density model outputs must be validated for each density classes within the forest type with ground observation. The correlation of mapped and ground observed density must be analyzed based on linear regression, or any other statistically appropriate technique with proper justification and a minimum correlation coefficient of 0.7.

For past data validation, high-res and in-situ maps must be used. In the absence of high-res and in-situ maps, accuracy may be assessed by surveys such as Focused Group Discussions (FGDs), expert interviews, focal point interviews and published scientific literatures.

8.1.6 Assess Forest Transition and Forest Scarcity

The “forest transition” concept was introduced by Mather in 1992 (Mather A. , 1992), and is used to demonstrate the manner in which forest cover first declines, reaches a minimum, and then the forest cover again rises and eventually stabilizes. It was demonstrated that with economic development, industrialization, and other DoFC, the forest cover changes in predictable ways.

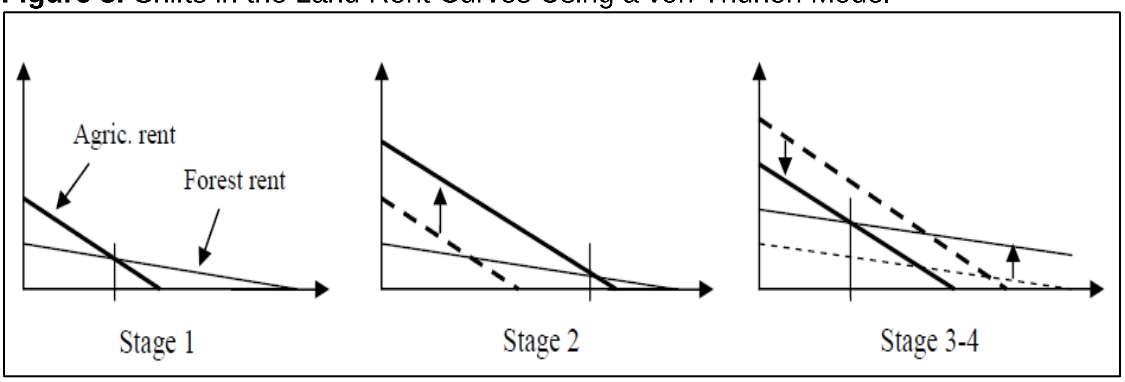
(Mather A. a., 1998). The theory also demonstrates that areas with vast forest cover which are initially characterized by rapid deforestation rates eventually stabilize the forest area after some time. Hence, it would be incorrect to assume that there will be linear decrease in forest until the forest land changes to other land use class. Forest transition was also demonstrated on the basis of Von Thünen framework (Angelsen, 2007).

The stages of forest transition are as follows:

1) Undisturbed forest: inaccessible forest with poor infrastructure and access to market.
2) Deforestation starts: DoFC starts acting on the forest and deforestation begins at a high level leading to forest scarcity. As deforestation begins, a reinforcing loop enlarges the DoFC due to expanded infrastructure and access. Further, the socio-economic and political pressure leads to converting reinforcing into stabilization loops (i.e., leading to a reduction in the rate of deforestation).
3) Forest scarcity: leads to mosaic deforestation/degradation as well.
4) Stabilizing loops dominate leading to recovery of the forest cover (natural or assisted). This was demonstrated by Rudel et al, 2005[8], that the stabilizing loops are mainly due to forest scarcity (i.e., increase in forest demand) and an economic development path (i.e., increased opportunity outside the triggering forces of forest change, like agriculture, and NTFP marketing). In 2013, Angelsen and Rudel, found that forest scarcity and other drivers like scarcity of ecosystem services, diminishing agriculture rent, economic development and policy/regulations changes may provide a strong stimulus for forest conservation and better forest management.

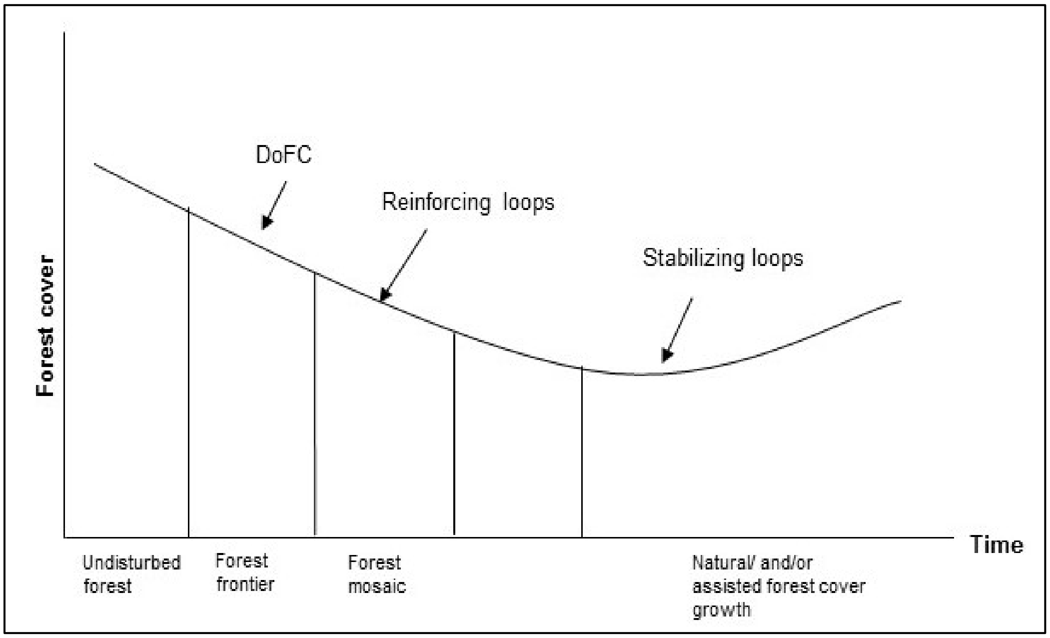
An example of the stages of forest transition is adapted from the Angelsen 2007 paper, as seen in Figures 8 and 9 below.

Figure 8: Shifts in the Land Rent Curves Using a von Thünen Model[27]



[8] Rudel, Thomas K., Oliver T. Coomes, Emilio Moran, Frederic Achard, Arild Angelsen, Jianchu Xu, and EricLambin. 2005. Forest transitions: towards a global understanding of land use change. Global Environmental Change 15:23-31. http://www.greenbiz.com/sites/default/files/document/CustomO16C45F64217.pdf

Figure 9: Main Stages of Forest Loss[9]



The forest transition theory makes two claims:

1) Where there is a significant area of forest there will (eventually) be a significant area of deforestation, while there will be limited deforestation in areas with little forest.
2) Forest cover eventually will be fully or partially restored and stabilized either through natural re-growth or plantations or both.

Since anthropogenic *forest transition* is not a natural process, and is influenced by various socio-economic scenarios, countries may be able to bridge the forest transition and save it from reaching very low levels before it stabilizes.

Detailed assessment of forest transition on the basis of forest scarcity must be made. Published and peer reviewed prediction and assessment methods must be adapted to calibrate and calculate forest scarcity (e.g., *Modeling the Forest Transition: Forest Scarcity and Ecosystem Service Hypotheses*, Akiko Satake and Thomas K. Rudel, 2007).

The average annual transition of land from one forest stratum to another must be estimated for the historical reference period. The historical reference period may be further broken down into two or more time periods. Conditions on selecting the time points in the historical reference period are given Section 223.

The transition must be estimated by mapping the change from one stratum to another, including both forest and non-forest strata, during one of the time periods and calculating the rate of annual transition in each of the stratum as follows:

[9] Adapted from Arlid Angelsen, 2007. Forest Cover Change in Space and Time: Combining the von Thünen and Forest Transition Theories, CIFOR and UMB, World Bank Policy Research Working Paper 4117

$$LT(1 \rightarrow 2)_{y2-y1} = (LC1_{y1} \rightarrow LC2_{Y2})/(y2 - y1)$$ Equation **1**

Where:

$LT(1\text{-}2)_{y2\text{-}y1}$	= Annual average land transition from stratum 1 to stratum 2 from time-point y_1 to time-point y_2 (ha)
$LC1_{y1} \rightarrow LC2_{Y2}$	= Total land classified as stratum LC1 (ha) in time point y1 which has undergone transition to land classified as stratum LC2 (ha) in time point y2 (ha)
Y_1	= Year of first time-point in the land transition analysis
Y_2	= Year of second time-point in the land transition analysis

From this value, the average annual rate of shift from one stratum to another (expressed as a percentage) is also estimated as follows:

$$LT(1 \rightarrow 2)_{y2-y1,rate} = (LT(1 \rightarrow 2)_{y2-y1}/LC1_{Y1}) * 100$$ Equation 2

Where:

$LT(1\text{-}2)_{y2\text{-}y1,\ rate}$	= rate of annual average land transition from stratum 1 to stratum 2 from time-point y_1 to time-point y_2 (%)
$LT(1\text{-}2)_{y2\text{-}y1}$	= Annual average land transition from stratum 1 to stratum 2 from time-point y_1 to time-point y_2 (ha)
$LC1_{y1}$	= Total land classified as stratum LC1 (ha) in time point y1 (ha)

This estimate must be conducted for each of the historical time-points selected for analysis of land transitions. Where more than four historical time-points are considered, the rate of transition from one stratum to another may be developed using regression equations. In the case of three time-points, the average rate of transition may be considered to estimate the overall rate of transition of forest from one stratum to another over the historical reference period. For estimation of baseline emissions, the rate of change of one stratum to another for the entire historical reference period must be estimated.

The same rate of change in the reference region must be applied to the project area. Models of forest scarcity must be applied appropriately to ensure that the rate of change of land from one stratum to another does not result in its complete loss before the end of the project crediting period. If it does, then emissions must be accounted for by:

1) Not accounting for emissions from those strata from that time point at which they will undergo complete transition to other strata; or
2) Applying a discounting factor to evenly distribute the estimated emissions in the entire project crediting period. The discounting factor may be calculated as the ratio of the time taken for the stratum to completely undergo the change to the total crediting period.

The discount factor referenced in (2) above must be calculated as follows:

$$N_{LT} = yLT(j), trans/\ y\ crediting\ period$$ Equation 3

Where:

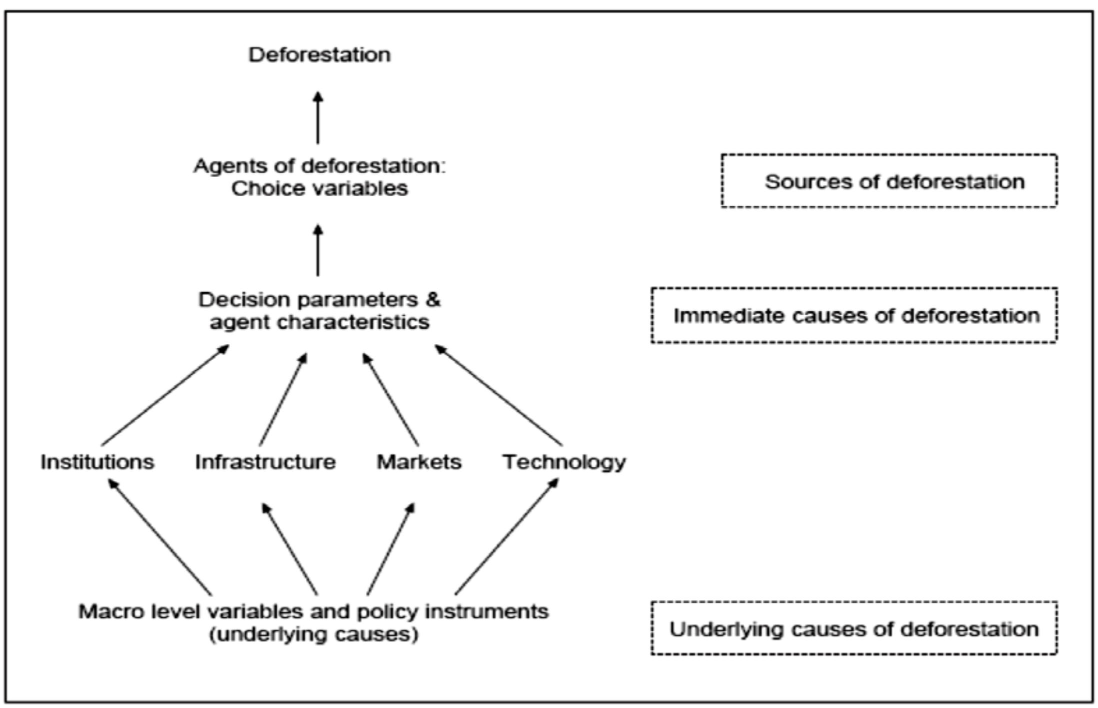
N_{LT}	= land transition discounting factor due to scarcity of land
$y_{LT(i),trans}$	= time taken for the stratum(i) to completely undergo transition to other strata (years)
$y_{crediting\ period}$	= project crediting period (years)

8.1.7 Analyzing Drivers of Forest Change (DoFC)

The project proponent must analyze the DoFC by considering and addressing the points given below:

1) National level driver analysis must be used for the project where available.
2) Where national level driver analysis is not available, or where it can be justified by the project proponent that national level driver analysis is not appropriate for use by the project, the project proponent must conduct a detailed analysis of drivers of forest change. This may be based on internationally accepted norms, such as the five factors proposed by David Kaimowitz and Arild Angelsen (1998) as described in Figure 10 below:

Figure 10: A Framework of Different Types of Variables Affecting Deforestation[10]



[10] Adapted from Kaimowitz, 1998

The project proponent must use the five simplified factors as detailed by David Kaimowitz and Arild Angelsen (1998) on which the analysis of DoFC depends, as given below:

1) **Magnitude and location of deforestation:** Assessed through RS analysis and field surveys.
2) **Agents of deforestation (sources of deforestation):** Analyze the major agents acting and involved in the region causing the forest change (e.g. individual, community, companies).
3) **Choice drivers/variables (sources of DoFC):** Determine the drivers and variables that result in the forest change activities undertaken by the agents (e.g., a community will clear land for agriculture activity or will encroach into the forest for NTFP extraction, whereby a community is an agent, agriculture activity and NTFP extraction are variable). Examples of this include, but are not limited to, the following:
    - Land allocation
    - Labour allocation and migration
    - Capital allocation
    - Consumption
    - Other technological and management decisions
4) **Agent decision parameters (immediate cause of deforestation):** These variables directly influence agents' decisions with respect to the choice variables, but are external to individual agents. This parameter decides the amount of forest change. Examples of this include, but are not limited to, the following:
    - Labor costs,
    - Other factor (input) prices,
    - Accessibility,
    - Available technology and information,
    - Risk,
    - Property regimes,
    - Government restrictions
    - Other constraints on factor use,
    - Environmental factors (physical).
5) **Macro-level variables and policy instruments or the underlying cause:** The impact of these variables are not direct on the agents. However, they impact forest change by affecting and influencing the agents' decision parameters. Examples of this include, but are not limited to, the following:

- Population growth/density of a country,
- Forest dependency ratio,
- Government policies,
- Tariffs,
- Tax rate,
- International exchange rate.

The estimation of the area affected and magnitude of DoFC is done through RS analysis. However, the estimation of land specific values for a given parameter and variables relies heavily on field sampling, which is frequently done through national forest inventories (Tier 2) and project measurement (Tier 3) data. REDD is not only associated with carbon and forest canopy, but also involves social, environmental and economic dimensions.

Based on the historical evidence collected from remote sensing analysis and socio-economic mapping, the project proponent must analyze the relationship between the main agent groups, key drivers, and underlying causes, and explain the sequence of events that typically leads to deforestation and degradation.

Table 5: Approach for Assessing and Evaluating the Socioeconomic Impacts of REDD

Methods of socioeconomic analysis		Stakeholder consultation	Prediction based on stakeholders' views	Use existing data	Collect own data
Primary data	Participatory Rural Appraisal	✓	✓	X	✓
	Household Survey	✓	✓	✓	✓
	Key informant interviews	✓	X	X	✓
	Focus group discussions	✓	X	X	✓
Secondary data	Population census, published scientific literature	X	X	✓	X

The design of survey tools must be made in a way that makes the understanding of natural resource management easier, leading to development and effective implementation of intervention activities. It must also provide information between the decision making system of the government, and the trends and priorities of the local communities. Similarly, information on community based institutions and their role in sustainable conservation of natural resources must be obtained which may be useful in understanding land tenure and rights. Socioeconomic assessments are therefore an efficient and cost effective tool for understanding the social, economic, cultural and political aspects of all the involved stakeholders. However, certain tools are more effective in mapping certain DoFC, which is detailed in the Table 7 below. The same must be demonstrated at the time of validation.

Table 6: Effectiveness of Selected Socio-Economic Tool in Evaluating the DoFC

Socio-economic tool	Drivers							
	Unsustainable extraction of Fuel-wood	Unsustainable extraction of NTFP	Uncontrolled grazing and fodder collection	Expansion of subsistence agriculture by conversion of forestland	Unplanned timber harvesting	Anthropogenic Forest fire	Encroachment	Unplanned mining and quarrying
Participatory Rural Appraisal (semi-structured focus group discussions)	Yes	Yes	Yes	Yes	NA	Yes	Yes	Yes
Household Survey	Yes	Yes	Yes	Yes	Yes	NA	Yes	NA
Key informant interviews	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Focus group discussions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Government census and records.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

This methodology allows different tools to collect socio-economic data, *inter alia*, including, but not limited to:

1) Detailed survey questionnaire
2) Checklist
3) Interviews and discussion notes
4) Interviews and discussion with audio and video records
5) Observation notes
6) Records of earlier surveys and studies

The frequency of conducting surveys must be at least once before every baseline update.

A statistically sound sampling design must be applied or any national/sub-national methodology or standard that is applied for government surveys also may be used. For example, 10 percent with 90 percent confidence level may be considered. Adequate geographical representation also must be appropriately considered in the sampling design.

8.1.7.1 Quantification of Carbon Stock Changes

Data regarding extraction from forests must be derived from the surveys on DoFC mentioned above. These changes in carbon stock and associated emission factors must be computed, and must also be used for back-calculations in assessing the robustness of changes in carbon stock resulting from spatial analysis.

8.1.8 Baseline Emissions from REDD Activities

Deforestation is the change of forest land into other land uses. The change in carbon stock must be derived directly in two GIS approaches: fractional downscaling, and using microwave applications such as SAR analysis and associated algorithms. Ground validation involves estimation of the carbon stock of each of the identified strata.

Stratification must be based on national guidelines. In the absence of national guidelines, forest must be classified into different forest types as per established international ecological norms. The carbon stock of each type of forest must be estimated from ground ecological data collected from each stratum. Carbon stock in each of the identified carbon pools must be estimated in each stratum. Where a national standard exists on forest inventory, the same may be followed. In the absence of such guidance, the requirements below must be followed.

Forest lands in the reference region must be divided into appropriate strata, based on forest types, and other sub-strata as applicable (such as aspect and slope). The carbon pools must then be identified and listed. The carbon pools considered in this methodology are detailed in Section 3 above. AGB measurement involves quantification of the carbon content of trees.

A statistically significant sampling methodology must be applied based on the IPCC GPGLULUCF or CDM tool on sampling. The size of the sample plots must be at least 0.25 ha for quantification of AGB. A smaller plot may be chosen based on regional or national guidance or other accepted international norms. A detailed inventory of all trees must be prepared with data and parameters collected which includes DBH and the height of the trees. The total living biomass carbon content of the strata is computed on a per hectare basis for each stratum.

Where the project proponent is including the SOC (i.e., the case where the baseline scenario is annual crop), the most recent version of the CDM methodological tool *Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities* must be applied.

Carbon content per hectare of a stratum must be estimated from the carbon estimations from the sample plots. Carbon stock in each of the pools must be estimated separately. Regional and national volume equations and allometric equations may be used for estimating AGB. Biomass Expansion Factors (BEF) may be sourced from IPCC GPG LULUCF. Wood density specific to the species of trees may be sourced from regional/national specific sources. Standard root to shoot ratios may be used for estimating BGB. Nationally applicable methodologies or techniques from peer reviewed publications will be applied for estimation of SOC, carbon content in deadwood, litter and other carbon pools.

$$\mathrm{C} - St_i = \Sigma(\mathrm{C})_{c-pool,i,SP} * 1/\mathrm{SP}$$ Equation 4

Where:

$C\text{-}St_i$	= Carbon stock per hectare of stratum i (tC/ha)
$(C)_{C\text{-}pool,I,SP}$	= Carbon stock in each of the carbon pool in the sample plot in stratum i (tC/sample plot)
SP	= Area of sample plot (ha)

Change in carbon stock due to degradation must be based on fractional downscaling or other such algorithm based analysis using SAR or LIDAR technology. In the absence of such technology, each forest type must be further divided based on the canopy cover. A minimum of 4 strata based on canopy cover must be established based on national approaches. In the absence of any national approach, or where it is better suited for the analysis, the forest canopy must be divided in such a way that each canopy density class is separated by at least 10 percentage points. Carbon stock of each of the stratum must be measured as explained in the section on deforestation. Emission factor matrices must be developed for each of the forest type, where the changes in carbon stock must be detailed where there is a change in the canopy classes.

This quantification must give details of carbon change in forests due to degradation in forest lands. From this data, an emission factor matrix on deforestation is developed which must give the emission factors for change from forest land to non-forest land. A second emission factor matrix must be developed based on changes from one forest type to another. These two matrices may be integrated into the same matrix depending on the techniques applied.

$$\mathrm{EF}\ (LT)(1 \rightarrow 2)_{y2-y1} \ = \ (CSt1_{y1} \rightarrow CSt1_{y2})$$ Equation **5**

Where:

EF(LT)(1→2)	= Change in carbon stock associated to transition from stratum 1 to stratum 2 (tC/ha)
CSt1	= Carbon stock in stratum 1 (tC/ha)
CSt2	= Carbon stock in stratum 2 (tC/ha)

From the net change in the carbon stock in the baseline scenario, the trend in change in the carbon stock is developed. This may be a linear regression projection or an average of each time point in case there are only three time points in the analysis. The total loss of carbon stock from the project area in the baseline scenario is computed as:

$$\mathrm{BSL}_{C,si} \ = \ \mathrm{EF(LT)(1{\rightarrow}2)} * \left((LT(1-2)_{y2-y1,rate}\right) * S_{REDD,i}$$ Equation 6

Where:

$BSL_{c,si}$	= Change in carbon stocks due to land transitions in the baseline in the REDD project area (tC/ha)
EF(LT)(1→2)	= Change in carbon stock associated to transition from stratum 1 to stratum 2 (tC/ha)
LT(1-2)y2-y1, rate	= rate of annual average land transition from stratum 1 to stratum 2 from time-point y1 to time-point y2 (%)
$S_{REDD,i}$	= Area in stratum i within the REDD project area (ha)

The total baseline emissions is estimated using the below equation.

$$\mathrm{BE}_{yREDD} \ = \sum(BSL_{C.si}) * 44/12$$ Equation 7

Where:

BE_{yREDD}	= Baseline emissions from REDD (tCO_2)
$BSL_{C,si}$	= Net change in carbon stocks due to land transitions in the baseline in the REDD project area (tC)

8.1.8.1 Additional Baseline Emission Sources

Detailed quantification of changes in carbon stock is already provided in previous sections where a full field analysis is conducted. This gives the net change in carbon in the landscape, and must also help in the landscape approaches of measuring changes in carbon stock.

However, the methodology also provides for a safeguard by allowing the project proponent to analyze the changes in land use and land cover in the reference region based on activity data. Based on the regression equations or the average rate of change from one LULC class to another, the rate of change from each LULC class to another is computed. The rate of change from each of the strata to other strata is also computed. Statistically insignificant changes may be ignored. From the emission factor matrices developed, and the LULC pattern within the project area, the baseline emissions in the project area may be computed.

In cases where ARR is involved, the baseline must include existing trees within the project area. Conservatively, the change in carbon stock within the baseline trees may be considered as zero, after application of appropriate tools regarding computing change in carbon stock which are approved under VCS or CDM. However, only living biomass carbon stock is to be considered in ARR components.

The project proponent must clearly record the contribution of each of the drivers to forest change and the effectiveness of the implementation of the intervention activity. This must be reflected in the ex-ante quantification. Ex-post emission reduction estimations are not based on the effectiveness values. The effectiveness of any driver intervention activity depends on local conditions and on probability of adoption of intervention activities. Contribution of each driver in causing emissions may be based on different instruments, such as surveys (FGDs and PRAs) published scientific literature, documented expert opinion, and pilot studies. Effectiveness in implementation must be measured on a scale of 0-1, where 0 is not at all effective and 1 is 100 percent effective. Table 8 provides an example of this below.

Table 7: Contribution of Each Drivers of Deforestation and Forest Degradation

Drivers	Contribution	Effectiveness of the intervention activity	Contribution factor (Con-F) to reductions in emissions
Driver 1	X%	0.a	$Con\text{-}F_1$ = X% * 0.a
Driver 2	Y%	0.b	$Con\text{-}F_2$ = Y% * 0.b
Driver 3	Z%	0.c	$Con\text{-}F_3$ = Z% * 0.c
…	…	…	

Once this is calculated, there is no need to calculate emissions due to each of the driver, except for back calculations and redundancy checks during monitoring and verification. The calculations for major drivers only for the redundancy checks are given below.

Carbon losses due to each of the drivers must be analyzed from the scientific studies in the reference region. This is used to assess and calculate the emission reductions for back-calculations and redundancy checks. The carbon losses due to each of the active and major drivers must be computed. Deforestation and degradation caused due to each of the drivers must be given a weight based on the scientific estimate and surveys, which must be the same as that provided in the Table 8 above. The intervention activities to counter each driver must be detailed. Efficiency of each driver also must be considered. This analysis is not mandated for ex-post estimation as ex-post estimations must be based on the actual stock, irrespective of the drivers and success of the intervention activities planned, but must help in redundancy checks. The major drivers are presented below for the redundancy checks.

Additional baseline emission sources shall be calculated as follows:

$$\mathrm{BE}_{yADD} = L_{fuelwood} + C_{fire} + C_{felling} + C_{ill} \qquad \text{Equation 8}$$

Where:

BE_{yADD}	= Total additional baseline emissions (tCO_2)
$L_{fuelwood}$	= Annual carbon loss due to fuelwood gathering, tonnes C. yr^{-1} per species
C_{fire}	= Annual carbon loss due to forest fire, tonnes C. yr^{-1}
$C_{felling}$	= Annual carbon loss due to timber harvesting, tonnes C. yr^{-1}
C_{ill}	= annual carbon loss due to illegal activities C. yr^{-1}

Fuelwood

The total amount of fuelwood consumed must be assessed from surveys. At least three sample weighs from each of stratum must be collected to validate the amount of fuelwood collected. Total fuelwood collected from forests and from other sources must be recorded separately. The values considered must be “air dry” biomass and moisture account for a maximum of 12 percent of the weight (FAO, 2003)[11] is deducted. A survey based assessment is sufficient to estimate consumption at larger spatial scales when logistic limitations make impossible following stocks of hundreds of households (Jones et. al., 2008).[12] Carbon loss from fuelwood assessed from surveys is calculated as follows:

$$L_{fuelwood} = FG_i \times D_i \times BEF \times CF \qquad \text{Equation 9}$$

Where:

$L_{fuelwood}$	= annual carbon loss due to fuelwood gathering, tonnes C. yr^{-1} per species
FG_i	= annual volume of fuelwood species i gathered, m^3 yr^{-1}
D_i	= basic wood density of fuelwood species, tonnes d.m. m^{-3}

[11] A Guide for Woodfuel Surveys, 2003. Sustainable Forest Management Programme. FAO, Rome.
[12] http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2664.2008.01487.x/full

BEF = biomass expansion factor for converting volumes of extracted wood to total aboveground biomass (including bark), dimensionless;

CF = carbon fraction of dry matter (default = 0.5), tonnes C (tonne d.m.$^{-1}$)

Where the weight of the fuelwood is directly calculated, the above equation must be ignored, and the weight must be directly extrapolated to calculate the total carbon loss due to fuelwood collection. Carbon loss from fuelwood is directly calculated as follows:

$$L_{fuelwood} = W_{fw} * CF \quad \text{Equation 10}$$

Where:

$L_{fuelwood}$ = annual carbon loss due to fuelwood gathering, tonnes C. yr^{-1}

W_{fw} = annual weight of fuelwood gathering, t yr^{-1}

CF = carbon fraction of dry matter (default = 0.5), tonnes C (tonne d.m.$^{-1}$)

Anthropogenic Forest Fire

Only forest fires that originate due to human induced activities may be considered. All forest fires must be mapped. The cause of forest fires must be ascertained as much as possible. If this is not possible, a perception-based demarcation of cause of forest fires may be done based on FGDs. The following two categories are mandatory:

1) Human induced fires.
2) Fires which are not started by human activity.

Only human induced fires are considered in this methodology. The methodology uses GOFC-GOLD Sourcebook, 2013 equation no. 2.6.2, which is an indirect method of estimating anthropogenic emissions from forest fire of IPCC guidelines. Carbon loss from fires is calculated as follows:

$$C_{fire} = Ax_{fire} \times Fl \times Be \times EF \times 10^{-3} \quad \text{Equation 11}$$

Where:

C_{fire} = annual carbon loss due to forest fire, tonnes C. yr^{-1}

Ax_{fire} = Area lost due to forest fire, ha Yr^{-1}

Fl = Fuel loading per unit area, g m-^{2}

Be = Burning efficiency, dimensionless

EF = Emission factor g kg^{-1}

To quantify emissions from forest fires, the area subject to fire must be characterized and stratified into forest types or ecological zones and further sub-divided in terms of fire characteristics (e.g., crown fires which are primarily uncontrolled, intense fires leading to large losses of forest covers, surface fires burning litter and undergrowth).

The quantification method uses a three-tiered approach. However, the project proponent must apply a Tier 3 or Tier 2 approach (i.e., in the absence of region specific data, country level data may be used). In the absence of any country level data, Tier 1 data may be applied.

To map forest fire, moderate resolution satellite data may be used and must have a spatial resolution not coarser than 100 m pixel size. Sub-hectare mapping of forest fire is not allowed in this methodology. Where the forest fire scars in the mapping are less than one hectare, such must not be considered. Monitoring and mapping the understory fire may need analysis based on SAR and appropriate ground validation. In the absence of country specific directions and procedures on SAR analysis, international sources may be used. GHGs other than CO_2 which may be emitted due to forest fires must also be accounted for if they are found to be significant (more than 5 percent of total emissions due to forest fires). Nationally accepted proxies or IPCC default values may also be used in the absence of any local data.

Unplanned Timber Harvesting

Wood that is harvested directly, without being sold, may not be included in the official statistics and must be estimated by survey. Hence, the project proponent must carefully consider these issues. Also, this activity is essentially linked with the socio-economic and geographical conditions of a particular area, and therefore may only be estimated through a Tier 3 approach. Similarly, the FAO approach used for fuelwood estimation may be applied to quantify timber harvesting by local communities. This estimation information must be incorporated into carbon emission accounting algorithms. Carbon loss from timber harvest is calculated as follows:

$$C_{felling} = HT_i \times D_i \times BEF \times CF \quad \text{Equation 12}$$

Where:

$C_{felling}$	= annual carbon loss due to timber harvesting, tonnes C. yr^{-1}
HT_i	= annual volume of harvested timber, species i, m^3 yr^{-1}
D_i	= basic wood density of species i, tonnes d.m. m^{-3};
BEF	= biomass expansion factor for converting volumes of extracted wood to total aboveground biomass (including bark), dimensionless;
CF	= carbon fraction of dry matter (default = 0.5), tonnes C (tonne d.m.)$^{-1}$

Illegal Mining and Quarrying, Encroachment and Expansion of Subsistence Agriculture by Conversion of Forest Lands

These drivers causing change in forest carbon must be illegal and unplanned, and therefore not accounted for in the national inventories. A Tier 3 approach may be used to assess the changes in the forest carbon stock due to illegal mining and quarrying, encroachment and expansion of subsistence agriculture. Analysis of satellite imagery (LULC change matrix) from the past is an effective way to estimate the carbon stock loss due to these activities. Further, to quantify the carbon emissions due to forest loss as a result of these activities, IPCC GPG LULUCF guideline equation no 3.2.9 must be followed. These losses are calculated as follows:

$$C_{ill} = A_{ill} \times B_w \times (1 - f_{biol}) \times CF \qquad \text{Equation 13}$$

Where:

C_{ill}	= annual carbon loss due to illegal activities C. yr^{-1}
A_{ill}	= forest area affected by illegal activities, ha yr^{-1}
B_w	= average biomass stock of forest areas, tonnes d.m. ha^{-1} (Tables 3A.1.2, 3A.1.3, and 3A.1.4 of IPCC GPG LULUCF)
f_{biol}	= fraction of biomass left to decay in forest (transferred to dead organic matter) (Table 3A.1.11 of IPCC GPG LULUCF)
CF	= carbon fraction of dry matter (default = 0.5), tonnes C (tonne d.m. $^{-1}$)

Grazing and Fodder

In order to quantify carbon losses due to grazing and fodder, studies on biomass consumed during grazing or extracted as fodder from forests must be used. In the absence of such studies, pilot studies may be carried out where the amount of biomass lost due to grazing is recorded. Since quantifying loss of biomass due to grazing and fodder collection also must consider different cultural practices, region specific or peer reviewed tools or methods may be applied to quantify this. The generic approach explained below may also be applied. In case the impact is found to be less than 5 percent, carbon losses due to grazing and fodder may be considered *de minimis*.

The total number of livestock grazing in the area must be estimated. Emissions from grazing are to be accounted for only if the total livestock grazing in the project area is more than the carrying capacity as estimated by the government or reported in peer-reviewed literature for the project area, or per unit of a similar landscape (same bio-geological zone), or else nationally recognized data may be used. Dry matter intake of cattle must be calculated based on the body weight of the livestock and estimated dietary net energy concentration of diet as explained in *IPCC Guidelines for National Greenhouse Gas Inventories 2006*. Since some supplementary feed might be given by herders, this must be considered in the quantification method, and must be established from surveys, government reports, or peer reviewed literature. From actual dry matter intake per cattle unit, dry matter intake by all the livestock that graze in the forest land must be calculated.

Available forage of the forest land may be estimated with reference to the past records of stocking rates of the grazing land reported by government agencies or research institutes. If the historical trend of the quality of the grazing land is steady or shows a decline, conservatively, the same stocking rate may be considered or must otherwise be revised. In the absence of any historical rates, available forage of similarly managed forests/grazing lands may be applied or else national data may be applied. From actual dry matter intake per animal and the available stocking rate, carrying capacity may be calculated.

Total carbon content in the intake must then be calculated from the difference of available forage and the dry matter intake of all the livestock that graze in the forest. Carbon fraction of the forage must then be either estimated in laboratory tests or is referred to from peer-reviewed literature including government reports. From carbon emissions due to grazing, carbon added to the forest soil in the form of excreta is discounted to avoid any double counting in instances where SOC is accounted as a carbon pool in the project. The discounting factor may be tier-2 data also based on carbon balance studies in pasture lands. This discount factor is to be conservatively applied.

Non-Timber Forest Produce (NTFP)

Where it is found that extraction of NTFP leads to unsustainable losses in biomass, the resulting emissions must be accounted for. This may be done by listing every NTFP that contributes to at least 5 percent of total extracted NTFPs in the reference region by quantity. This may be established through surveys, expert opinion, key informant interviews and secondary literature studies where the use of the NTFPs and the plant parts are recorded. The damage due to extraction of each of the NTFP must be assessed based on expert opinion, direct observations and recording, and/or surveys in such a way that the extraction practices are taken into account. Where government reports or information from peer reviewed literature is available on the carrying capacity of a particular NTFP, the same may be used. In the absence this, expert opinion on the carrying capacity must be established.

8.1.9 Baseline Emission Removals from ARR Activities

Estimation of baseline emission removals from ARR activities must refer to methodology *AR-AMS0007*, the equations for which are presented below.

The baseline net GHG removals by sinks must be calculated as follows:

$$BE_{ARR} = \Delta C_{TREE\_BSL,t} + \Delta C_{SHRUB\_BSL,t} + \Delta C_{DW\_BSL,t} + \Delta C_{LI\_BSL,t} \qquad \text{Equation 14}$$

Where:

$\Delta C_{TREE\_BSL,t}$ = Change in carbon stock in baseline tree biomass within the project boundary in year *t*, as estimated in the tool *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*; tCO_2e

$\Delta C_{SHRUB\_BSL,t}$ = Change in carbon stock in baseline shrub biomass within the project boundary, in year *t*, as estimated in the tool *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*; tCO_2e

$\Delta C_{DW\_BSL,t}$ = Change in carbon stock in baseline dead-wood biomass within the project boundary, in year *t*, as estimated in the tool *Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities*; tCO_2e

$\Delta C_{LI\_BSL,t}$	=	Change in carbon stock in baseline litter biomass within the project boundary, in year *t*, as estimated in the tool *Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities;* tCO_2e
BE_{ARR}	=	Total baseline emission removals by sinks, tCO_2e

8.2 Project Emissions (PE)

Project emissions are the emissions which occur inside the project boundary as a result of the project activities.

8.2.1 Project Emissions from REDD Activities

Project emission from REDD activities are provided in Table 9.

Table 8: Sources of Project Emissions

Parameters	Description
Fossil fuel combustion (PE_{ff})	Combustion of all types of fossil fuels associated with the project must be calculated. Activities such as forest patrolling, biomass ground inventory, fire prevention activities, installation of fences, boundary poles, Assisted Natural Regeneration (ANR) activities, introducing and providing intervention activities, eco-tourism (if allowed), NTFP market channel and other activities (as livelihood options) (distance travelled by vehicle type, type of fossil fuel used, type of machine used, quantity of fossil fuel used, inside and outside of the project boundary as a part of the project activity/ies). Reference tool: CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion*
Woody biomass removal for fire prevention activities (PE_{wbf})	Loss of carbon must be accounted for if losses of woody biomass takes place due to activities such as installation of fire breaks, clearing of shrubs, dry and dead wood, invasive species, small trees that may act as fuel for fires, thinning of forests to prevent wildfires, or burning woody biomass. Reference tool: CDM tool for *Estimation of non-CO_2 GHG emissions resulting from burning of biomass attributable to an A/R CDM project activity.*
Woody biomass removal during assisted natural regeneration (ANR) activities (PE_{wbanr})	Loss of carbon must be accounted for if removal of woody biomass such as short trees and shrubs, dead wood, invasive species takes place due to project activities, to allow natural regeneration. Reference tool: CDM tool *Estimation of non-CO2 GHG emissions resulting from burning of biomass attributable to an A/R CDM project activity* must be applied and the resulting emissions must be accounted.

Increased use of fertilizer (PE_f)	Application of fertilizer causing significant N_2O emission from the project activity must be accounted for. Reference tool: CDM tool for *Estimation of direct nitrous oxide emission from nitrogen fertilization to calculate emission.*
Biomass burning/ Fire from natural disturbance/ Forest fire used for harvesting/ site preparation (PE_{bb})	Emissions from biomass burning in the project scenario, whether due to anthropogenic or natural disturbances or as a part of the project activities, must be accounted for. Reference tool: CDM tool for *Estimation of non-CO_2 GHG emissions resulting from burning of biomass attributable to an A/R CDM project activity* to calculate emission.
Unplanned timber harvesting (PE_{uthy})	Where the socio-economic survey finds that there is no unplanned extraction of timber from the project area, then the emissions from unplanned timber harvesting may be assumed to be zero. Reference tool: PE due to unplanned timber harvesting must be estimated using equation no. 11, Section 8.1.8.1, which is based on IPCC GPG-LULUCF.

All project emissions from REDD activities are calculated using the following equation:

$$PE_{REDDy} = PE_{ffy} + PE_{wbanry} + PE_{fy} + PE_{bby} + PE_{uthy} + PE_{ny} + PE_{wbfy}$$ Equation 15

Where:

PE_{REDDy} = Project emissions from REDD activities in year y; t CO_2e

PE_{ffy} = Project emissions from fossil fuel combustion in year y; t CO_2e

PE_{wbfy} = Project emissions from woody biomass removal for fire prevention activities in year y; t CO_2e

PE_{wbanry} = Project emissions from woody biomass removal during ANR activities in year y; t CO_2e

PE_{fy} = Project emissions from direct use of fertilizer in year y; t CO_2e

PE_{bby} = Project emissions from biomass burning in year y; t CO_2e

PE_{uthy} = Project emissions from unplanned timber harvesting in year y, t CO_2e

PE_{ny} = Project emissions from n activities in year y; t CO_2e

8.2.2 Project Emissions and Sequestration from ARR Activities

Project emissions and sequestration from ARR activities are quantified using CDM methodology *AR-AMS0007*. The net GHG removals by sinks must be calculated as below:

$$PS_{ARR} = \Sigma\Delta C_{c-pool,i,SP} * \frac{1}{\text{SP}} * S_{ARR,i} * 44/12$$ Equation 16

Where:

PS_{ARR}	=	Total project sequestration from ARR, tCO_2e
$\Delta C_{c\text{-pool},i,sp}$	=	Total carbon content of all the carbon pools within the sample plots in stratum i, (tC/smaple plot)
SP	=	Area of sample plot, ha
$S_{ARR,i}$	=	Area under stratum i in ARR in ha

The project proponent must also include losses of carbon where the ARR project scenario includes harvesting. This loss is in the form of the long-term average GHG benefit. The maximum number of GHG benefit should not exceed the total long-term average GHG benefit. VCUs may be issued until the long-term average is reached.

This calculation must be performed in accordance with the VCS rules.

8.3 Leakage Emissions (LE)

The project may include activities aimed to reduce leakage or provide alternative economic opportunities to the dependent communities in the project area which necessarily result in emissions. Such emissions must be accounted for and deducted from net emission reductions.

Leakage refers to the displacement of GHG emission sources from inside the project area to outside the project area due to emission reduction activities in the project area. The potential for all possible leakage must be identified and quantified and the project proponent must include LMZs as part of the overall project design.

The project proponent must address leakage by minimizing leakage risks through robust design of a project activity implementation to tackle the DoFCs and the inclusion of leakage inducing activities, and then discount the remaining leakage due to the project activity from the net carbon gain.

De minimis emissions from leakage are not required to be accounted for. The significance of leakage may be determined using the CDM A/R methodological tool *Tool for testing significance of GHG Emissions in A/R CDM Project Activities.*

Leakage occurring outside the host country are not required to be accounted for.

8.3.1 Leakage Management Zones

LMZ are assessed using the following steps:

1) LMZs must be estimated in order to assess leakage due to displacement of unplanned DoFC.
2) LMZs must be determined using socio-economic surveys and local intelligence

3) The assessment must be agent-centric and robust monitoring must be conducted to account for leakage.

4) All communities which are dependent on the project area for any kind of need must be monitored periodically or at least once at the time of verification through surveys. This will help in finding out what are the current requirements that are fulfilled with the help of the project activity and what are the remaining requirements for which the community has to depend on some other forest area.

8.3.2 Activity Shifting Leakage (ALEt)

The application of conservation practices in the project area may lead to undesirable and unintended movement of DoFC outside the project area leading to emissions of GHG due to deforestation and forest degradation of those areas. Where the shifting of activities increases the rate of DoFC, the related land use change, carbon stock/density changes and non-CO_2 emissions must be estimated and accounted as leakage.

The magnitude of activity shifting leakage will vary greatly across conservation projects. If neighbouring forested lands are easy to access and the DoFC are mobile, activity-shifting leakage is likely. Where forested land is not easily accessible or the DoFC are not mobile, the risk of activity-shifting leakage may be quite low.

Activity shifting leakage must be determined using the tools in Table 10 below.

Table 9: Sources of Leakage Emissions

Leakage source	Description
Fossil fuel combustion	Leakage due to all type of fossil fuel as a result of project activity must be calculated. Reference tool: CDM *Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion*
Shifting of grazing and livestock production	Leakage due to shifting of grazing and livestock production as a result of the project activity must be accounted. Reference tool: CDM tool for the *Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity*
Shifting of agriculture activities	Leakage due to shifting of agricultural activities as a result of the project activity must be accounted. Reference tool: CDM tool for the *Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity*
Increased use of fertilizer	Leakage due to application of fertilizer causing significant N_2O emission from the project activity must be accounted. Reference tool: CDM tool for the *Estimation of direct nitrous oxide emission from nitrogen fertilization*

Unplanned timber harvesting	Leakage emission due to unplanned timber harvesting are required to be accounted. However, if the socio-economic survey found that there is no unplanned extraction of timber from the project area, then the leakage emissions from unplanned timber harvesting may be assumed to be zero. Reference tool: Through the selected socio-economic survey option and expert reviews
Biomass Collection	As per the general guidance on leakage in biomass project activities "the project participant must evaluate *ex-ante* if there is a surplus of the biomass residues in the region of the project activity, which is not utilised. If it is demonstrated (e.g., using published literature, official reports, surveys) at the beginning of each crediting period that the total/aggregated quantity of available biomass residues in the region (e.g., 50 km radius), is at least 25 per cent larger than the quantity of biomass residues that are utilised in the region including the project activity, then this source of leakage may be neglected. Otherwise, this leakage must be estimated and deducted from the emission reductions. Projects with more than one biomass residue type may, in principle, treat all relevant biomass residues as one type of biomass residue when estimating the surplus of the biomass in the region."[13]

8.3.3 Market Leakage (CLEt)

Market leakage must be quantified where, due to the conservation practices inside the project area, there is an impact on the supply chain of forest products which result in a shift of production of forest products elsewhere to fulfil the demand supply chain.

Market leakage emissions must be quantified by multiplying the net change in carbon stock with a leakage discount factor as follows:

$$CLE_y = LF_{md} \times \Delta C_{net,bsl,t} \qquad \text{Equation 17}$$

Where:

CLE_y,	=	Total market leakage as a result of REDD+ activities, in the year y since the start of the project activity, tCO_2e;
LF_{md}	=	The dimensionless leakage factor for market-effects calculations
$\Delta C_{net.bsl,y}$	=	Net greenhouse gas emissions in the baseline scenario in the year y since the start of the project activity, tCO_2e.

[13]http://cdm.unfccc.int/filestorage/e/x/t/extfile-20140515165832305-SSCWG44_annex11_Guideline_Leakage_in_biomass_ver04.0.pdf/SSCWG44_annex11_Guideline_Leakage%20in_biomass_ver04.0?t=b0R8bmZtejR5fDDWHSaVyD4kxwXkvvKoLsBw

Market leakage must be accounted for where unplanned timber harvesting is considered in the baseline emissions. Restriction to timber extraction may result in leakage. This may be attributed to (i) identified agents or (ii) unidentified agents.

In the case of identified agents, where timber extraction is/was a part of planned deforestation, the agent will have right over the forest land within the project area. All other forest land within the same management practice must be part of leakage management plan in such cases. If appropriate management plans exist to ensure no leakage occurs and it is demonstrated that there have been no marked increase in timber extraction in lands within the LMZ managed by the agent, leakage may be considered as zero. In case there is a marked increase in timber extraction from the forest lands within the LMZ (more than 5% as compared to the land management plan may be considered to be as a departure), then leakage must be calculated from the records of the actual activity on ground. In the absence (or difficulty in collection) of such information, the leakage discount factors that is to be used in case of unidentified agents (as explained in the next paragraphs) may be applied.

In the case of unidentified agents, comparable market leakage figures (from same forest type within the host country or comparable timber species within the host country) may be applied from scientific peer reviewed journals. As an alternative, a discount factor, which is estimated *ex-post* and revised along with baseline, may be applied to the net GHG changes associated with countermeasures that decrease timber harvest.

The leakage discount factor is estimated on the basis of a comparison between the ratio of merchantable biomass to total biomass across all strata in the project area in base year, and the ratio of merchantable biomass to total biomass within the area from where harvesting would likely be displaced to. The following discount factors may be applied for market leakage:

1) Countermeasures to decrease drivers have no or minimal effect on total timber harvest volume – apply discount factor 0%.
2) Countermeasures that decrease occurrences of harvesting (such as a moratorium), but eventually causing minimal reduction in harvested timber in the long run – apply discount factor 0.1.
3) In the case of countermeasures that substantially reduces harvest level permanently, three discount factors may be applied based on the availability of biomass which is of comparable use and quality in the LMZ as the mercantile biomass within the project area. The three discount factors are as follows:
    - If ratio of merchantable biomass to the total biomass in the leakage area is higher than that of the project area (more than 15%) - discount factor 0.2.
    - If ratio of merchantable biomass to the total biomass in the leakage area is similar to that of project area (within +/-15%) - discount factor 0.4.

- If ratio of merchantable biomass to the total biomass in leakage area is lower than the project area (less than 15%) - discount factor 0.7.

The leakage factor is determined by considering where due to the conservation project activity in the project area the country logging will be increased as a result of the decreased supply of the timber caused by the project. The market leakage may be neglected if it may be demonstrated that no market-effects leakage will occur within national boundaries, due to market leakage and annual extracted volumes increase is negligible within existing national boundary (emission is less than 5% of the total project's GHG emission reduction (i.e., *de minimis*) and illegal logging is absent in the project host country.

Leakage outside the host country is not required to be accounted.

8.3.4 Total Leakage

Total leakage is calculated as follows:

$$LE_y = CLE_y + ALE_y + LK_y \quad \text{Equation 18}$$

Where:

LE_y	=	Leakage emissions in year y, tCO_2e
CLE_y	=	Total market leakage emissions as a result of REDD+ activities, in the year y since the start of the project activity, tCO_2e;
ALE_y	=	Activity shifting leakage emissions in year ytCO_2e
LK_y	=	GHG emissions due to leakage of ARR activities, in year *y*; t CO_2-e

ARR project emissions due to activities such as vehicular emissions and fodder application are not to be accounted for. In line with *AR-AMS0007*, leakage emissions must be estimated as follows:

$$LK_y = LK_{AGRIC,y} \quad \text{Equation 19}$$

Where:

LK_y	=	GHG emissions due to leakage, in year *y*; t CO_2-e
$LK_{AGRIC,y}$	=	Leakage due to the displacement of agricultural activities in year *y*, as calculated in the CDM tool *Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity*; t CO_2-e

8.4 Calculation of Uncertainty

In every step of GHG emission quantification of a project activity, the level of uncertainty must be determined. Uncertainty includes measurement errors in the sample collection, inventory and laboratory processing. The project proponent must clearly state the uncertainty associated with the project activity and describe how much uncertainty must be addressed at what confidence level and must use the 2006 *IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4, AFOLU for uncertainty analysis. Tables 11 and 12 provide the appropriate guidance.

Table 11: Assessing Uncertainty While Accounting for Degradation

Accounting Type	Guidance Document
Assessing uncertainty while accounting degradation	2006 *IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4, AFOLU, Chapter 4, Section 4.2 or nationally accepted standard

Table 12: Assessing Uncertainty While Accounting for Deforestation

LULC Class	Guidance document
Forest land to cropland	2006 *IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4, AFOLU, Chapter 5, Section 5.3
Forest land to grassland	2006 *IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4, AFOLU, Chapter 6, Section 6.3
Forest land to settlement	2006 *IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4, AFOLU, Chapter 8, Section 8.3
Forest land to other lands	2006 *IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4, AFOLU, Chapter 9, Section 9.3

Where uncertainty is found to be less than zero, (i.e., if there is any possibility of NERs being underestimated) the uncertainty factor (UF) must be considered to be zero. In all other cases $UF_{projectREDD}$ is calculated using the guidances in tables 11 and 12 above.

8.5 Net GHG Emission Reduction and Removals

Net GHG emission reductions and removals are calculated as follows:

REDD

Net GHG emission reductions are removals from REDD activities are calculated using the following equation:

$$ER_{yREDD} = (BE_{yREDD} + BE_{yADD} - PE_{yREDD} - LE_y)(1 - \mathrm{UF}_{\mathrm{projectREDD}}) \quad \text{Equation 20}$$

Where:

ER_{yREDD} = Total GHG emissions reductions and removals in year y; tCO_2e
BE_{yREDD} = Baseline emissions from REDD activities in year y; tCO_2e
BE_{yADD} = Total additional baseline emissions in year y; tCO_2
PE_{yREDD} = Project emissions from REDD activities in year y; tCO_2e
LE_y = Leakage in year y; tCO_2e
$UF_{projectREDD}$ = Uncertainty (REDD)

ARR

Net GHG emission reductions and removals from ARR activities are calculated using the following equation:

$$ER_{yARR} = BE_{ARR} - PS_{ARR} - LK_t \quad \text{Equation 21}$$

Where:

ER_{yARR} = Net GHG removals by sinks, in year *t*; t CO_2-e
BE_{ARR} = Baseline net GHG removals by sinks, in year *t*; t CO_2e
LK_t = GHG emissions due to leakage, in year *t*; t CO_2e
PS_{ARR} = GHG emissions reductions and removals in year y; tCO_2e

Net GHG Emission Reductions/Removals

$$\mathrm{NER_y} = \mathrm{ER_{yREDD}} + \mathrm{ER_{yARR}} \quad \text{Equation 22}$$

Where:

NER_y = Net GHG emissions reductions and removals in year y; tCO_2e
ER_{yREDD} = GHG emissions reductions and removals by REDD project activities in year y; t CO_2e
ER_{yARR} = GHG emissions reductions and removals by ARR project activities in year y; t CO_2e

Buffer Contribution

Buffer credits are set aside to address risks of non-permanence and are determined using the net change in carbon stocks and the risk rating determined using the *AFOLU Non-Permanence Risk Tool*, using the following equations:

$$\mathrm{Buffer_y} = \Delta C_y \times \mathrm{RR_y} \quad \text{Equation 23}$$

$$\mathrm{VCU_y} = \mathrm{NER_y} - \mathrm{Buffer_y} \quad \text{Equation 24}$$

Where:

VCU_y = VCUs eligible for issuance in year y; tCO_2e

NER_y = Net GHG emissions reductions and removals in year y; tCO_2e

$Buffer_y$ = Buffer credits to be deposited in the AFOLU Pooled Buffer Account in year y; t CO_2e

ΔC_y = Net change in carbon stocks for REDD and ARR project activities in year y; t CO_2e

RR_y = Risk rating determined in year y

9 MONITORING

9.1 Data and Parameters Available at Validation

Data / Parameter	$BEF_{2,j}$
Data unit	Dimensionless
Description	Biomass expansion factor for conversion of stem biomass to above ground tree biomass for tree species *j*
Equations	4, 11
Source of data	Values from IPCC Good Practice Guidance for LULUCF (2003) Table 3A.1.10. Default values of biomass expansion factors (BEFs)
Value applied	IPCC GPG Default value
Justification of choice of data or description of measurement methods and procedures applied	BEF must be sourced from data on local ecological systems. In case of unavailability of this data, regional, national and international data must be used, in that order.
Purpose of Data	Project emissions and project sequestration
Comments	

Data / Parameter	CF_{Tree}
Data unit	$tCtd.m.^{-1}$
Description	Carbon fraction of dry matter for species of type *j*
Equations	4, 8, 9,11, 12
Source of data	Methodological tool: “*Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities” Latest version.*

Value applied	A default value of 0.47 is used following the AR CDM methodological tool.
Justification of choice of data or description of measurement methods and procedures applied	To convert the dry biomass into carbon weight
Purpose of Data	Project emissions and project sequestration
Comments	To calculate CO_2 sequestered in equation $C_{Tree,\,t}$ = 44/12 * $B_{Tree,\,t}$ * CF_{Tree} where CF_{Tree} is the carbon fraction and C_{Tree} gives the CO_2 content in tonnes.

Data / Parameter	D_j
Data unit	t d.m. m^{-3}
Description	Density overbark of tree stem for tree species j.
Equations	4, 8, 11
Source of data	Good Practices IPCC Guidelines, 1996 and Published literature
Value applied	To be calculated
Justification of choice of data or description of measurement methods and procedures applied	*Dj* must be sourced from data on local ecological systems. In case of unavailability of this data, regional, national and international data must be used, in that order.
Purpose of Data	Project emissions and project sequestration
Comments	

Data / Parameter	$V_{TREE,j,p,i,t}$
Data unit	m^3
Description	Stem volume of trees of species j in sample plot p of stratum i at time t calculated using a volume Table or volume equation or allometric equations. In case a field analysis such as fractional downscaling has been conducted, this data need not be recorded.
Equations	4

Source of data	Field measurements for tree parameters (i.e. GBH, Height) measured in sample plot p of stratum i at time t. Volume equations of each species were taken from nationally accepted and published data. Not required in cases where fractional downscaling analysis is conducted.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	$V_{TREE,j,p,i,t}$ must be sourced from data on local ecological systems. In case of unavailability of this data, regional, national and international data must be used, in that order.
Purpose of Data	Project emissions and project sequestration
Comments	

Data / Parameter	R_j
Data unit	Dimensionless
Description	Root-shoot ratio appropriate for biomass stock, for species *j*
Equations	4
Source of data	As per the field data analysis.
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Rj must be sourced from data on local ecological systems. In case of unavailability of this data, regional, national and international data (Values from IPCC Good Practice Guidance for LULUCF (2003) Table 3A.8 "*Average belowground to aboveground biomass ratio (root-shoot ratio, r) in natural regeneration by broad category (tons dry matter/ton dry matter)" may be considered as per the forest type.)* must be used, in that order.
Purpose of Data	Project emissions and project sequestration
Comments	

Data / Parameter	$S_{REDD,i}$
Data unit	Ha
Description	Land area on which REDD activities are planned under the project scenario for year t and in stratum i
Equations	6
Source of data	To be monitored from the records of project implementation and associated records such as KML files, vector files of land-use activities
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Follow the procedures described in Section 8.1.8
Purpose of Data	Project emissions and project sequestration
Comments	

Data / Parameter	$S_{ARR,i}$
Data unit	Ha
Description	Land area on which ARR activities are planned under the project scenario for year t and in stratum i
Equations	16
Source of data	To be monitored from the records of project implementation and associated records such as KML files, vector files of land-use activities
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Follow the procedures described in Section 8.2.2
Purpose of Data	Project emissions and project sequestration
Comments	Only to be included if ARR activities are implemented.

Data / Parameter	EF

Data unit	$g\ kg^{-1}$
Description	Emission factor of forest fires
Equations	10
Source of data	At the time of validation of baseline
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Follow the procedure described in Section 8.1.8.1, under Forest Fire
Purpose of Data	Project emissions
Comments	

Data / Parameter	Be
Data unit	Dimensionless
Description	Burning efficiency
Equations	10
Source of data	Surveys and/or government approved reports
Value applied	
Justification of choice of data or description of measurement methods and procedures applied	Follow the procedure described in Section 8.1.8.1, under Forest Fire
Purpose of Data	Project emissions
Comments	

9.2 Data and Parameters Monitored

Data / Parameter	ER_{yREDD}
Data unit	tCO_2e
Description	Net GHG emission reductions in year t. Here only REDD activities are being considered and only sinks based on REDD is to be recorded.
Equations	21

Source of data	Based on field inventories and implementation data. Where applicable data as per the SAR/LIDAR and /or Fractional downscaling is acceptable.
Description of measurement methods and procedures to be applied	Measurement methods involves appropriate stratification and sampling and field data collection of biomass and SOC.
Frequency of monitoring/recording	Before each verification
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Calculation of project emission reductions
Calculation method	
Comments	

Data / Parameter	BE_{yREDD}
Data unit	tCO_2e
Description	Baseline GHG emission reductions in year t. Here only REDD activities are being considered and only sinks based on REDD is to be recorded.
Equations	7, 20,
Source of data	Calculated
Description of measurement methods and procedures to be applied	N/A
Frequency of monitoring/recording	Before each verification
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Calculation of baseline emission
Calculation method	
Comments	

Data / Parameter	ER_{yARR}
Data unit	tCO_2e

Description	Net GHG removals by sinks, in year t. Here only ARR activities are being considered and only sinks based on ARR is to be recorded.
Equations	21
Source of data	Based on field inventories and implementation data
Description of measurement methods and procedures to be applied	The total stock of new plantations as per ARR activity is calculated. Carbon content in the stock is estimated over time. The rate of change of carbon stock of each stratum is added to arrive at the total change in carbon.
Frequency of monitoring/recording	Before each verification
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Project emissiosn and project sequestration
Calculation method	
Comments	

Data / Parameter	PS_{ARR}
Data unit	tCO_2e
Description	Project sequestration of GHG emission reductions in year t. Here only ARR activities are being considered and only sinks based on ARR is to be recorded.
Equations	22
Source of data	Calculated
Description of measurement methods and procedures to be applied	N/A
Frequency of monitoring/recording	Before each verification
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Calculation of project emission
Calculation method	
Comments	

Data / Parameter	BE_{ARR}
Data unit	tCO_2e
Description	Baseline GHG emission reductions in year t. Here only ARR activities are being considered and only sinks based on ARR is to be recorded.
Equations	22
Source of data	Calculated
Description of measurement methods and procedures to be applied	N/A
Frequency of monitoring/recording	Before each verification
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Calculation of baseline emission
Calculation method	
Comments	

Data / Parameter	$B_{Trees\text{-}ARR}$
Data unit	Number/dimensionless
Description	Number of baseline trees for the ARR component
Equations	16
Source of data	Field survey
Description of measurement methods and procedures to be applied	Data collected from field enumerations. Details of the trees are to be recorded appropriately.
Frequency of monitoring/recording	At the start of the project activity and every five years since the initial verification or before each verification.
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	To monitor carbon sinks
Calculation method	
Comments	

Data / Parameter	$Fuelwood_{forest}$
Data unit	t/year
Description	Amount of fuelwood collected from forests in a year.
Equations	8, 9
Source of data	Survey records, government documents
Description of measurement methods and procedures to be applied	The fuelwood collection pattern must be based on surveys and government data such as working plan and micorplans which have been approved. Separate fuelwood assessment studies also may be undertaken for this.
Frequency of monitoring/recording	At the start of the project activity and every five years since the initial verification or before each verification.
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Project and leakage emissions
Calculation method	
Comments	

Data / Parameter	$Fuelwood_{agri}$
Data unit	t/year
Description	Amount of fuelwood collected from agriculture land in a year.
Equations	8, 9
Source of data	Survey records, government documents
Description of measurement methods and procedures to be applied	The fuelwood collection pattern must be based on surveys and government data such as working plan and micorplans which have been approved. Separate fuelwood assessment studies also undertaken for this.
Frequency of monitoring/recording	At the start of the project activity and every five years since the initial verification or before each verification.
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Project and leakage emissions
Calculation method	

Comments	

Data / Parameter	FG_i
Data unit	$m^3 yr^{-1}$
Description	Annual volume of fuelwood species i gathered,
Equations	8, 9
Source of data	Surveys and/or government approved reports
Description of measurement methods and procedures to be applied	The fuelwood collection pattern must be based on surveys and government data such as working plan and micorplans which have been approved. Separate fuelwood assessment studies also may be undertaken for this.
Frequency of monitoring/recording	At the start of the project activity and every five years since the initial verification or before each verification.
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Project and leakage emissions
Calculation method	
Comments	

Data / Parameter	HTi
Data unit	$m^3 yr^{-1}$
Description	Annual volume of harvested timber, species i
Equations	11
Source of data	Surveys and/or government approved reports
Description of measurement methods and procedures to be applied	As per section 8.1.8.1, under the Unsustainable Timber Harvesting
Frequency of monitoring/recording	At the start of the project activity and every five years since the initial verification or before each verification.
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Project and leakage emissions

Calculation method	
Comments	

Data / Parameter	Ax_{fire}
Data unit	ha Yr^{-1}
Description	Area lost due to forest fire
Equations	10
Source of data	Surveys and/or government approved reports
Description of measurement methods and procedures to be applied	Area affected by forest fires may be ascertained from government reports. In the absence of such reports, or if these reports are inconclusive, FGDs may be conducted. The FGDs must be conducted of forest managerial staff
Frequency of monitoring/recording	At the start of the project activity and every five years since the initial verification or before each verification.
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Project and leakage emissions
Calculation method	
Comments	

Data / Parameter	*Fl*
Data unit	g m^{-2}
Description	Fuel loading per unit area
Equations	8, 9
Source of data	Surveys and/or government approved reports
Description of measurement methods and procedures to be applied	The fuelwood collection pattern must be based on surveys and government data such as working plan and micorplans which have been approved. Separate fuelwood assessment studies also may be undertaken for this.
Frequency of monitoring/recording	At the start of the project activity and every five years since the initial verification or before each verification.

QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Project and leakage emissions
Calculation method	
Comments	

Data / Parameter	B_w
Data unit	ha yr-^{1}
Description	Average biomass stock of forest areas
Equations	12
Source of data	Tables 3A.1.2, 3A.1.3, and 3A.1.4 of IPCC GPG LULUCF
Description of measurement methods and procedures to be applied	As per section 8.1.8.1, under Illegal Mining and Quarrying, Encroachment and Expansion of Subsistence Agriculture by Conversion of Forest Lands
Frequency of monitoring/recording	At the start of the project activity and every five years since the initial verification or before each verification.
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Project and leakage emissions
Calculation method	
Comments	

Data / Parameter	F_{biol}
Data unit	Dimensionless
Description	Fraction of biomass left to decay in forest (transferred to dead organic matter)
Equations	12
Source of data	Default value to be sourced from table 3A.1.11 of IPCC GPG LULUCF
Description of	Follow the procedure described in Section 8.1.8.1 given

measurement methods and procedures to be applied	under the Illegal Mining and Quarrying, Encroachment and Expansion of Subsistence Agriculture by Conversion of Forest Lands
Frequency of monitoring/recording	At the start of the project activity and every five years since the initial verification or before each verification.
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Project and leakage emission
Calculation method	
Comments	

Data / Parameter	$Fire\ type$
Data unit	Dimensionless
Description	The cause of forest fire: Major categories being human induced or fire due to natural causes.
Equations	10
Source of data	Surveys and/or government approved reports
Description of measurement methods and procedures to be applied	Cause of forest fires may be ascertained from government reports. In the absence of such reports, or if these reports are inconclusive, FGDs may be conducted. The FGDs must be conducted of forest managerial staff
Frequency of monitoring/recording	At the start of the project activity and every five years since the initial verification or before each verification.
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Project and leakage emissions
Calculation method	
Comments	

Data / Parameter	$LC1y1 \rightarrow LC2Y2$
Data unit	ha
Description	Total land classified as stratum LC1 (ha) in time point y1 which has undergone transition to land classified as stratum LC2 (ha) in time point y2
Equations	3

Source of data	Remote sensing analysis
Description of measurement methods and procedures to be applied	Calculate based on the remote sensing classification and stratification procedures, as described under section 8
Frequency of monitoring/recording	At least once before every baseline update
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Determination of baseline scenario
Calculation method	It may be used for producing baseline transition matrix for new instances to be added into the project area.
Comments	

Data / Parameter	N_{LT}
Data unit	$hayr^{-1}$
Description	Land transition discounting factor due to scarcity of land
Equations	3
Source of data	Remote sensing analysis
Description of measurement methods and procedures to be applied	Described under section 8
Frequency of monitoring/recording	At least once before every baseline update
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Determination of baseline scenario
Calculation method	It may be used for producing baseline transition matrix for new instances to be added into the project area.
Comments	

Data / Parameter	$LC1_{Y1}$
Data unit	Ha
Description	Total area of LULC class or forest stratum 1 at time 1

Equations	2
Source of data	Remote sensing analysis
Description of measurement methods and procedures to be applied	Described under section 8.1.6
Frequency of monitoring/recording	At least once before every baseline update
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Project and leakage emissions
Calculation method	
Comments	

Data / Parameter	$area_{projectareawithharvest,projectscenario}(t,i)$
Data unit	ha yr^{-1}
Description	Size of strata i within the project area with harvest activities during year t under the project scenario.
Equations	16
Source of data	Remote sensing analysis
Description of measurement methods and procedures to be applied	This is relevant for ARR and LMZ
Frequency of monitoring/recording	At least once before verification
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Calculation of project emissions
Calculation method	
Comments	

Data / Parameter	$FW_{commercial}$
Data unit	$m^3 yr^{-1}$
Description	Annual volume of fuel wood gathering for commercial

	sale
Equations	8, 9
Source of data	1. Participatory rural appraisals 2. Recent (<10 yr) literature in the reference region 3. Recent (<10 yr) literature in an area similar to the reference region
Description of measurement methods and procedures to be applied	Estimate among participating communities and communities living in the leakage area.
Frequency of monitoring/recording	At the start of the project activity and every five years since the initial verification or before each verification.
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Calculation of project emissions
Calculation method	
Comments	

Data / Parameter	LE_y
Data unit	tCO_2e
Description	Leakage emission in year y
Equations	18
Source of data	Surveys and spatial analysis
Description of measurement methods and procedures to be applied	Estimate among participating communities and communities living in the leakage area.
Frequency of monitoring/recording	Before each verification and at the time of baseline update
QA/QC procedures to be applied	Standard SOPs recommended in the methodology must be applied. Review of monitoring records
Purpose of Data	Calculation of leakage emissions
Calculation method	
Comments	

9.3 Description of the Monitoring Plan

9.3.1 Monitoring Plan

Monitoring involves measuring and recording emissions, including carbon sequestered in the project area and any emissions due to leakage in the leakage area.

9.3.2 Methods of Monitoring

The project proponent may either use professional foresters or community members for carrying out monitoring of the carbon stock.

Extensive research on case studies[14] from around the world demonstrate that carbon stock estimates generated by community-based monitoring provide similar levels of uncertainty as estimates generated by an expert study. This demonstrates that trained and equipped members of local communities may collect accurate data. This also provides additional benefits to the project, as it was also found that involving community-based monitoring in REDD project can help in providing the opportunity of getting community members involved in the design and implementation of REDD projects. Additionally, use of technology like smart phones allows for real time data, and will likely also increase the efficiency of data collection.[15]

A further discussion of the benefits and challenges of community-based monitoring can be found in Box 1 below.

[14]http://forestcompass.org/case-studies/assessing-accuracy-and-cost-efficacy-community-based-monitoring-redd
http://forestcompass.org/case-studies/community-monitoring-chico-mendes-extractive-reserve-acre-brazil
http://forestcompass.org/case-studies/community-carbon-accounting-cca-action-research-project-indonesia
http://forestcompass.org/case-studies/community-monitoring-chico-mendes-extractive-reserve-acre-brazil
http://forestcompass.org/case-studies/iges-fpcd-community-based-forest-monitoring-project-papua-new-guinea
http://forestcompass.org/case-studies/community-based-forest-monitoring-north-rupununi-guyana
[15]http://forestcompass.org/case-studies/community-based-forest-monitoring-north-rupununi-guyana

Box 1: Benefits and Challenges of Community-based Monitoring

Community monitoring helps communities take informed decision to participate in REDD policy dialogue, and allows communities to retain control over their forests. This leads to strengthening of forest management through increased coordination among project proponents, forest departments, communities and other relevant stakeholders. Participation will also help in spreading awareness about climate change impacts and mitigation activities. The following are examples of these activities:

- Offering way forward since the customary forest owners will help in generating scientific data; this will help the communities in making decisions related to forest management while retaining their control over land.
- Giving communities a sense of involvement and in assuring the safeguards of their rights providing
- Transparency and effectiveness in forest management;
- Respect for the traditional knowledge and rights of indigenous people;
- Full and effective participation of communities;
- The action which communities are asked and incentivized for is conservation of natural forests, biodiversity and emission reduction.

Through various case studies around the world it was found that the challenges in the community-based monitoring:

- Initial costs in community-based monitoring are high due to technology and capacity building of communities, though with time (i.e., from 2nd or 3rd monitoring period) the cost will considerably decrease. Also, considering travelling, wages and accommodation of costs of professional forestry experts could be outweighed by the capacity building costs.
- Low social cohesion and rights over common resources have been found to be a challenge for assessing drivers of forest change. Additionally, insufficient understanding of monitoring among neighbouring clans has been found to be one of the major challenges to resolve. Moreover, creating a common understanding about the monitoring procedure and benefit sharing within and between stakeholder groups is a time consuming process.
- Logistics for data collection in remote and uninhabited areas and information dissemination is difficult; therefore, it is favourable if community members undertake monitoring of the activity for the project within the proximity of their homes to decrease the logistical challenges.
- Communities may be clearly in a position to collect basic data from the forest, such as tree species, tree count and DBH. However, the measurements may not always be of high quality in the initial years. It is therefore necessary to have a parallel process to supplement the gaps in the basic data quality of the data collected by community(s).

Requirements of Communities for Performing Monitoring Activities

The following are requirements for monitoring activities:

- Well-designed training by forestry professionals.
- Good payment for their service in-cash or in-kind as required by the communities.
- Full and effective involvement of communities in design and implementation of REDD project.
- New and advanced technology like computers and smart phones may help further increase the community management of forest.

QA/QC in Community-Based Monitoring

A detailed project based risk-abatement plan must be developed before the start of the first monitoring activity. This must also be submitted to the verifier at the time of verification. The minimum frequency of monitoring must range from annually to every 5 years at maximum.

QA/QC Requirements of All Monitoring Methods

QA/QC of field data collected must be assured by the following:

- People involved in field measurement must be fully trained in field data collection and data analysis.
- List the names of all the field teams and the project leader and the dates of the training sessions.
- Record which teams have measured the sampling plots, record who was responsible for which task.
- Develop Standard Operating Procedures (SOPs) for each step of the field measurements and adhere to these at all times, both *ex-ante* and *ex-post.*
- Put a mechanism in place to correct potential errors or inadequacies in the SOPs by a qualified person.
- Verify that plots have been installed and measured correctly. Appropriate internal auditing mechanism must be established.

9.3.3 Monitoring Report Components

The following must be included in monitoring reports:

1) Land use change by deforestation
2) Forest degradation
3) Selected carbon pools
4) Biomass increase due to ANR

5) Leakage area
6) Project emissions
7) Loss events

The monitoring report must contain the information on activities listed below:

1) Changes in LULC in the project area, and leakage area, including a description of the remote sensing techniques; methods of analysis; accuracy assessment and validation used for assessing change in forest land i.e. deforestation and expansion of forest area.

2) Changes of forest cover within forest in the project area and leakage are, including a description of the remote sensing or stratification technique analysis method, accuracy assessment and validation to assess changes (increase or decrease) within the forest i.e. degradation.

3) The change in carbon stocks densities in the selected pool from project area in the project area and leakage area, including a description of the tier used, stratification techniques, techniques used for carbon change analysis, accuracy assessment to assess changes (increase or decrease) in the selected carbon pools in the project area.

4) The increase in the ANR area.

5) Project emissions from the selected carbon pools in the project and leakage area.

6) Loss events (if applicable).

7) Intervention activities in the project area and leakage area.

8) Monitoring of grouped project (if applicable).

9.3.4 Monitoring Steps

Changes in forest cover in the project area (and leakage belt for unplanned deforestation) must be measured before each verification as part of monitoring. All types of forest area need to be monitored for each reporting period. If resources are not sufficient to cover wall to wall coverage, a suitable method of sampling is recommended.

In cases where the project area is located within a region the jurisdictional program or any other VCS or UNFCCC registered MRV, the MRV data generated by the jurisdictional program must be used. In any other case, monitoring must be conducted by the project proponent or the outsourced to a third party having sufficient expertise to carry out the monitoring activities of the project.

All variables used at validation must remain the same. Where the project proponent uses new data and variables in the current fixed baseline period, the baseline must be recalculated using the new data and variables.

9.3.4.1 Monitoring LULC Change in the PA

Calculating actual forest change due to deforestation during the monitoring period, the project proponent must quantify and report the land use change due to deforestation in the PA.

Acquire RS data at the time of monitoring and compare it with the last acquired data and use the same procedure of analysis as used in the baseline for analysing LULC and forest cover. A minimum required selection of imagery and coverage, pre-processing (cloud shadow correction, geometric correction and radiometric correction) and classification of data will be as recommended in Section 8 in the methodology.

Several drivers cause forest degradation and loss of carbon stocks within forests but monitoring all of them with high accuracy is always a challenge. However, high resolution RS data and robust socio-economic surveys helps in achieving 90% - 95% of certainty in data collection. As discussed in Section 8, the gaps in the canopy caused by different drivers (unplanned) may be detected in imagery such as using frequently collected imagery through advanced analytical techniques available and acceptable at National level.

9.3.4.2 Drivers, Agents and Underlying Cause

The drivers, agents and underlying cause identified at the time of the start of the project must be re-assessed, verified and reported as discussed in Section 8.1.7 in the methodology.

9.3.4.3 Biomass Stock Density in LULC Class and Degraded Patch

As per the change quantified and reported, the project proponent must calculate the biomass change in the selected carbon pools in the PA as per the given procedures and tools used in Section 8.1.8 in the methodology.

9.3.4.4 Increase in Biomass Due to ARR

The project proponent must calculate the biomass increase in the current monitoring phase from the consecutive baseline or monitoring phase using biomass inventories. The increase in biomass must be calculated and reported against which the project proponent may claim credit. The project proponent must follow the monitoring procedure as described in *AR-AMS0007 A/R Small-scale Methodology: Afforestation and reforestation project activities implemented on lands other than wetlands*.

9.3.4.5 Monitoring of Project Emission

The resulting project emission due to the project activity must be monitored and accounted before each verification period using the same tools and procedures described in Section 8.2.

9.3.4.6 Monitoring of Leakage Area and LMZ

Increases in anthropogenic emission outside the project boundary due to activity shift or market leakage must be monitored and reported at each reporting period. Such emission must be deducted from the emission reduction to determine the net carbon benefit.

Two types of activities need to be monitored:

A) Increase in GHG emission or decrease in carbon stock due to activity shift or Market Leakage in the Leakage Area

Areas selected as leakage areas which are subjected to unplanned deforestation and forest degradation and cause significant decrease in carbon stock must be estimated and monitored before each verification.

B) Increase in GHG emission or decrease in carbon stock due to leakage prevention activities in the LMZ

In areas which are subject to LMZ for leakage prevention measures must be measured and accounted before each verification, this will offset the carbon emission due to the leakage in leakage area.

Monitoring ex-post Land use change and forest cover change in leakage area

Apply the same method used to monitor deforestation and degradation in the PA.

The reason of anthropogenic emission in the leakage area may be due to some external factor and not because of the project activity and if the project proponent may prove this by giving proper justification in the monitoring report, then the project proponent are allowed to adjust the baseline rate of emission reduction. In such case the rate of deforestation and degradation is assessed by calculating the rate in the RR through RS and then using this in the adjusted baseline.

Calculation of Leakage

Project proponent must apply the same procedures and tools used to calculate activity shift and Market leakage in Section 8.3 of the methodology.

In case if the Leakage area is located within a region within the jurisdictional program MRV, the MRV data generated by the jurisdictional program must be used.

In any other case monitoring must be done by the Project proponent or the outsourced third party having sufficient expertise to carry out the monitoring activities of the REDD project.

9.3.4.7 Monitoring intervention activities in the project area and LMZ

Project proponent must monitor and report the intervention activities taking place as a part of emission reduction program of the project activity. The project proponent must monitor and calculate the emission reduction through the approved standard methodologies of CDM or VCS.

The project proponent must exclude the energy efficient intervention activities sources which were already available in the baseline inside the project area and LMZ.

Also, once due to effective implementation of intervention activities or due to any other factor the project area is no longer in danger from the fuel wood emission, the benefit from the energy efficient intervention activities must be excluded. The effectiveness of the intervention activities or in an another word that the biomass stock in the project area is not depleting due to the fuel wood collection may be measured through socio-economic survey or any national data, local statistics, census, FRA reports, RS data, decrease in fuel wood price, trends showing tie and distance travelled by the fuel wood collectors.

9.3.4.8 Monitoring of the Sample Design and Stratification

The carbon stocks are monitored before or at each verification event by conducting a forest inventory using permanent or temporary sample plots. Re-measurement and re-assessment of sample plots is periodically needed and the results must be calculated and reported. Due to any unforeseen natural disaster and deforestation, the permanent sample plots have to be neglected and must not be considered during measurement of carbon stocks. Similarly, in order to measure the increase in forest stock, additional sample plots must be established in order to accurately account the forest carbon stocks. The Project proponent must use latest inventory method and emission factor to calculate ex-post emission reductions and removals.

9.3.4.9 Updates to Baseline Net GHG Removals by Sinks

The baseline must be re-measured and re-assessed after every 10 years and must be validated at the subsequent verification as per the VCS AFOLU Requirements.

9.4 Procedures for Managing Data Quality

The following are procedures that must be followed for managing data quality:

- The data collected must be documented and archived for a period of at least two years after the end of the last crediting period of the project activity.
- The PD must contain description about the Standard Operating Procedure (SOP)
- The SOP of field measurement and reporting must describe each step of field carbon and socio-economic measurement.
- The SOP document must contain the QA/QC procedure of field data measurement, monitoring steps and parameters and how to collect information and data with accuracy.

- Remedial action must be taken including:
  - Errors in the measurement procedure
  - Errors in stratification of forest
  - Effectiveness of intervention

QA/QC must contain (adapted from: MacDonald, 1994):

Precision: precision is a measure of mutual agreement among individual measurements or values of a variable taken under similar conditions.

Accuracy: accuracy is a degree of agreement between a measured value and the true or expected value of the variable.

Completeness: completeness is the percentage of measurement made, that are judged to be valid.

Representativeness: is the degree to which data accurately and precisely represent a characteristic of a population, variations at a sampling point, or an environmental condition. The program must be designed so that the samples collected are as representative as possible of the habitat or populations and a sufficient number of samples are collected.

Comparability: is a measure of the confidence with which one data set may be compared to another. Comparability is not quantifiable. However, it must be considered when designing sampling plans, analysis procedures, quality control and data reporting. Employing consistent data forms and survey protocols will maximize comparability.

- SOPs and QA/QC procedures for inventory operations, including field data collection and data management, must be calculated, recorded and used. SOPs from published handbooks at National level or from the "IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry 2003" Section 3.2.6,[16] is recommended.
- Data requirement may be found in the recommended tools in the methodology
- Data and parameters obtained from measurement must be monitored as required in the tools.

For further guidance on monitoring QA/QC, the project proponent may also consult:

- IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry.
- GOFC-GOLD Sourcebook (FAO, 2013) A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation. Report COP19, Ver. 2, 2013.

[16] http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/GPG_LULUCF_FULL.pdf

- Building Forest Carbon Projects - Carbon Stock Assessment Guidance, Inventory and Monitoring Procedures (Diaz, 2011).

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Verified Carbon Standard

VCS Methodology

VM0038

Methodology for Electric Vehicle Charging Systems

Version 1.0

18 September 2018

Sectoral Scopes 1 & 7

This methodology was developed by the Climate Neutral Business Network, a project of Strategic Environmental Associates Inc, based upon generous support from the EV Charging Carbon Coalition (EVCCC).

The EVCCC seeks to open up access to the carbon capital markets for EV charging systems in order to strengthen their business case fundamentals and accelerate deployment. Beyond GM's business case development, founding members include:

- Electrify America LLC/Audi of America
- Exelon
- EVgo Services LLC
- Siemens
- Connecticut Green Bank
- Carbon Neutral Cities Alliance (including Portland, San Francisco, Seattle, Palo Alto, NYC, Minneapolis, Vancouver BC, Sydney, Adelaide, AU)

Table of Contents

1 SOURCES

This methodology uses the latest version of the following module:

- *VMD0049 Activity Method for Determining Additionality of Electric Vehicle Charging Systems*

This methodology used the latest version the following tools:

- CDM methodological tool *Demonstration of additionality of small-scale project activities*
- CDM methodological *Tool for the demonstration and assessment of additionality*

This methodology is based upon approaches used in the following methodology:

- CDM methodology *AMS-III.C. Emission Reductions by Electric and Hybrid Vehicles*[1].

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	• Projects eligible to apply module VMD0049: Activity method • All other projects: Project method
Crediting Baseline	Project method

This methodology applies to the charging of electric vehicles (EVs) through EV charging systems, including their associated infrastructure, whose GHG emission reductions are achieved through the displacement of emissions from conventional fossil fuel vehicles used for passenger and freight transportation as a result of the electricity delivered by the project chargers.

This methodology provides easy-to-use monitoring parameters to quantify emission reductions, and also establishes default factors for the estimation of certain parameters for projects located in the United States and Canada as an alternative to project-specific calculations.

Finally, this methodology is applicable globally, and provides a positive list for determining additionality for regions with less than five percent market penetration of electric vehicles. The positive list is found in VCS module *VMD0049 Activity Method for Determining Additionality of Electric Vehicle Charging Systems.*

[1] This methodology was based on AMS.III.C.,version 15.0. See CDM website: https://cdm.unfccc.int/methodologies/index.html

3 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions apply to this methodology:

Applicable Fleets

The class of EVs eligible and technically able to charge at EV chargers associated with the project. For LDV projects, these applicable fleets comprise[2] BEVs and PHEVs for L1 and L2 chargers, and BEVs for DCFCs. For HDV projects, these applicable fleets comprise the MDV/HDV electric vehicles eligible to charge at the project's set of EV chargers.

Associated Infrastructure (AI)

Stationary battery storage devices[3] and dedicated renewable energy systems (e.g., solar or biofuel from on-site or other locations which use dedicated direct transmission lines) integrated as part of EV charging systems and managed by their control units. Associated infrastructure includes on-site battery storage systems which can store and dispatch electricity to and/or from any on-site renewable power systems, the grid, and/or the EV batteries. Associated infrastructure also includes the EV batteries themselves and thus includes EV vehicle-to-grid (V2G) and EV to on-site battery exchanges of electricity.

Associated Infrastructure Metering Systems

Systems used to track electricity flows between AI devices, whether using meters and/or associated measurement systems within or external to the EV charger. These may include upstream metering on the grid-side of the adequate metering system (e.g., where meters are installed grid-side of an on-site battery) and/or downstream metering (e.g., where metering takes place within the charger unit itself, downstream of the on-site battery).

Battery Electric Vehicle (BEV)

An EV which relies exclusively upon electricity delivered from an external EV charging system for its power in order to propel its motion

Charging Networks

A collection of charging systems which service any given applicable fleet

Closed Charging Networks

A collection of charging systems for which composition of the applicable fleet is constrained to a particular sub-set of EVs whose composition and operating characteristics of both the applicable

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[2] There may be a very few PHEVs which also have the plug capability to charge at DCFCs (e.g., Mitsubishi Outlander); these are considered de minimis. Similarly, the BMW i3 REX (with range extender) is technically a PHEV, but only 5% of i3s use the range extender in practice. Moreover, Argonne National Laboratory and California classify the REX as a BEV, and therefore it is included in the BEV category for default factor calculation purposes in this methodology.

[3] For larger powered systems (e.g., 150kw, 320kw), stationary battery systems may become a more typical integrated part of the EV charging system infrastructure over time (e.g., to mitigate demand peak charges from utilities); they are controlled by the charging system's control unit and are located close to the site within the charging system's metering to the utility.

and comparable fleets can be specifically identified and documented (e.g., a transit agency's e-bus charging network)

Comparable Fleets
Those fossil-fuel vehicles whose travel characteristics have been defined to be comparable to the EVs in each applicable fleet as determined in Section 4 below

DC Fast Charger (DCFC)
A charger which provides direct current charging (typically at 200-1000V) from an off-board[4] charger with a power rating above 11kw. Typical DCFC ratings are 50kw, with the newest systems for passenger vehicles in the 150kw and 320 kw ranges. DCFC classifications are defined as:

- DCFC 50kw: capable of delivering maximum power from 11kw to 62.5kw
- DCFC 100kw: capable of delivering maximum power from 63kw to 110kw (i.e., 200A)
- DCFC 150kw: capable of delivering maximum power from 111kw to 160kw (i.e., 200A@800V or 350A@400V, some with cooled connectors)
- DCFC 320kw: capable of delivering maximum power from 161kw and 360kw (i.e., cooled connectors)
- DCFC 500kw: capable delivering maximum power from 361kw and above (i.e., different connectors)

Where no kw classification is specified in this methodology, DCFC includes all classes defined above.

Dedicated Renewable Energy
Renewable power (e.g., solar, wind, and bio-fuel) supplied either from sources on-site within the associated infrastructure of the project, or received from a dedicated supply source via a direct transmission line. These renewable sources represent a distinct segment, differentiated from the renewable electricity supplied via the broader grid. These dedicated renewables may also be delivered in part for use on the main grid.

Electric Vehicle (EV)
Vehicles, including BEVs and PHEVs, spanning both passenger cars, LDVs and HDVs, powered by the external electricity sources of charging systems. EVs do not include hybrid-only vehicles since they do not consume electricity from externally generated sources.

[4]See SAE standards:
http://grouper.ieee.org/groups/earthobservationsSCC/IEEE_SAE_J1772_Update_10_02_08_Gery_Kissel.pdf

EV Chargers

Charging dispensers and their metering systems including L1, L2 and/or DCFC units which provide electricity to EVs within an applicable fleet and which may form part of an EV charging system

EV Charging Systems

A set of EV chargers including L1, L2 and/or DCFC and their associated infrastructure (if any) which, when located at a given charging site, provide electricity to EVs within a given applicable fleet, and which may form part of a charging network

EV Market Share

The number of EVs on the road within a geographic region, expressed as a percentage of total vehicles on the road within a geographic region, segmented for applicable fleets across LDV and HDV sectors

Heavy Duty Vehicles (HDV)

Vehicles consistent with definitions provided by the governing national regulatory system(s) of the project location. HDVs may also include medium duty vehicles (MDVs). These must be consistent with the data sources used in the standardized tests and default ER factors applied, if any[5].

Kwh/100 Mile Ratings

Ratings as provided by credible national government/regulatory sources which establish the kwh consumed to travel 100 miles, sourced for each EV model within applicable fleets, and used to calculate the weighted average Applicable Fleet's Electricity Consumption (AFEC) rating

Level 1 Charger (L1)

A charger which provides 120V alternating current charging services to the vehicle's on-board charger with a power rating up to 1.8kw

Level 2 Charger (L2)[6]

A charger which provides 240V alternating current charging services to the vehicle's on-board charger with a power rating up to 20kw (typically from 3.3kw to 6.6 kw)

Light Duty Vehicles (LDV)

Cars and trucks consistent with definitions provided by the governing national regulatory system(s) of the project location. These must be consistent with the data sources used in the standardized tests and default ER factors applied, if any[7].

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[5] For example, in the United States, HDVs are specified as including both HDVs and those MDVs with Gross Vehicle Weight Ratings (GVWR) of more than 14,000lbs (typically from class 4 and above), consistent with the IHS Markit data sources applied in the development of the default factors. HDV vehicles include both e-buses and e-trucks.

[6] Note that, in London UK, L2 chargers have been referenced as fast chargers. And, DCFCs are referenced as rapid chargers. Regardless of nomenclature, the chargers will be defined against the technical criteria provided in this methodology.

[7] For example, in the United States, LDVs are specified as including vehicles with) GVWR up to and including 14,000lbs, (classes 1, 2, and 3) and must therefore include those Medium Duty Vehicles (MDVs) up to this same

Medium and Heavy Duty Electric Vehicle (HDV EV)
Medium duty and heavy duty vehicles (collectively defined as *HDV*) comprising both BEV and PHEV HDV electric vehicles, including e-buses and e-truck categories, which rely upon electricity delivered from external EV charging systems for their power

Miles per gallon (MPG) ratings
Mile per gallon ratings as provided by credible national government/regulatory sources establish the miles traveled per gallon of fuel consumed, for those fossil fuel vehicles deemed comparable per Section 4 to the EV's applicable fleet[8]

Open Charging Networks
A charging network where the applicable fleet is not constrained to a particular sub-set of EVs whose composition and operating characteristics of both the applicable and comparable fleets can be identified and documented, as with a closed charging network

Plug-in Hybrid Electric Vehicle (PHEV)
A vehicle combining an internal combustion engine and one or more electric motors, which must also be capable of receiving delivered electricity by plugging into an external EV charging system for its power in order to propel its motion

Private Charging Networks
Charging systems where charger access is limited to a defined applicable fleet. For example, residential chargers would be considered private since access is restricted, as would a city's chargers if their use was limited to the charging of the city's own EV fleet vehicles. Private refers to the limited degree of access to the chargers, not the charging system's owner's status (since public city chargers can use private charging networks). The composition of those EVs accessing the network need not be known (that is, both open (e.g., residential) and closed (e.g., e-bus transit agency charging) networks can be private if access is limited).

4 APPLICABILITY CONDITIONS

This methodology applies to project activities which install EV charging systems, including their associated infrastructure, in order to charge EV applicable fleets whose GHG emission reductions are achieved through the displacement of conventional fossil fuel vehicles used for passenger and freight transportation as a result of the electricity delivered by project chargers.

weight limit, consistent with the IHS Markit data sources applied in the development of the default factors. This 14,000lbs GVWR values is based upon definitions used and supplied by IHS Markit data for light duty vehicles, whose data forms the basis for most US EV market analysis publications. Commercial applications in the 8500-14000 lb Class 2b and 3 are a de minimis proportion of total LDV's. See also: http://changingears.com/rv-sec-tow-vehicles-classes.shtml and https://www.afdc.energy.gov/data/10380 Lighter MDV's include the types of vehicles which also use the main LDV charging networks (e.g., retirement home vans).

[8] For countries using other metrics (e.g., ratings in Europe for CO2 per km), conversion guidance is given in Section 8 below.

Projects must comply with all applicability conditions set out below:

1) The applicable fleets of projects applying this methodology are limited to all LDV BEVs and PHEVs[9], and HDV EVs. For LDV projects, these applicable fleets comprise[10] BEVs and PHEVs for L1 and L2 chargers, and BEVs for DCFCs. For HDV projects, these applicable fleets comprise MDV/HDV electric buses and trucks, both BEV and PHEV, eligible to charge at the project's set of EV charging systems.

2) Project proponents must demonstrate that the EV models comprising the applicable fleet of the project are comparable to their conventional fossil fuel baseline vehicles using the following means:

    - Project and baseline vehicles belong to the same vehicle category (e.g., car, motorcycle, bus, truck, LDV, MDV, HDV);

    - Project and baseline vehicles have comparable passenger/load capacity (comparing the baseline vehicle with the respective project vehicle).

    Note that where project proponents apply the baseline emission default factors for MPG and AFEC determined for the US and Canada, this comparability requirement between applicable and comparable fleet models has already been completed and satisfied.

3) In order to demonstrate that double counting of emission reduction will not occur, the project proponent must maintain an inventory of EV chargers included in the project, including their L1/L2/DCFC classifications and unique identifiers; other measures may include disclosure of credit ownership to EV drivers. Double counting relative to any issued GHG credits[11] from projects that introduce EV fleets[12] will be addressed using the emission reduction discount adjustments in Section 8.4 below[13]. Where associated infrastructure and/or renewable power (on-site and/or direct transmission) are included in an EV charging system, this must be referenced and described in the charging system's inventory. Project documentation must also include the following for each EV charger:

    - Classification using the performance voltage, AC/DC basis and kw power specifications given for L1, L2 and DCFC 50/100/150/320/500 definitions

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[9] Hybrid-only vehicles, which do not have batteries capable of receiving electricity to propel their motion, are not eligible under this methodology

[10] There may be a very few PHEVs which also have the plug capability to charge at DCFCs (e.g., Mitsubishi Outlander); these are considered de minimis. Similarly, the BMW i3 REX (with range extender) is technically a PHEV, but only 5% of i3s use the range extender in practice. Moreover, Argonne National Laboratory and California classify the REX as a BEV, and therefore it is included in the BEV category for default factor calculation purposes in this methodology.

[11] Credits for GHG emission reductions issued by a GHG program such as the American Carbon Registry (ACR) Climate Action Reserve (CAR), Verified Carbon Standard (VCS), or the UNFCCC's Clean Development Mechanism (CDM).

[12] For example, projects that apply CDM methodology AMS.III.C.

[13] Double counting related to any jurisdictional emission trading systems or commitments (e.g., cap-and-trade programs, etc.) must still be assessed per the VCS rules.

- Unique identifiers, including the geo-spatial coordinates and one other unique reference such as NEMA codes, customer codes, equipment serial numbers, charger ID codes, or AFDC ID codes

4) This methodology is applicable to EV charging systems utilizing AI to provide electricity to and from EVs, on-site batteries and renewables[14] under the condition that the AI must include adequate metering systems (e.g., meters/sub-meters and/or associated measurement systems). These metering systems must measure and accurately trace all electricity deliveries and receipts from all such interrelated associated infrastructure sources. This includes electricity sourced from/returned to the grid, dedicated renewable energy generated on-site (including RE sourced from direct transmission lines), on-site storage batteries, and/or the EV's on-board battery.

5) Projects with estimated annual emission reductions of over 60,000 tCO_{2e}[15] (large-scale) are permitted where project proponents can demonstrate that the project is located in a country with credible national data sources for GHG emission calculations. Otherwise, projects are limited to annual emission reductions equal to or under 60,000 tCO_{2e} (small-scale). Projects located in Annex I and II countries, and countries referenced by EIA data sources, are automatically eligible to be of any scale. All regions listed in module *VMD0049 Activity Method for Determining Additionality of Electric Vehicle Charging Systems* meet these criteria and thus are not limited in scale.

6) Project proponents must demonstrate proof of ownership of emission reductions which may be achieved through the following:

    - With the charging system owners through contractual agreements, terms of service, utility program participation rules, or other means, and/or

    - With EV drivers through disclosure of credit ownership (e.g., through dispenser notices, screen displays, terms of service, etc.).

5 PROJECT BOUNDARY

The project boundary is comprised of the following:

1) The applicable fleets for the project EV chargers;
2) The geographic boundaries where the EV charging systems are located;
3) The EV charging systems of the project activity including their electricity supply sources and associated infrastructure.

The greenhouse gases included in or excluded from the project boundary are shown in Table 1 below.

[14] AI may store and dispatch electricity both to and from multiple sources, both on site and regionally.
[15] The small and large scale boundary was drawn from CDM methodology AMS-III.C.

Table 1: GHG Sources Included In or Excluded From the Project Boundary

Source		Gas	Included?	Justification/Explanation
Baseline	Fossil fuel combustion of vehicles displaced by project activities	CO_2	Yes	Main emission source
		CH_4	Optional	May be excluded for simplification
		N_2O	Optional	May be excluded for simplification
		Other	No	Not Applicable
Project	Electricity consumption via grid	CO_2	Yes	Main emission source
		CH_4	Optional	May be excluded for simplification. Where included in the baseline, source must also be accounted in project emissions.
		N_2O	Optional	May be excluded for simplification. Where included in the baseline, source must also be accounted in project emissions.
		Other	No	Not Applicable.
	Renewables via on-site/direct transmission	CO_2	Yes	Main emission source
		CH_4	Optional	May be excluded for simplification. Where included in the baseline, source must also be accounted in project emissions.
		N_2O	Optional	May be excluded for simplification. Where included in the baseline, source must also be accounted in project emissions.
		Other	No	Not Applicable
	On-site battery storage	CO_2	Yes	Main emission source
		CH_4	Optional	May be excluded for simplification. Where included in the baseline, source must also be accounted in project emissions.
		N_2O	Optional	May be excluded for simplification. Where included in the baseline, source must also be accounted in project emissions.
		Other	No	Not Applicable
		CO_2	Yes	Derived emission source[16]

[16] The EV battery is a derived emission source based upon the kwh received from the grid, dedicated renewables and on-site battery. It does not have a separate independent emissions factor since any kwh the EV battery returns to the grid or the on-site battery are netted out (in NEC and NECT) against the kwh delivered to the EV from these sources using their respective emissions factors. See Equations 7, 8, and 9 and Appendix 2.

Source		Gas	Included?	Justification/Explanation
	EV battery storage in vehicle	CH_4	Optional	May be excluded for simplification. Where included in the baseline, source must also be accounted in project emissions.
		N_2O	Optional	May be excluded for simplification. Where included in the baseline, source must also be accounted in project emissions.
		Other	No	Not Applicable

6 BASELINE SCENARIO

The baseline scenario is the operation of comparable fleets (the comparability of baseline and project applicable fleet vehicles to be demonstrated as per indicators set out in applicability conditions in Section 4 above), that would have been used to provide the same transportation service in the absence of the project.

7 ADDITIONALITY

Project proponents applying this methodology must determine additionality using the procedure described below:

Step 1: Regulatory Surplus

Project proponents must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the *VCS Standard*.

Step 2: Positive List

The applicability conditions of the latest version of VCS module *VMD0049 Activity Method for Determining Additionality of Electric Vehicle Charging Systems* represent the positive list. The positive list was established using the activity penetration option (Option A in the *VCS Standard*). Projects that meet all applicability conditions of this methodology and VCS module *VMD0049 Activity Method for Determining Additionality of Electric Vehicle Charging Systems* are deemed additional.

Step 3: Project Method

Where Step 2 is not applicable, project proponents may apply the following[17]:

- Where the project is small-scale, the project proponent must demonstrate that the project activity would otherwise not be implemented due to the existence of one or more

[17] When applying either tool, regardless of which entity is implementing the project, project proponents may demonstrate that barriers apply for charging service providers and/or their associated partners (e.g., installation customers, utilities, end-users, charging system network service providers, and EV manufacturer/retailer).

barrier(s) listed in the latest version of the CDM methodological tool *Demonstration of additionality of small-scale project activities*.

- Where the project is large-scale, the project proponent must apply the latest version of the CDM *Tool for the demonstration and assessment of additionality*.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

Baseline emissions are calculated by converting the electricity used to charge project applicable fleet vehicles at the EV chargers into distance travelled, and multiplying this by the emission factor for fossil fuels used by baseline comparable fleet vehicles to travel the same distance. Baseline emissions must be calculated as follows:

$$BE_y = \sum_{i,f} ED_{iy} * EF_{ify} * 100 * IR_i^{y-1} / (AFEC_{iy} * MPG_{iy}) \quad (1)$$

Where:

BE_y = Baseline emissions in year *y* (tCO_2e)
$ED_{i,y}$ = Electricity delivered by project charging systems serving applicable fleet *i* in project year *y* (kwh)
$EF_{j,f,y}$ = Emission factor for the fossil fuel *f* used by comparable fleet vehicles *j* in year *y* (tCO_2e/gallon)
$IR_{i,}$ = Technology improvement rate factor for applicable fleet *i*
$AFEC_{i,y}$ = Weighted average electricity consumption per 100 miles rating for EVs in applicable fleet *i* in project year *y* (kwh/100 miles)
$MPG_{i,y}$ = Weighted average miles per gallon rating for the fossil fuel vehicles comparable to each EV in applicable fleet *i*, in project year y (miles per gallon)

Default values for $MPG_{i,y}$, $AFEC_{i,y}$, $EF_{j,f,y}$, and $IR_{i,}$ across both LDV and HDV applicable fleets can be found in the parameter tables in Section 9.1 below for the United States and Canada.

The weighted average electricity consumption per 100 miles rating for EVs in applicable fleet *i,* is calculated as follows:

$$AFEC_{iy} = \sum_a (EV_{aiy} * EVR_{aiy}) / \sum_a EVR_{aiy} \quad (2)$$

Where:

$AFEC_{i,y}$ = Weighted average electricity consumption per 100 miles rating for EVs in applicable fleet *i* in project year *y* (kwh/100 miles)
$EV_{a,j,y}$ = Electricity consumption per 100 miles rating for model *a* EV in applicable fleet *i* in project year *y* (kwh/100 miles)
$EVR_{a,j,y}$ = Total number of model *a* EV in applicable fleet *i* on the road by project year *y* (cumulative number of EVs)

The weighted average miles per gallon rating for the comparable fleet associated with each applicable fleet *i*, is calculated as follows:

$$MPG_{iy} = \sum_a (MGP_{aiy} * EVR_{aiy}) / \sum_a EVR_{aiy} \quad (3)$$

Where:

$MPG_{i,y}$ = Weighted average miles per gallon rating for fossil fuel vehicles comparable to each EV in applicable fleet *i* in project year *y* (miles per gallon)

$MPG_{a,j,y}$ = Mile per gallon rating for the fossil fuel vehicle model deemed comparable to each EV model a from applicable fleet *i* in project year *y* (miles/gallon)

$EVR_{a,i,y}$ = Total number of EV models within applicable fleet *i* on the road by project year y (cumulative number of EVs)

Guidance regarding the calculation procedures for $AFEC_{i,y}$ and $MPG_{i,y}$ and their associated parameters is given in the parameter tables in Section 9.2 and applicability condition #2.

Further details for the calculation of the default values for $MPG_{i,y}$, $AFEC_{i,y}$, can be found in Appendix 1 and the accompanying *Default MPG and AFEC Workbook* on the Verra website.

8.2 Project Emissions

Project emissions include the electricity consumption associated with the operation of the applicable fleet and must be calculated as follows:

$$PE_y = \sum_{ij} EC_{ijy} * EFkw_{ijy} \quad (4)$$

Where:

PE_y = Project emissions in year *y* (tCO_2e)

$EC_{i,j,y}$ = Electricity consumed by project chargers sourced from region *j* serving applicable fleet *i* in project year *y* (kwh/year)

$EFkw_{i,j,y}$ = Emission factor (average) for the electricity sourced from region *j* consumed by project charging systems serving applicable fleet *i* in year *y* (tCO_2e/kwh)

Where "time-of-day" estimates (i.e., estimates segmented by time periods within a single 24-hour day) for project emissions are available, Equation 5 may be applied, thus replacing Equation 4, provided that:

1) There are no time periods in which electricity is provided but not accounted for within *PEy* (i.e., the sum of all such time-of-day time periods *t* equals 24 hours in any given full day within the project).

2) Time-of-day estimates for electricity emission factors $EFkwTOD_{i,j,t,y}$ are drawn from credible, applicable sources and are provided on at least an hourly basis (e.g., the regional Independent System Operation (ISO) or applicable utility generation sources).

$$PE_y = \sum_{ijt} ECTOD_{ijty} * EFkwTOD_{ijty} \quad (5)$$

Where:

PE_y = Project emissions in year *y* (tCO_2e)

$ECTOD_{i,j,t,y}$ = Electricity consumed by project chargers sourced from region *j* serving applicable fleet *i* during time of day period *t* in project year *y* (kwh/time period *t*)

$EFkwTOD_{j,,j,t,y}$ = Emission factor for the electricity sourced from region *j* consumed by project chargers serving applicable fleet *i* during time of day period *t* in year *y* (tCO_2e/kwh)

Where ISO does not provide greenhouse gas emission factors on an hourly basis in region *j*, but does provide fuel consumption data for electricity generation on an hourly basis, $EFkwTOD_{ji,j,t,y}$ may be estimated on a weighted average basis as follows:

1) Projects must combine the hourly fuel consumption figures (typically given as the percentage of each type of fuel consumed that hour (e.g., 50% coal, 50% natural gas)) with the emission factors for these same fuels to create a weighted average emission rate for each hourly period.

2) Emission rates for each fuel must be drawn from the same source (e.g., ISO) or consistent publication sources for region *j.*

Equations supporting these fuel-consumption based time-of-day calculations for $EFkwTOD_{j,,jy}$ are given in the equation below:

$$\mathrm{EFkwTOD_{ijty}} = \sum_{\mathrm{f}} \mathrm{F\%_{ijtfy}} * \mathrm{EFkwF_{ijtfy}} \quad (6)$$

Where:

$EFkwTOD_{j,j,t,y}$ = Emission factor for the electricity sourced from region *j* consumed by project chargers serving applicable fleet *i* during time of day period *t* in year *y* (tCO_2e/kwh)

$EFkwF_{i,j,t,f,y}$ = Emission factor applicable for the fuel type *f* used to generate the kwh sourced from region *j* consumed by project charging systems serving applicable fleet *i* during time of day period t in year y (tCO_2e/kwh)

$F\%_{i,j,t,f,y}$ = Percentage of fuel type *f* used to generate the kwh during each time of day period *t*, sourced from region *j* and consumed by EV charging systems serving applicable fleet *i* in year *y* (%)

Where projects include associated infrastructure within their charging systems, project emissions must be quantified for all such sources *s* following Equation 7, which must replace Equation 4, where the following applies:

1) The electricity emissions factor for the on-site battery must be calculated using the net weighted average of the grid and on-site renewable emission factors as provided in Equation 8 below.

2) The charging system's metering system must adequately and accurately measure and trace such net electricity kwh provided to the charging system (i.e., deliveries minus receipts) from all electricity sourced from/returned to the grid and the dedicated renewables. This includes, for example, electricity sourced from the grid, dedicated renewables (e.g., on site) and delivered to the EV directly and/or via on-site batteries, net of kwh returned back to such sources from the EV batteries[18]. See Appendix 2 for guidance on adequate metering systems.

$$PE_y = \sum_{ijs} NEC_{ijsy} * EFkwAI_{ijsy} - \sum_{ij} LEC_{ijy} * EFkwonsitebatt_{ijy} \quad (7)$$

Where:

PE_y	= Total project emissions in year y (tCO_2e)
$NEC_{i,j,s,y}$	= Electricity consumed by EV charging systems supplied from associated infrastructure source *s* net of any kwh EV/charger returned to this same source within region *j* serving applicable fleet *i* in project year *y* (kwh/year)
$EFkwAI_{j,,j,s,y}$	= Emission factor for the electricity from each associated infrastructure source *s* within region *j* consumed by project chargers serving applicable fleet *i* in year *y* (tCO_2e/kwh)
$LEC_{j,,j,y}$	= Electricity provided to the grid and/or building from on-site storage battery within region *j* serving applicable fleet *i* in project year *y* (kwh/year)
$EFkwonsitebatt_{i,j,y}$	= Emission factor for the electricity from the on-site battery associated infrastructure source *s* within region *j* consumed by project charging systems serving applicable fleet *i* in year *y* (tCO_2e/kwh)

Where projects include associated infrastructure, the emission factor for electricity from on-site battery associated infrastructure must be calculated using the net weighted average of the grid and on-site renewable emission factors as follows:

$$EFkwonsitebatt_{ijy} = \sum_z ECB_{ijzy} * EFkwAIZ_{ijzy} \quad (8)$$

[18] It should be noted that metering systems for associated infrastructure can include "downstream" meters close to the EV, such as those provided by DCFC onboard meters, and "upstream" meters, located grid-side such as meters monitoring kwh delivered to the on-site batteries. Guidance provided in Appendix 2 is designed to assist the application of Eq 7 given the particular features of a project's adequate metering systems.

Where:

$EFkwonsitebatt_{i,j,y}$	= Emission factor for the electricity from the on-site battery associated infrastructure source *s* within region *j* consumed by project charging systems serving applicable fleet *i* in year *y* (tCO_2e/kwh)
$ECB_{i,j,z,y}$	= Electricity consumed by on-site battery from associated infrastructure sources *z*, which comprise only the grid-connected and dedicated renewable sources, within region *j* serving applicable fleet *i* in project year *y* (kwh/year)
$EFkwAI\text{-}Z_{i,j,z,y}$	= Emission factor for the electricity from the associated infrastructure sources *z*, which comprise only the grid-connected and dedicated renewable sources, within region *j* consumed by on-site batteries serving applicable fleet *i* in year *y* (tCO_2e/kwh)

Guidance for sourcing the emission factors for the other associated infrastructure sources *s* is provided in the monitoring parameter boxes found in Section 9; guidance regarding adequate metering systems is found in Appendix 2.

Where projects include associated infrastructure and estimates for time-of-day project emissions are available, Equation 9 may be followed, thus replacing Equations 4, 5 and 7, provided that:

- There are no time periods in which electricity is provided but not accounted for within *PEy* (i.e., the sum of all such time-of-day time periods, t, equals 24 in any given full day within the project)
- Time-of-day estimates for electricity emission factors, $EFkwTODAI_{j,j,s,t,y}$ are drawn from credible, applicable sources (e.g., the regional ISO or applicable utility generation source).
- Equation 7 must be applied to calculate $EFkwTODAI_{j,j,s,t,y}$ where electricity generation's hourly fuel consumption data is relied up to provide time-of-day emission rates for each associated infrastructure source (e.g., grid-derived electricity).
- The electricity emissions factor for the on-site battery must be calculated using the net and time weighted average of the grid and on-site renewable emission factors given in Equation 8.
- The provisions regarding the charging system's adequate metering systems as given for Equation 7 and 8 (including guidance offered in Appendix 2) also apply for Equation 9 in order to adequately and accurately measure and trace net electricity consumption (NECT) from sources *s*, but are applied during each time-of day period *t* provided that:
    - For time-of-day applications of associated infrastructure calculations pertaining to the NECT for an on-site battery's kwh delivered to the EV charger, metering must be applied "upstream", on the grid-side of the on-site battery. That is, for the calculation of NECT for an on-site battery, Equation 9 will, using upstream meters, calculate the kwh delivered to EV chargers via the on-site battery from grid and/or dedicated renewable sources during the time of day period t taking

into account *when* these kwh are actually delivered *to the on-site battery* (i.e., not when delivered from this battery to the EV charger), since the GHG impacts for these kwh arise on the grid system when they are first delivered into this associated infrastructure system (that is, are delivered to the on-site battery)

- For these applications, kwh supplied by the EV to the on-site battery can be set aside (since they return to the EV at a later date) unless, during a given time period *t*, the LECT less the kwh received by the on-site battery from grid and renewable sources less the on-site battery's stored kwh is greater than zero – that is, LECT is so large that it must have drawn upon the kwh delivered to the on-site battery from the EV

In the context of these NECT calculations for the on-site battery, note that the electricity supplied from the grid to the EV charging system directly, and the electricity supplied by the EV back to the grid during any time period *t* are considered separately in the calculation of NECT for the grid.

$$PE_y = \sum_{ijst} NECT_{ijsty} * EFkwTODAI_{ijsty} - \sum_{ijt} LECT_{ijty} * EFkwonsitebatt_{ijty} \qquad (9)$$

Where:

PE_y	= Project emissions in year *y* (tCO_2e)
$NECT_{i,j,s,t,y}$	= Electricity consumed by project chargers supplied from associated infrastructure source *s* net of any kwh EV/charger returned to this same source during time-of-day period *t*, within region *j* serving applicable fleet *i* in project year y (kwh/time period *t*)
$EFkwTODAI_{i,j,s,t,y}$	= Emission factor for the electricity from associated infrastructure source *s* within region *j* consumed by project chargers serving applicable fleet *i* during time-of-day period *t* in year *y* (tCO_2e/kwh)
$LECT_{i,j,t,y}$	= Electricity provided to the grid and/or building from on-site storage battery during time-of-day period *t* within region *j* serving applicable fleet *i* in project year *y* (kwh/year)
$EFkwTODonsitebatt_{i,j,t,y}$	= Emission factor for the electricity from the on-site battery associated infrastructure source *s* during time-of-day period *t* within region *j* consumed by project chargers serving applicable fleet *i* in year *y* (tCO_2e/kwh)

8.3 Leakage

Leakage is not considered an issue under this methodology, and is therefore set at zero.[19]

8.4 Net GHG Emission Reductions and Removals

Net GHG emission reductions must be calculated as follows, including application of a discount factor, D_y, to adjust pro-rata where EV fleet credits have been issued within the project region:

$$ER_y = (BE_y - PE_y - LE_y) * D_y \quad (10)$$

Where:

ER_Y = Net GHG emissions reductions and removals in year *y* (tCO_2e)

BE_Y = Baseline emissions in year *y* (tCO_2e)

PE_y = Project emissions in year *y* (tCO_2e)

LE_y = Leakage in year *y* (tCO_2e)

D_y = Discount factor to be applied in year *y* (%)

Where:

$$D_y = ERC_y/(ERF_y + ERC_y) \quad (11)$$

Where:

D_y = Discount factor to be applied in year *y* (%)

ERC_y = Sum of GHG credits[20] issued by all projects under this methodology (or others which support the introduction of EV charging systems) across this project's applicable fleet *i* categories within this total project region in project year y-1 (tCO_2e)

ERF_y = Sum of GHG credits issued by all projects under methodologies which support the introduction of EV fleets (e.g., CDM AMS.III.C) located within this project's total region

[19] This is consistent with CDM methodology AMS-III.C, which sets leakage at zero. Further analysis of crediting substitution risks between ineligible and eligible EV chargers confirmed substitution risks to be de minimis in the US due to a number of factors. These include: the large distances between public DCFC's and unlikely substitution of public DCFC by public L2 charging; a very low portion of L2s are simultaneously public, accessible (e.g. not restricted workplaces) and excluded from project crediting period under VCS grandfathering rules (when 80-90% of L2 charging takes place in homes). Furthermore, L2 to L2 substitution between eligible and ineligible chargers in this de minimis segment can also be reciprocal reducing leakage still further.

[20] Credits for GHG emission reductions issued under GHG programs such as the American Carbon Registry (ACR) Climate Action Reserve (CAR), Verified Carbon Standard (VCS), or the UNFCCC's Clean Development Mechanism (CDM).

where the applicable fleet *i* categories are the same for both this EV charging system project and projects introducing EV fleets[21], in project year y-1 (tCO_2e)

Where no GHG credits have been issued for projects that introduce EV fleets in the EV charging system project's region, D_y will be 1 (i.e., there is no discount applied).

Where project proponents can demonstrate that the EV charging systems included in the project are comprised of a private or closed charging network (e.g., a private charging network that is in secure garages, or a closed charging network for e-buses owned by a transit agencies where chargers are reserved exclusively for its own public agency fleet), and can demonstrate that relative to this closed or private charging network, no GHG credits have been issued for the introduction of EVs using the network, then D_y will be 1 (i.e., there is no discount applied)[22].

Where GHG credits have been issued for projects that introduce EV fleets for a region larger than the proposed EV charging system project (e.g., a GHG project introducing a fleet of EVs U.S.-wide, while the EV charging system project is confined to one state), then a sensible pro-rata share of the GHG credits issued for the introduction of EV fleets can be estimated for the EV charging system project's region (e.g., using the pro-rata number of EVs on the road in the EV charging system project state compared to the total in the US, using sources such as ZEVFacts.com).

9 MONITORING

Project proponents must follow the monitoring procedures provided below, noting that Sections 9.1., 9.2 and 9.3 below set out parameters and requirements for monitoring projects.

9.1 Data and Parameters Available at Validation

In addition to the parameters given below, estimates for project parameters EF, AFEC, MPG, EV, EVR, $MPG_{a,l,y}$ and ED, which are found in section 9.2, will also be provided as needed at validation.

Data / Parameter:	IR_i
Data unit	Number
Description	Technology improvement factor for applicable fleet i in year y for default value BE calculations.

[21] Therefore, to determine *ERFy*, project proponents must assess projects that introduce EV fleets both based on their location and applicable fleet category to address any potential double counting between GHG credits issued for such projects which introduce fleets of EVs and the GHG credits issued for this EV charging system project.
[22] This is allowed as private and closed charging networks, even if publicly owned, are not subject to the risk that EV fleets with issued certified GHG credits would have access to its charging network, and the EV fleets that do use the network have not issued separate GHG credits of their own. Public charging system operating as open networks would not normally be able to demonstrate such lack of access and therefore must determine if a discount factor must be applied.

Equations	1
Source of data	CDM AMS-III.C which uses the same discount rate in baseline calculations
Value applied	If baselines are calculated using updated BEy parameters for each project year y, $IR_i = 1$ If default values are used for these BEy parameter calculations, For LDV applicable fleets, $IR_i = 1$ For HDV applicable fleets, $IR_i = 0.99$
Justification of choice of data or description of measurement methods and procedures applied	If the baseline is calculated each year using the applicable fleet and conventional fleet statistics in each project year y, then no technology improvement rates need to be applied (since annual accurate data is used each year) $IR_{i,y}$ is therefore set to be 1. IR_i when applied to LDV projects using default values is 1 because default values for MPG factors use individual, specific MPG figures for each fossil fuel vehicle comparable to each EV model in the applicable fleet (see Appendix 1). These MPG figures only change substantially when a fossil fuel model is re-designed/updated by manufacturers which takes place on a 7-10 year cycle: this timeframe is longer than the Verra five year update cycle for parameter updates. IR_i when applied to HDV projects using default values is 0.99 because the defaults values use market-wide, class based comparable MPG factors for default calculations rather than individual, specific MPG figures for the fossil fuel vehicles comparable to each EV model (see Appendix 1) provided that: • This 0.99 improvement rate is applied to each calendar year. • This rate is taken to be 0.99 consistent with the IR default in CDM-III.C. • For project year 1, IR^(y-1) must be 1 (since any number to power 0 is 1). See justification in MPG below.
Purpose of Data	Calculation of baseline emissions
Comments	For LDV projects, the default equivalent MPG are taken from specific comparable vehicles (rather than classes of vehicles) whose MPG are only likely to change with major model upgrades (and thus remain steady for many years).

9.2 Data and Parameters Available at Verification

Data / Parameter:	$EF_{j,f,y}$
Data unit	tCO_2 or CO_2e/gallon
Description	Emission factor for the fossil fuel *f* used by the fossil fuel vehicles deemed comparable to each EV in applicable fleet *i* in year *y*
Equations	1
Source of data	Use values from credible international or national government sources such as, for the US, the EPA emissions factor[23].
Value applied	For LDV projects located in the US and Canada: L1/L2 (BEV and PHEV average) = 0.0088 tCO_2 or 0.0088 tCO_2e per gallon DCFC (BEV average) = 0.0088 tCO_2 or 0.0088 tCO_2e per gallon For HDV projects located in the US: e-buses = 0.0102 tCO_2 or 0.0102 tCO_2e per gallon e-trucks = 0.0102 tCO_2 or 0.0102 tCO_2e per gallon Projects must apply the default value using units (CO_2 or CO_2e) consistent with their project boundary choices, consistent across all project activity sources.
Justification of choice of data or description of measurement methods and procedures applied	International and national government transportation fuel emission rates have been widely established and peer reviewed. US & Canada default values calculated in Appendix 1. Note that if countries provide EF fuel emission factors using slightly different units such as CO_2 per liter simple conversions must be made during validation One common conversation from CO_2 per liter to CO_2 per gallon is given below: CO2 per gallon = CO2 per liter * 3.785 Based upon conversion factors of: 1 gall = 3.785 liters
Purpose of Data	Calculation of baseline emissions
Comments	Calculated annually, based on the fuels consumed by the fossil fuel vehicles deemed comparable to the EV models on the road each year in the applicable fleet, unless default values for baseline calculations for LDVs and/or HDVs are used.

[23] https://www.epa.gov/sites/production/files/2015-11/documents/emission-factors_nov_2015.pdf

Data / Parameter:	$AFEC_{iy}$
Data unit	kwh/100 miles
Description	Weighted average electricity consumption per 100 miles rating for EVs in applicable fleet *i* in project year *y*
Equations	1 and 2
Source of data	Calculated in Equation 2
Value applied	For LDV projects located in the US: L1/L2 (BEV and PHEV average) = 33.32 DCFC (BEV average) = 31.88 For HDV projects located in the US: e-buses = 300 e-trucks = 140 For LDV projects located in Canada: L1/L2 (BEV and PHEV average) = 35.44 DCFC (BEV average) = 33.00
Justification of choice of data or description of measurement methods and procedures applied	Analysis calculations can be found in Appendix 1. Changes in the value of $AFEC_{iy}$ are very gradual over time. Default values for $AFEC_{iy}$ must be updated each 5 years alongside the activity method updates US & Canada default values calculated in Appendix 1.
Purpose of Data	Calculation of baseline emissions
Comments	Calculations for AFEC for open networks (where the exact EV models charging are not known) must be established using such data sources which must be compiled on a national basis (that is, for example, the number of BEV's of each model on the road in the US for open DCFC networks). Calculations for AFEC for closed networks (e.g. where the composition and operating characteristics of both the applicable and comparable fleets are known and documented, such as with transit agency e-bus fleets) may be made using the specific composition of these fleets (that is, for example, EVR must be the number of e-buses on the road for that particular transit agency fleet). For both open and closed networks, the individual EV model's EV ratings (kwh/100 miles) must be used as applicable to the government rating agencies from which they have been sourced, (e.g. nationally for US; supra-nationally for EU), including in the periodic update of default values.

	Note again that if EVs are rated using slightly different variables such as kwh/100 km in Europe simple conversions must be made during validation. One common conversation from kwh/100km to kwh/100 miles is given below: kwh per 100 miles = kwh per 100km * 0.6215 Based upon conversion factors of: 100 km = 62.15 miles

Data / Parameter:	MPG_{iy}
Data unit	miles per gallon
Description	Weighted average miles per gallon rating for fossil fuel vehicles deemed comparable to each EV in applicable fleet *i* in project year *y*
Equations	1 and 3
Source of data	Derived in Equation 3
Value applied	<u>For LDV projects located in the US:</u> L1/L2 (BEV and PHEV average) = 29.18 DCFC (BEV average) = 29.10 <u>For HDV projects located in the US:</u> e-buses = 4.34 e-trucks = 8.60 <u>For LDV projects located in Canada:</u> L1/L2 (BEV and PHEV average) = 29.65 DCFC (BEV average) = 27.71
Justification of choice of data or description of measurement methods and procedures applied	US & Canada default values calculated in Appendix 1 For LDV projects, changes in the value of MPG_{iy} are very gradual over time given that a particular EV model's comparable fossil fuel vehicle rating must remain relatively steady for many years until the vehicle is significantly re-engineered. Thus for LDV projects, the default equivalent MPG's are taken from specific comparable vehicles (rather than classes of vehicles) whose MPG's are only likely to change with major model upgrades (and thus remain static for many years). For HDV projects, the class average MPG has been taken as the source data (see Appendix 1) so the discount rate IR_i of 0.99 must still apply. Default values for MPG_{iy} must be updated each 5 years with the activity method updates.

Purpose of Data	Calculation of baseline emissions
Comments	Consistent with guidance provided in AFEC above, weighted average is calculated for project year y based upon the number of EVs of each EV model type a in applicable fleet i on the road in project year *y* (EVR_{aiy}) combined with the mile per gallon ratings for each of these EV model's comparable fossil fuel vehicle ($MPG_{a,I,y}$). Calculations for comparable fleet's average MPG for open networks (where the exact EV models charging are not known) must be established using such data sources which must be compiled on a national basis (that is, for example, the number of BEV's of each model on the road in the US for open DCFC networks). Calculations for these fleet's MPG for closed networks (e.g. where the composition and operating characteristics of both the applicable and comparable fleets are known and documented, such as with transit agency e-bus fleets) may be made using the specific composition of these fleets (that is, for example, EVR must be the number of e-buses on the road for that particular transit agency fleet). For HDV closed networks, if the composition and operating characteristics of both the applicable and comparable fleets are known and documented (e.g. for transit agency EV charging infrastructure where the MPG's for the agency's own baseline bus operations can be established as the agency's comparable fleet of fossil fuel buses) using any of the CDM AMS-III.C Approach 1, Options 1 – 5, paragraphs 32 - 37. For both open and closed networks, the individual fossil fuel model's MPG ratings must be used as applicable to the government rating agencies from which they have been sourced (e.g., nationally for US; supra-nationally for EU), including in the periodic update of default values. MPG_{iy} is calculated annually unless the default values for baseline calculations for LDVs and/or HDVs is used following Equation 4, which employs the default value $DMPG_{iy}$. US & Canada default values calculated in Appendix 1. If standard emission values are provided using different parameters (such as CO_2/km as fossil fuel vehicle emission factors in Europe) conversions to given variable units will be made. One common conversation from liters per 100 km to miles per gallon is given below:

	MPG = 235.24 / liters per 100 km Based upon conversion factors of: 1 gall = 3.785 liters 100 km = 62.15 miles

Data / Parameter:	EV_{aiy}
Data unit	kwh/100 miles
Description	Electricity kwh consumption per 100 miles rating for EV model a within applicable fleet *i* in project year *y*
Equations	2
Source of data	Use values from credible national governmental sources such as the ratings for the US provided by US DoE Fuel Economy program[24].
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	National, governmental ratings provide independent third party public source.
Purpose of Data	Calculation of baseline emissions
Comments	See guidance for AFEC above. For both open and closed networks, the EV_{aiy} ratings must be used as applicable to the government rating agencies from which they have been sourced, e.g. nationally for US; supra-nationally for EU.

Data / Parameter:	EVR_{aiy}
Data unit	Cumulative number of EVs
Description	Total number of EV model *a* within applicable fleet *i* on the road by project year *y*
Equations	2 and 3
Source of data	Use values from credible national governmental sources such as the statistics provided for the US provided by the Argonne National Laboratory's monthly email updates[25]

[24] https://www.fueleconomy.gov/feg/evsbs.shtml
[25] Such as the *U.S. E-Drive vehicle monthly updates_February 2017* provided via email by ANL. The main ANL web link is found here including the email address for the database manager: https://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates
[25] https://www.fueleconomy.gov/feg/pdfs/guides/FEG2016.pdf

	Closed networks may also use the number of EV's on the road using their known composition and operating characteristics of the applicable fleets they serve.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Argonne National Laboratory is an independent, trusted government source of EV data for the US market.
Purpose of Data	Calculation of baseline emissions
Comments	This value is calculated for project year y based upon the cumulative number of EVs of each EV model type *a* in applicable fleet *i* on the road by project year *y*, consistent with AFEC guidance above. In the USA, statistics for the number of EVs on the road by model type is available from several sources including Argonne National Laboratory, in their monthly emails[26], which draws upon data from hybridcars.com[27].

Data / Parameter:	$MPG_{a,I,y}$
Data unit	miles/gallon
Description	Mile per gallon rating for fossil fuel vehicle model(s) deemed comparable to EV model a from applicable fleet *i* in project year *y*
Equations	3
Source of data	See guidance for MPG_{iy} above. Use values from credible national government sources such as the US rating found in the *2016 Fuel Economy Guide*[28] For both open and closed networks, the $MPG_{a,I,y}$ ratings must be used as applicable to the government rating agencies from which they have been sourced (e.g., nationally for US; supra-nationally for EU.)
Value applied	N/A

[26] See U.S. E-Drive vehicle monthly updates_February 2017 provided via email by ANL. https://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates
[27] Argonne National Lab's (ANL) monthly emails uses data sourced from the hybridcars.com web site: http://www.hybridcars.com/december-2016-dashboard/ The main ANL web link is found here including the email address for the database manager: https://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates
[28] https://www.fueleconomy.gov/feg/pdfs/guides/FEG2016.pdf

Justification of choice of data or description of measurement methods and procedures applied	National governmental ratings such as those found in the US Fuel Economy Guides for the US market are independent, trusted government sources of fuel consumption ratings.
Purpose of Data	Calculation of baseline emissions
Comments	If standard emission values are provided using parameters which already incorporate fuel emission factors such as CO_2/km ratings for fossil fuel vehicle emission factors in Europe then conversions to the appropriate combination of variables must be made to establish equivalence to the parameters in these equations. For example, in Europe, fossil fuel vehicle are rated in terms of CO_2 per km (given here as EFEU). Therefore, if the EV ratings are still given as kwh per 100 miles, then such a conversion would be: CO_2 per mile = $EF_{j,f,y}$ / $MPG_{a,l,y}$ = EFEU / 0.62.

Data / Parameter:	$ED_{i,y}$
Data unit	Kwh/year
Description	Quantity of electricity delivered to EV's by project chargers serving applicable fleet i in project year y
Equations	1
Source of data	kwh delivered to EV's for project charging network using systems' actual or estimated kwh values, as below. Note that for L2 chargers, the electricity delivered, ED, will be considered the same as electricity consumed by the chargers EC since L2's are highly efficient chargers with de minimis losses due to their own power consumption. (i.e. ED = EC) For DCFC, baseline emission calculations must use ED which must be based upon the kwh delivered to the EV's which is what the chargers' own internal smart DCFC's meter measure. (By contrast, for project emissions measurements which are based on the electricity consumed by the DCFC (where efficiency losses can be more material) kwh data can be sourced either A) from this ED provided that a DCFC efficiency factor is applied or B) from kwh data metered on the grid-side of the charging system and any associated AI. See EC, ECTOD, NEC and NECT parameter boxes below for PE applications.)
Value applied	Measured value based on kwh delivered by charging systems in year y

Description of measurement methods and procedures to be applied	The kwh delivered by the charging systems for each applicable fleet i must be sourced using the following hierarchy, where projects must apply first those listed highest on the list: 1) Actual kwh sourced using smart charger measurement systems or (for L2's only) on-site grid electricity meters 2) Estimates for a project's dumb network charger segments based upon the portions of the project which has available such smart network project averages or utility-style project user survey data applicable to these same segments (e.g. for each applicable fleet across comparable segments (public, workplace, residential etc)) 3) Investments to upgrade chargers to provide actual "smart" data results by installing technologies which effectively retrofit metering[29] 4) Use of reasonable regionally applicable pilot project data (such as local utility project results) for non-metered project chargers that don't have smart actual measurements when this pilot data reasonably corresponds to comparable utilization rates to those in the project 5) In the US, use of the Department of Energy/Idaho National Laboratory's (DoE/INL) EV Project data[30] to apply average kwh per charging event data which is provided across a) different settings (public, residential, non-private residential) and b) for each US state For #2 and 4, validator reviews must consider whether projects are applying "smart"/utility/pilot project data using an appropriate project segmentation basis, so that there is a reasonably comparable basis upon which chargers operate in the "dumb" and "smart" segments. This comparability provides a reasonable basis upon which to apply the representative smart segment averages to the corresponding dumb segments of the project. Use calibrated electricity meters/smart charging system measurement systems. Calibration must be conducted according to the equipment manufacturer's specifications.
Frequency of monitoring/recording	Measured actual data must be monitored and recorded on at least an annual basis; monitoring periods for metered data can be consistent with utility reports. Estimated consumption can be

[29] For example, EMotorWerks Juicebox
[30] https://avt.inl.gov/project-type/ev-project

	made on annual basis from sources which monitor using measured/actual or metered sources per the hierarchy above.
QA/QC procedures to be applied	The consistency of metered electricity consumption should be cross-checked with receipts from electricity purchases where applicable
Purpose of Data	Calculation of baseline emissions
Calculation method:	
Comments	N/A

Data / Parameter:	$EC_{i,y}$
Data unit	Kwh/year
Description	Quantity of electricity consumed by project chargers serving applicable fleet *i* in project year *y*
Equations	4
Source of data	kwh consumption for project charging network using systems' actual or estimated kwh values, as below Note that for L2 chargers, the electricity consumed EC will be considered the same as electricity delivered to the EV's by the chargers, ED, since L2's are highly efficient chargers with de minimis losses due to their own power consumption. (i.e. ED = EC) For DCFC, EC must be based upon the kwh consumed by the charging system (since efficiency losses can be more material for DCFC's). DCFC EC data can therefore either be sourced via: A) ED, the chargers' own internal smart DCFC's meter data, provided that a DCFC efficiency factor of 92.3% is applied to the smart charger metered data[31] or B) meters which are on the grid-side of the DCFC units/AI If a project can demonstrate to validators a more accurate efficiency factor for their particular DCFC systems (for example due to improvements in DCFC technology efficiencies over time) this updated accurate efficiency factor may be substituted for the 92.3% default efficiency value.
Value applied	Measured value based on kwh consumed by charging systems in year y For DCFC, using approach A, $EC_{i,y} = ED_{i,y}/0.923$

[31] The 92.3% DCFC efficiency factor is derived from Idaho National Lab powerpoint findings as reviewed with the VVB.

Description of measurement methods and procedures to be applied	The kwh consumed by the charging systems for each applicable fleet i must be sourced using the following hierarchy, where projects must apply first those listed highest on the list: 1) Actual kwh consumed using smart charger measurement systems or on-site electricity meters 2) Estimates for a project's dumb network charger segments based upon the portions of the project which has available such smart network project averages or utility-style project user survey data applicable to these same segments (e.g. for each applicable fleet across comparable segments (public, workplace, residential etc)) 3) Investments to upgrade chargers to provide actual "smart" data results by installing technologies which effectively retrofit metering[32] 4) Use of reasonable regionally applicable pilot project data (such as local utility project results) for non-metered project chargers that don't have smart actual measurements when this pilot data reasonably corresponds to comparable utilization rates to those in the project 5) In the US, use of the Department of Energy/Idaho National Laboratory's (DoE/INL) EV Project data[33] to apply average kwh per charging event data which is provided across a) different settings (public, residential, non-private residential) and b) for each US state For #7 and 9, validator reviews must consider whether projects are applying "smart"/utility/pilot project data using an appropriate project segmentation basis, so that there is a reasonably comparable basis upon which chargers operate in the "dumb" and "smart" segments. This comparability provides a reasonable basis upon which to apply the representative smart segment averages to the corresponding dumb segments of the project. Use calibrated electricity meters/smart charging system measurement systems. Calibration must be conducted according to the equipment manufacturer's specifications.
Frequency of monitoring/recording	Measured actual data must be monitored and recorded on at least an annual basis; monitoring periods for metered data can be consistent with utility reports. Estimated consumption can be made on annual basis from sources which monitoring using measured/actual or metered sources.

[32] For example, EMotorWerks Juicebox
[33] https://avt.inl.gov/project-type/ev-project

QA/QC procedures to be applied	The consistency of metered electricity consumption should be cross-checked with receipts from electricity purchases where applicable
Purpose of Data	Calculation of baseline and project emissions
Calculation method:	
Comments	N/A

Data / Parameter	$EFkw_{i,j,y}$
Data unit	tCO_2e/kwh
Description	Emission factor for the electricity sourced from region *j* consumed by project chargers serving applicable fleet *i* in year *y*
Equations	4
Source of data	Use credible government data sources such as, for the US, the regional eGRID emission factors published by EPA[34]
Description of measurement methods and procedures to be applied	The emission factor must be consistent with the region j from which electricity is sourced (e.g. for the US with the utility's eGRID region[35]). Published utility specific emission factors are allowed for the kwh consumed from that source consistent with VCS practices which allow well documented more local electricity sources' GHG emission factors to be applied. Average emission factors (not marginal) must be used Grid-sourced and dedicated renewable kwh is treated as having zero tCO2e/kwh. Biogenic sources used on-site to generate electricity are considered dedicated renewables. Other on-site biofuels used to generate electricity must apply and justify their own emission factors for the biofuel used, such as those referenced in the same EPA source from which the other fuel emission default factors (EF) were derived[36].
Frequency of monitoring/recording	Annual updates from these published sources
QA/QC procedures to be applied	
Purpose of data	Calculation of project emissions

[34] https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid
[35] https://www.epa.gov/sites/production/files/2017-02/documents/egrid2014_summarytables_v2.pdf
[36] https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf

Calculation method:	Look up value
Comments:	Region *j* represents any region from which electricity is sourced, each of which must have a well-documented emissions factor for the electricity provided. For US projects, electricity emissions must be estimated using the EPA regional eGRID emission rates, unless other more accurate local/regional sources are available (e.g. from utilities directly serving the charging network).

Data / Parameter	$ECTOD_{i,j,t,y}$
Data unit	Kwh/time period t
Description	Quantity of electricity consumed by project chargers sourced from region j serving applicable fleet i during time of day period t in project year y
Equations	5
Source of data	kwh consumption for project charging network using systems' actual values provided these are generated using time-of-day metering The same guidance provided for $EC_{i,y}$ relative to the sources of data for L2 and DCFC apply here. So L2 data can be sourced from kwh measured as delivered to EV's or consumed by the chargers since efficiency losses are de minimis. And DCFC data may either be sourced via A) DCFC's own internal smart meter systems, provided that a DCFC efficiency factor of 92.3% is applied; or B) meters which are on the grid-side of the DCFC units/AI. Thus again for DCFC, using approach A, the value applied would be $ECTOD_{i,j,t,y}/0.923$ If a project can demonstrate to validators a more accurate efficiency factor for their particular DCFC systems (for example due to improvements in DCFC technology efficiencies over time) this updated accurate efficiency factor may be substituted for the 92.3% default efficiency value.
Description of measurement methods and procedures to be applied	The kwh supplied by the charging systems applying time of day calculations in equation 6 must be sourced as follows: 1. Using actual time-of-day kwh measurements using smart charger measurement systems or on-site electricity meters, capable of recording/monitoring kwh consumption on at minimum an hourly basis

	3. Investments to upgrade chargers to provide such time-of-day actual data results are permitted provided they supply comparable hourly reporting Electricity meters' calibration must be conducted according to the equipment manufacturer's specifications.
Frequency of monitoring/recording	Data must be monitored continuously and recorded on at least an hourly basis.
QA/QC procedures to be applied	The consistency of metered electricity generation should be cross-checked with receipts from electricity purchases where applicable
Purpose of data	Calculation of project emissions
Calculation method:	
Comments:	The sum of all such time-of-day time periods, t, must equal 24 in any given full day within the project (i.e. there are no time periods in which electricity is provided but not accounted for within PEy). This is applicable only if PE emissions are to be calculated on a time-of-day basis.

Data / Parameter	$EFkwTOD_{j,j,t,y}$
Data unit	tCO_2e/kwh
Description	Emission factor for the electricity sourced from region j consumed by project chargers serving applicable fleet i during time of day period t in year y
Equations	5
Source of data	Use credible governmental or regional utility data sources such as, for the US, those published in the US by ISO's which rely upon utilities' hourly fuel consumption figures (e.g. see PJM publications[37]) Time of day estimates for electricity emission factors, $EFkw_{i,j,t,y}$ must be drawn from credible, applicable sources (e.g. the regional ISO or applicable utility generation sources).
Description of measurement methods and procedures to be applied	If $EFkwTOD_{j,j,y}$ has already been published by utilities in region j on an hourly basis, then these figures must be used. Since hourly EFkwTOD publications may not readily be available, if in region j utilities or ISOs are publishing time of day emission factors on a basis other than hourly, then projects may use this other basis provided it is accepted by validators as reasonable (for

[37] http://www.monitoringanalytics.com/data/marginal_fuel.shtml

	example PJM publishes on-peak and off-peak emission factors) in order to accommodate ISO/utility gradual improvements in best practices for time of day emission factor reporting[38]. If in region j, the ISO provides fuel consumption data on an hourly basis, $EFkwTOD_{j,j,y}$ may be estimated on a weighted average basis using equation 6 Grid-sourced and dedicated renewable kwh is treated as having zero tCO2e/kwh Biogenic sources used on-site to generate electricity are considered dedicated renewables. Other on-site biofuels used to generate electricity must apply and justify their own emission factors for the biofuel used, such as those referenced in the same EPA source from which the other fuel emission default factors (EF) were derived[39].
Frequency of monitoring/recording	Source data (for emission factor $EFkwTOD_{j,j,y}$) must be monitored continuously and recorded on at least an hourly or prevailing best practice basis.
QA/QC procedures to be applied	
Purpose of data	Calculation of project emissions
Calculation method:	If $EFkwTOD_{j,j,y}$ is estimated using hourly fuel consumption reports (e.g. from an ISO), the weighted average calculations are given in equation 6
Comments:	The sum of all such time-of-day time periods, t, must equal 24 in any given full day within the project (i.e. there are no time periods in which electricity is provided but not accounted for within PEy). This is applicable only if PE emissions are to be calculated on a time-of-day basis

Data / Parameter	$EFkwF_{j,j,t,f,\ y}$
Data unit	tCO_2e/kwh
Description	Emission factor applicable for the fuel type f used to generate the kwh during time of day period t sourced from region j consumed by project chargers serving applicable fleet i in year y
Equations	6

[38] There are no utility/ISO EFkw hourly published rates yet available (only fuel consumption rates) but as the PJM on-peak/off-peak publications indicate such TOD rates will become more accessible over time
[39] https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf

Source of data	Use credible governmental or regional utility data sources such as, for the US, those published in the US by ISO's which rely upon utilities' hourly fuel consumption figures (e.g. see PJM publications[40])
Description of measurement methods and procedures to be applied	If in region j, the ISO provides fuel consumption data on an hourly basis, $EFkwF_{j,j,t,f,y}$ may be estimated on a weighted average basis using equation 6 as follows: • Projects must combine the hourly fuel consumption figures (typically given as the percentage of each type of fuel consumed that hour (50% coal, 50% natural gas)) with the emission factors for these same fuels to create a weighted average emission rate for each hourly period. • Emission rates for each fuel must be drawn from the same (e.g. the ISO) or consistent publication sources for region j (noting that these need not be generated on an hourly basis but must be updated on at least an annual basis)
Frequency of monitoring/recording	Each fuel's emission rate need not be generated on an hourly basis but averages must be generated on at least an annual basis.
QA/QC procedures to be applied	
Purpose of data	Calculation of project emissions
Calculation method:	
Comments:	Applicable only if PE emissions are to be calculated on a time-of-day basis using utility/ISO hourly fuel consumption inputs

Data / Parameter	$F\%_{ijtfy}$
Data unit	%
Description	Percentage of fuel type f used to generate the kwh DURING EACH time of day period t, sourced from region j and consumed by project chargers serving applicable fleet I in year y
Equations	6
Source of data	Use credible governmental or regional utility data sources such as, for the US, those published in the US by ISO's which rely upon utilities' hourly fuel consumption figures (e.g. see PJM publications[41])

[40] http://www.monitoringanalytics.com/data/marginal_fuel.shtml
[41] http://www.monitoringanalytics.com/data/marginal_fuel.shtml

Description of measurement methods and procedures to be applied	The hourly fuel consumption figures are typically given as the percentage of each type of fuel consumed that hour (50% coal, 50% natural gas)).
Frequency of monitoring/recording	This fuel sourced parameter data must be monitored and recorded on at least an hourly basis. Since the emission factors for each fuel type f need not be generated on an hourly but can be supplied on an annual basis, the percentage of each fuel type f used to generate the kwh during each time period will be supplied for each such time period.
QA/QC procedures to be applied	Typically a look up value
Purpose of data	Calculation of project emissions
Calculation method:	
Comments:	Applicable only if PE emissions are to be calculated on a time-of-day basis using utility/ISO hourly fuel consumption inputs

Data / Parameter	$NEC_{i,j,s,y}$
Data unit	kwh/year
Description	Electricity consumed by project chargers supplied from associated infrastructure source s net of any kwh EV/charger returned to this same source within region j serving applicable fleet i in project year y
Equations	7
Source of data	Net kwh consumption/generation for project chargers must be secured for each associated infrastructure source (whether derived from the grid, dedicated renewables or the on-site battery) as actual net kwh values using chargers' adequate metering systems The same core guidance provided for $EC_{i,y}$ relative to the sources of data for L2 and DCFC apply here. So L2 data can be sourced from kwh measured as delivered to EV's by the charger meter or as the kwh consumed by the chargers from a grid-based source since losses are de minimis. And DCFC data may either be sourced via A) DCFC's own internal smart meter systems capable of differentiating the net kwh delivered to the EV's from each source s, provided that a DCFC efficiency factor of 92.3% is applied; or B) meters which are on the grid-side of the DCFC units/AI for each source s.

	Thus again for DCFC, using approach A, the value applied would be $NEC_{i,j,s,y}$ /0.923 If project can demonstrate to validators a more accurate efficiency factor for their particular DCFC systems (for example due to improvements in DCFC technology efficiencies over time) this updated accurate efficiency factor may be substituted for the 92.3% default efficiency value.
Description of measurement methods and procedures to be applied	Projects must track the net kwh consumption/generation for charging systems from across all potential associated infrastructure sources, s, (whether grid, dedicated renewable sources, on-site battery), net of kwh supplied back from the EV battery to such sources, using the charger's metering system to track such net kwh calculations. To apply equation 7, such net kwh values must be sourced as follows: 1) Using actual kwh consumption and generation measurements using on-site or smart chargers' metering systems, capable of recording/monitoring kwh both consumed and generated on at minimum a yearly basis 2) Investments to upgrade chargers to provide such net metered actual data results are permitted provided they supply comparable reporting Associated infrastructure sources, s, for which NEC is calculated include: • grid-connected electricity from region j • and/or dedicated renewable energy generated on-site (including RE sourced from direct transmission lines) • and/or the EV vehicle's on-board battery Each of the grid and renewables sources, s, must have a well-documented emissions factor for the electricity sourced and/or dispatched Project metering systems' calibration must be conducted according to the equipment manufacturer's specifications. Projects must incorporate adequate metering systems when applying Eq 7. Guidance for the design/application of such metering systems is provided in Appendix 2.
Frequency of monitoring/recording	Measured actual data must be monitored and recorded on at least an annual basis. Monitoring periods for metered net data can be consistent with reports which the charging systems' metering system provides.

QA/QC procedures to be applied	The consistency of net metered electricity generation should be cross-checked with receipts and invoices from electricity purchases and sales where applicable
Purpose of data	Calculation of project emissions
Calculation method:	
Comments:	The charging system's metering system must adequately and accurately measure and traces such electricity deliveries and receipts from these associated infrastructure sources, (including for example electricity sourced from/returned to the grid, on-site/dedicated renewables, on-site batteries, EV batteries). Applicable only if PE emissions are to be calculated on a net metered basis integrating multiple associated infrastructure sources, s. Note: time of day, hourly monitoring of EV charging/associated infrastructure deliveries and receipts is not a necessary requirement to apply Equation 7. For combined associated infrastructure metering and time of day PE estimates, see parameters for equation 9.

Data / Parameter	$EFkwAI_{i,,j,s,y}$
Data unit	(tCO_2e/kwh)
Description	Emission factor for the net electricity from each associated infrastructure source s within region j consumed by project chargers serving applicable fleet i in year y
Equations	7
Source of data	Each of associated infrastructure source, s, must have a well-documented emissions factor for the electricity it supplies and/or dispatches as follows: • Grid-connected electricity from region j must follow the same procedures as for parameter $EFkw_{i,j,y}$ in Equation 4 (see above) • Dedicated renewable energy generated on-site, including renewable energy sourced via direct transmission lines, must set emission factors at zero • On-site storage batteries must assume the weighted average emission factor based upon the proportionate net consumption of grid and dedicated renewable energy at the charging system (see equation 8)

Description of measurement methods and procedures to be applied	For grid-connected electricity, see procedures for parameter $EFkw_{i,j,y}$ in Equation 4 For dedicated renewables, emission factors are set at zero. For on-site storage batteries, the calculations are given in equation 8. Projects must incorporate adequate metering systems when applying Eq 7 and 8. Guidance for the design/application of such metering systems is provided in Appendix 2.
Frequency of monitoring/recording	Annual, per procedures for parameter $EFkw_{i,j,y}$ in Equation 4
QA/QC procedures to be applied	
Purpose of data	Calculation of project emissions
Calculation method:	For on-site batteries see equation 8
Comments:	Applicable only if PE emissions are to be calculated on a net metered basis integrating multiple associated infrastructure sources, s. Note: time of day, hourly monitoring of EV charging/associated infrastructure deliveries and receipts is not a necessary requirement to apply Equation 7. For combined associated infrastructure metering and time of day PE estimates, see parameters for equation 9.

Data / Parameter	$LEC_{j,,j,y}$
Data unit	kwh/year
Description	Electricity provided to the grid and/or building from on-site storage battery within region j serving applicable fleet i in project year y (kwh/year)
Equations	7
Source of data	From on-site battery/charging system's adequate measurement systems
Description of measurement methods and procedures to be applied	LEC arises if on-site batteries provide kwh back to the grid or local building (for example if used as back up generators/sources of power). These kwh are not supplied to the EV charging system

	and do not result in EV miles drive and so are deducted out in Eq 7. Projects must incorporate adequate metering systems when applying Eq 7. Guidance for the design/application of such metering systems is provided in Appendix 2. Project metering systems' calibration must be conducted according to the equipment manufacturer's specifications.
Frequency of monitoring/recording	Measured actual data must be monitored and recorded on at least an annual basis.
QA/QC procedures to be applied	The consistency of such kwh should be cross-checked with other information sources where applicable
Purpose of data	Calculation of project emissions
Calculation method:	
Comments:	Applicable only if PE emissions are to be calculated on a net metered basis integrating multiple associated infrastructure sources, s. Note: time of day, hourly monitoring of EV charging/associated infrastructure deliveries and receipts is not a necessary requirement to apply Equation 7. For combined associated infrastructure metering and time of day PE estimates, see parameters for equation 9.

Data / Parameter	$EFkwonsitebatt_{i,j,s,y}$
Data unit	(tCO_2e/kwh)
Description	Emission factor for the electricity from the on-site batteries as associated infrastructure sources s within region j consumed by project chargers serving applicable fleet i in year y
Equations	8
Source of data	See data sources for Equation 8 variables below
Description of measurement methods and procedures to be applied	The emission factors for the on-site battery as an associated infrastructure source are calculated using the net weighted average of the grid and on-site renewable emission factors given using equation 8 • On-site storage batteries must assume the weighted average emission factor based upon the proportionate net consumption of grid and dedicated renewable energy at the charging system (using equation 8)

	Projects must incorporate adequate metering systems when applying Eq 8. Guidance for the design/application of such metering systems is provided in Appendix 2.
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	As for equation 8 variables below
Purpose of data	Calculation of project emissions
Calculation method:	
Comments:	Applicable only if PE emissions are to be calculated on a metered basis integrating multiple associated infrastructure sources, s.

Data / Parameter	$ECB_{i,j,z,y}$
Data unit	kwh/year
Description	Electricity consumed by on-site battery from associated infrastructure sources z, which comprise only the grid-connected and dedicated renewable sources, within region j serving applicable fleet i in project year y
Equations	8
Source of data	As for $NEC_{i,j,s,y}$ in equation 7
Description of measurement methods and procedures to be applied	As for $NEC_{i,j,s,y}$ in equation 7 Projects must incorporate adequate metering systems when applying Eq 8. Guidance for the design/application of such metering systems is provided in Appendix 2. In particular, metering systems must need to measure the kwh delivered to the onsite battery from grid and/or renewable sources as distinct from those delivered directly to the EV charger from the grid and/or dedicated renewable sources
Frequency of monitoring/recording	As for $NEC_{i,j,s,y}$ in equation 7
QA/QC procedures to be applied	
Purpose of data	Calculation of project emissions
Calculation method:	As for $NEC_{i,j,s,y}$ in equation 7
Comments:	Applicable only if PE emissions are to be calculated on a metered basis integrating multiple associated infrastructure sources, s,

	when these sources are grid-connected electricity and dedicated renewable energy.

Data / Parameter	$EFkwAI\text{-}Z_{j,,j,z,y}$
Data unit	(tCO_2e/kwh)
Description	Emission factor for the electricity from the associated infrastructure sources, z, which comprise only the grid-connected and dedicated renewable sources, within region j consumed by on site battery serving applicable fleet i in year y
Equations	8
Source of data	As for $EFkwAI_{j,,j,s,y}$ for grid connected and renewable energy in equation 7
Description of measurement methods and procedures to be applied	As for $EFkwAI_{j,,j,s,y}$ for grid connected and renewable energy in equation 7 Projects must incorporate adequate metering systems when applying Eq 8. Guidance for the design/application of such metering systems is provided in Appendix 2.
Frequency of monitoring/recording	As for $EFkwAI_{j,,j,s,y}$ for grid connected and renewable energy in equation 7
QA/QC procedures to be applied	
Purpose of data	Calculation of project emissions
Calculation method:	As for $EFkwAI_{j,,j,s,y}$ for grid connected and renewable energy in equation 7
Comments:	Applicable only if PE emissions are to be calculated on a metered basis integrating multiple associated infrastructure sources, s, when these sources are grid-connected electricity and dedicated renewable energy.

Data / Parameter	$NECT_{i,j,s,t,y}$
Data unit	Kwh/time period t
Description	Electricity consumed by project chargers supplied from associated infrastructure source s net of any kwh EV/charger returned to this same source during time-of-day period t, within region j serving applicable fleet i in project year y
Equations	9

Source of data	Net electricity consumed by project chargers during time-of-day period t from associated infrastructure sources s, within region j serving applicable fleet i in project year y The same core guidance provided for $EC_{i,y}$ relative to the sources of data for L2 and DCFC apply here. So L2 data can be sourced from kwh measured as delivered to EV's by the charger meter or as the kwh consumed by the chargers from a grid-based source since losses are de minimis. And DCFC data may either be sourced via A) DCFC's own internal smart meter systems capable of differentiating the net kwh delivered to the EV's from each source s during time period t, provided that a DCFC efficiency factor of 92.3% is applied; or B) meters which are on the grid-side of the DCFC units/AI for each source s and time period t. Thus again for DCFC, using approach A, the value applied would be $NECT_{i,j,s,t,y}$ /0.923 If a project can demonstrate to validators a more accurate efficiency factor for their particular DCFC systems (for example due to improvements in DCFC technology efficiencies over time) this updated accurate efficiency factor may be substituted for the 92.3% default efficiency value.
Description of measurement methods and procedures to be applied	Follow those for parameters $EC_{i,j,t,y}$ in equation 5 and $NEC_{i,j,s,y}$ in equation 7 Projects must incorporate adequate metering systems when applying Eq 9. Guidance for the design/application of such metering systems, considered as applied to each time period t, is provided in Appendix 2. In addition, for time of day applications of associated infrastructure calculations pertaining to the NECT for an on-site battery's kwh delivered to the EV charger, metering must be applied "upstream", on the grid-side of the on-site battery. That is for the calculation of NECT for an on-site battery, Eq 9 must, using upstream meters, calculate the kwh delivered to EV chargers via the on-site battery from grid and/or dedicated renewable sources during the time of day period t taking into account *when* these kwh are actually delivered *to the on-site battery* (not when delivered from this battery to the EV charger) since the GHG impacts for these kwh arise on the grid system when they are first delivered into this associated infrastructure system (that is are delivered to the on site battery) For these applications, kwh supplied by the EV to the on-site battery can be set aside (since they return to the EV at a later

	date) unless, during a given time period t, the LEC less the kwh received by the on site battery from grid and renewable sources less the on-site battery's stored kwh is greater than zero – that is LEC is so large that it must have drawn upon the kwh delivered to the on-site battery from the EV In the context of these NECT calculations for the on-site battery, it should be noted that the kwh supplied from the grid to the EV charging system directly – and those kwh supplied by the EV back to the grid – during any time period t are still considered separately in the calculation of NECT for the grid.
Frequency of monitoring/recording	Follow those for parameters $EC_{i,j,t,y}$ in equation 5 and $NEC_{i,j,s,y}$ in equation 7
QA/QC procedures to be applied	Follow those for parameters $EC_{i,j,t,y}$ in equation 5 and $NEC_{i,j,s,y}$ in equation 7
Purpose of data	Calculation of project emissions
Calculation method:	
Comments:	Follow those for parameters $EC_{i,j,t,y}$ in equation 5 and $NEC_{i,j,s,y}$ in equation 7 Applicable only if PE emissions are to be calculated on a time-of-day basis when also incorporating charging systems' associated infrastructure sources on a metered basis.

Data / Parameter	$EFkwTOD\text{-}AI_{i,j,s,t,y}$
Data unit	tCO_2e/kwh
Description	Emission factor for the electricity from associated infrastructure source s within region j consumed by project chargers serving applicable fleet i during time-of-day period t in year y
Equations	9
Source of data	Follow those for parameters $EFkwTOD_{j,,j,t,y}$ in equation 5 and $EFkwAI_{j,,j,s,y}$ in equation 7
Description of measurement methods and procedures to be applied	Follow those for parameters $EFkwTOD_{j,,j,t,y}$ in equation 5 and $EFkwAI_{j,,j,s,y}$ in equation 7 Projects must incorporate adequate metering systems when applying Eq 9. Guidance for the design/application of such metering systems, considered as applied to each time period t, is provided in Appendix 2.

Frequency of monitoring/recording	Follow those for parameters $EFkwTOD_{j,,j,t,y}$ in equation 5 and $EFkwAI_{j,,j,s,y}$ in equation 7
QA/QC procedures to be applied	
Purpose of data	Calculation of project emissions
Calculation method:	Follow those for parameters $EFkwTOD_{j,,j,t,y}$ in equation 5 and $EFkwAI_{j,,j,s,y}$ in equation 8
Comments:	Follow those for parameters $EFkwTOD_{j,,j,t,y}$ in equation 5 and $EFkwAI_{j,,j,s,y}$ in equation 8 Applicable only if PE emissions are to be calculated on a time-of-day basis when also incorporating charging systems' associated infrastructure sources on a net metered basis.

Data / Parameter	$LECT_{j,,j,t,\ y}$
Data unit	kwh/time period *t*
Description	Electricity provided to the grid and/or building from on-site storage battery during time-of-day period t within region j serving applicable fleet i in project year y (kwh/year)
Equations	9
Source of data	From on-site battery/charging system's adequate measurement systems
Description of measurement methods and procedures to be applied	Project metering systems' calibration must be conducted according to the equipment manufacturer's specifications. Projects must incorporate adequate metering systems when applying Eq 9. Guidance for the design/application of such metering systems, considered as applied to each time period t, is provided in Appendix 2.
Frequency of monitoring/recording	Measured actual data must be monitored and recorded on at least an annual basis.
QA/QC procedures to be applied	The consistency of such kwh should be cross-checked with other information sources where applicable
Purpose of data	Calculation of project emissions
Calculation method:	
Comments:	Applicable only if PE emissions are to be calculated on a net metered basis integrating multiple associated infrastructure sources, s.

Data / Parameter	$EFkwTODonsitebatt_{i,j,s,t,y}$
Data unit	tCO_2e/kwh
Description	Emission factor for the electricity from the on-site battery during time-of-day period t (both on-site infrastructure and EV on-board batteries) associated infrastructure source s within region j consumed by project chargers serving applicable fleet i in year y
Equations	9
Source of data	See data sources for Equation 8 variables above
Description of measurement methods and procedures to be applied	The emission factors for one associated infrastructure source -- for the on-site battery -- are calculated using the net weighted average of the grid and on-site renewable emission factors given using equation 8, but this time applied for each time-of-day period t On-site storage battery must assume the weighted average emission factor based upon the proportionate net consumption of grid and dedicated renewable energy at the charging system (using equation 9 applied during each time of day period basis) Projects must incorporate adequate metering systems when applying Eq 9. Guidance for the design/application of such metering systems, considered as applied to each time period t, is provided in Appendix 2.
Frequency of monitoring/recording	Consistent with the practices applied for monitoring the $EFkwTOD\text{-}AI_{i,j,s,t,y}$ in equation 9
QA/QC procedures to be applied	As for equation 8 variables
Purpose of data	Calculation of project emissions
Calculation method:	
Comments:	Applicable only if PE emissions are to be calculated on a metered basis integrating multiple associated infrastructure sources, s, on a time-of-day basis.

Data / Parameter	D_y
Data unit	%
Description	Discount factor to be applied in year y
Equations	10 and 11
Source of data	See data sources for data parameters in equation 13

Description of measurement methods and procedures to be applied	Discount factor applied if GHG credits have been issued in the project region for GHG credits issued for projects that introduce EV fleets (e.g. using the CDM AMS-III.C EV fleet methodology)
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	
Purpose of data	Calculation of emission reductions
Calculation method:	Look up value
Comments:	If there are no GHG credits issued for projects that introduce EV fleets in the project region, D_y must be 1 (ie there is no discount applied). Private networks can also demonstrate that D = 1 if there is no access to chargers beyond a defined set of EV's for which it can be demonstrated that no GHG credits from projects that introduce EV fleets have been issued. See guidance in section 8.4 regarding open and closed networks. If GHG credits have been issued for projects that introduce EV fleets for a region larger than the proposed EV charging project (e.g. the project introducing EVs is US-wide while the EV charging system project is confined to one state), then a sensible pro-rata share of the GHG credits issued to projects that introduce EV fleets can be made (e.g. using the pro-rata number of EV's on the road in the EV charging system project state compared to the total in the US, using sources such as ZEVFacts.com).

Data / Parameter	ERC_y
Data unit	tCO_2e
Description	Sum of GHG credits issued by all projects under this methodology (or others which support the introduction of EV charging systems) across this project's applicable fleet *i* categories within this total project region in project year y-1
Equations	11
Source of data	VCS (and other voluntary and regulated credit registries if they develop similar EV charging system methodologies), with GHG credits issued from EV charging system projects within this same project's region (e.g. for complementary charging networks)

Description of measurement methods and procedures to be applied	Simple tallies of the total GHG credits issued from EV charging system project year 1 through year y-1 within this project's region These GHG credits include those issued under this VCS charging system methodology (or similar ones developed by other certification groups) whose credits arise within the same region as this project but cover credits issued from complementary charging network systems (e.g. workplace chargers from a complementary project located in the same region as this project's residential chargers).
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	
Purpose of data	Calculation of emission reductions
Calculation method:	Look up values
Comments:	N/A

Data / Parameter	ERF_y
Data unit	tCO_2e
Description	Sum of GHG credits issued by all projects under methodologies which support the introduction of EV fleets (e.g., CDM AMS.III.C) within this project's same total region where the applicable fleet *i* categories are the same for both this EV charging system project and projects introducing EV fleets, in project year y-1
Equations	11
Source of data	VCS and other voluntary and regulated credit registries, with GHG credits issued from projects that introduce EV fleets within the project region
Description of measurement methods and procedures to be applied	Simple tallies of the total GHG credits issued for projects that introduce EV fleets within this project's region from project year 1 through year y-1 These GHG credits are those issued under EV fleet methodologies such as CDM AMS-III.C whose credit potentially double count with those issued through EV charging system projects where the applicable fleet of the EV charging system project include those that were introduced in the EV fleet project
Frequency of monitoring/recording	Annual

QA/QC procedures to be applied	
Purpose of data	Calculation of emission reductions
Calculation method:	
Comments:	If GHG credits have been issued projects introducing EV fleets for a region larger than the proposed EV charging system project (e.g. the project introducing EVs s US-wide while the EV charging system project is confined to one state), then a sensible pro-rata share of the GHG credits issued to the project that introduced EV fleets can be made (e.g. using the pro-rata number of EV's on the road in the EV charging system project state compared to the total in the US, using sources such as ZEVFacts.com).

9.3 Description of the Monitoring Plan

The project proponent must establish, maintain and apply a monitoring plan and GHG information system that includes criteria and procedures for obtaining, recording, compiling and analyzing data, parameters and other information important for quantifying and reporting GHG emissions.

All data collected as part of monitoring should be archived electronically and be kept at least for two years after the end of the last project crediting period. All data must be monitored unless indicated otherwise in the tables above.

Project reporting must include the following information for EV charging systems included in a project:

For activities monitored once up-front during project validation or as new project activity instances are admitted to a grouped project during verification:

1) Inventory and geographic location for each EV charging system included in the project.
2) Where EV charging systems' AI is utilized to provide electricity to EVs, in order to store and dispatch electricity to and from multiple sources, both on site and regionally, the monitoring plan must include plans for how data will be processed from the AI's metering systems (e.g., meters/sub-meters and/or associated measurement systems). Guidance for such metering is provided in Appendix 2.
3) Review of any previously issued VCUs for EV charging projects to verify that there is no overlap of ownership with chargers included in the project description, for example, using the unique EV charging identifiers supplied in the project description's EV charging system inventory. For grouped projects, such verification must apply to any new project activity instances and for new chargers subsequently added to the grouped project (e.g.,

by referencing the unique EV charging identifiers for these new project activity instances in project monitoring reports).

4) Review of any previously issued EV fleet credits to confirm the value established for the discount factor, *Dy*.

For activities monitored each year during verification for credit issuance:

1) Data on electricity consumption consistent with guidance provided in the parameter boxes above for each EV charger, which must be reported in a consistent manner with supporting data, such as invoices or utility or on site meter records. Where projects include LDV and HDV applicable fleets, electricity consumption must be monitored separately.

2) Supporting documentation used to determine parameters for use in quantification of annual baseline emissions if default factors (per Appendix 1) are not used.

The project proponent must establish and apply quality management procedures to manage data and information. Written procedures must be established for each measurement task outlining responsibility, timing and record location requirements. Record keeping practices must include:

- Electronic recording of values of logged parameters for each monitoring period
- Offsite electronic back-up of all logged data
- Maintenance of all documents and records in a secure and retrievable manner for at least two years after the end of the project crediting period.

Quality assurance/quality control procedures must also be applied to add confidence that all measurements and calculations have been made correctly. These may include, but are not limited to:

- Protecting monitoring equipment (sealed meters and data loggers)
- Protecting records of monitored data (hard copy and electronic storage)
- Checking data integrity on a regular and periodic basis (manual assessment, comparing redundant metered data, and detection of outstanding data/records)
- Comparing current estimates with previous estimates to identify any abnormal readings
- Providing sufficient training to project participants to install and maintain project devices
- Establishing minimum experience and requirements for operators in charge of project and monitoring
- Performing recalculations to make sure no mathematical errors have been made

10 REFERENCES

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APPENDIX 1: CALCULATION OF BASELINE DEFAULT VALUES FOR THE US AND CANADA

This appendix outlines the basis for the calculation of the optional default values used in the baseline emission calculations for U.S. LDV and HDV projects, and Canadian HDV projects. Values used to calculate the default value results were presented to the VVB via a separate Excel workbook during the approval process of the methodology.

Projects must apply the default value using units for EF (CO_2 or CO_2e) consistent with their project boundary choices, consistent across all project activity sources.

LDV Weighted Averages in the United States

Weighted averages for LDVs are based upon:

- The total number of each BEV and PHEV model on the road by end of 2015, based upon cumulative US sales data for 2010-2015 sourced from Argonne National Laboratories' monthly emails and web site[42]
- Kwh/100 mile and MPG ratings sourced from www.fueleconomy.gov or the 2016 Fuel Economy Guide, https://www.fueleconomy.gov/feg/pdfs/guides/FEG2016.pdf
- Gasoline was the fuel which the comparable fossil fuel cars consumed

The simple weighted average has been calculated for each applicable fleet (BEV+PHEV and BEV) based upon the number of EV models of each type on the road by end of 2015 multiplied by its corresponding kwh/100 mile value (AFEC) and equivalent fossil fuel vehicle's MPG value (MPG), which are listed in the table below.

Table A1: LDV Project Default Value Table

Applicable fleet	$AFEC_{iy}$	MPG_{jy}	EF_{jy}
L1/L2 (BEV and PHEV average)	33.32	29.18	19.56 lbs CO2/gal = 0.0088 tCO2/gal or 0.0088 tCO_2e/gal
DCFC (BEV average)	31.88	29.10	19.56 lbs CO2/gal = 0.0088 tCO2e/gal or 0.0088 tCO_2e/gal

HDV Weighted Averages in the United States

Each of these e-bus and e-truck weighted averages are based upon:

- The total number of each e-bus and e-truck models on the road in the US by beginning of 2017, based upon on data sourced from IHS Markit

[42] Argonne National Lab's (ANL) monthly emails uses data sourced from the hybridcars.com web site: http://www.hybridcars.com/december-2016-dashboard/ The main ANL web link is found here including the email address for the database manager: https://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates

- The corresponding GWV classification for each model of e-bus and e-truck on the road, based upon data sourced from IHS Markit
- Kwh/mile data sourced for e-buses from commercial sources (confidential) and for e-trucks from Smith Electric and NREL reports for e-delivery truck vehicles as follows:
    - http://insideevs.com/smith-electric-vehicles-distance-energy-consumption/
    - http://www.nrel.gov/docs/fy17osti/66382.pdf
- Average MPG ratings for the corresponding class of MDV/HDV, as sourced from independent academic sources, specifically: https://www.nap.edu/read/12845/chapter/4#18
- Diesel fuel was the dominant baseline bus and truck fuel

The simple weighted average is calculated for each applicable fleet (e-bus and e-truck) based upon the number of EV models of each type on the road by beginning of 2017 multiplied by its corresponding kwh/100 mile value (AFEC) and equivalent GWV class of fossil fuel vehicle's average MPG value (MPG), which are listed in the table below.

Table A2: HDV Project Default Value Table

Applicable fleet	$AFEC_{iy}$	MPG_{jy}	EF_{jy}
e-buses	300	4.34	22.4 lbs CO2/gal = 0.0102 tCO2/gal or 0.0102 tCO_2e/gal
e-trucks	140	8.60	22.4 lbs CO2/gal = 0.0102 tCO2e/gal or 0.0102 tCO_2e/gal

LDV Weighted Averages in Canada

These weighted averages are based upon:

- The total number of each BEV and PHEV model on the road by end of 2016, based upon cumulative Canada data; kwh/100 mile and MPG ratings, all sourced from Natural Resources Canada
- Gasoline was the fuel which the comparable fossil fuel cars consumed

The simple weighted average has been calculated for each applicable fleet (BEV+PHEV and BEV) based upon the number of EV models of each type on the road by beginning of 2017 multiplied by its corresponding kwh/100 mile value (AFEC) and equivalent fossil fuel vehicle's MPG value (MPG), which are listed in the table below.

Table A3: LDV Project Default Value Table for Canada

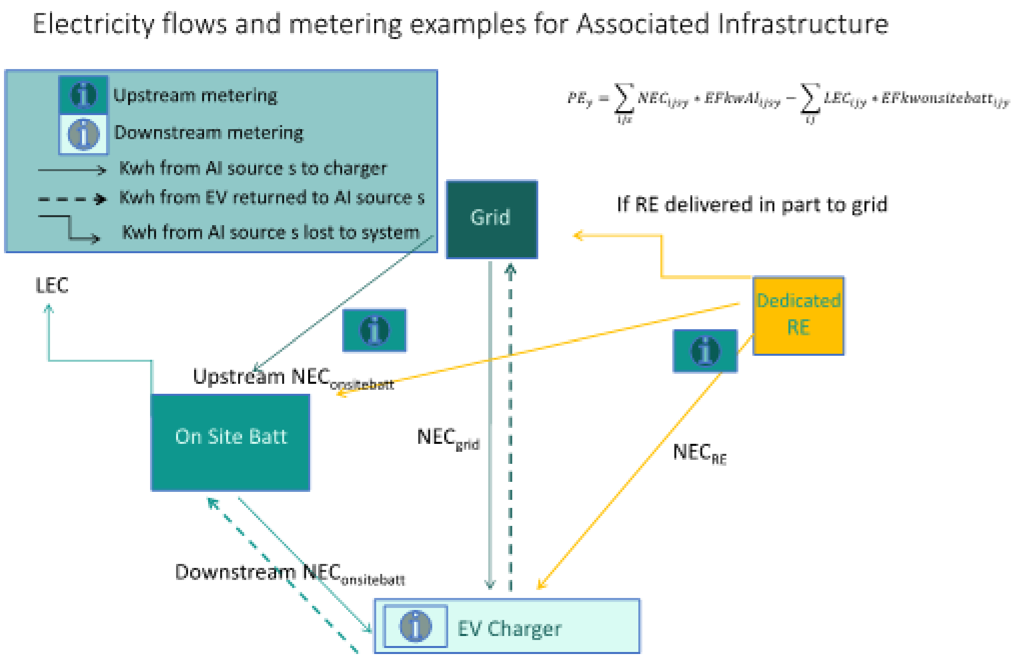
Applicable fleet	$AFEC_{iy}$	MPG_{jy}	EF_{jy}
L1/L2 (BEV and PHEV average)	35.44	29.65	19.56 lbs CO_2/gal = 0.0088 tCO_2/gal or 0.0088 tCO_2e/gal

DCFC (BEV average)	33.00	27.71	19.56 lbs CO_2/ga = 0.0088 tCO_2/gall or 0.0088 tCO_2e/gal

APPENDIX 2: GUIDANCE FOR DESIGN OF ADEQUATE METERING SYSTEMS FOR AI PROJECTS

This appendix outlines guidance for the design and application of metering systems of charging systems to adequately measure electricity exchanges when associated infrastructure (AI) is incorporated into projects when they apply to the determination of project emissions, as shown in Figure A1. If associated infrastructure is incorporated into the project boundary, PE equations 7, 8, or 9 are applicable.

Figure A1: Examples of Associated Infrastructure and Electricity Flows



When incorporating associated infrastructure, the charging system's metering system must adequately and accurately measure and trace the net electricity kwh provided to the charging system (i.e., deliveries minus receipts) from all electricity sourced from and returned to the grid, and the dedicated renewables. This may include dedicated renewable energy (e.g., on site) delivered to the EV directly and/or via on-site batteries, and net of kwh returned back to such sources from the EV batteries.

Note that metering systems for associated infrastructure can include "downstream" meters close to the EV, such as those provided by DCFC onboard meters (and referenced specifically in the ED parameter for kwh *delivered* by a charger to the EV which applies to the BE calculations), and "upstream" meters, located grid-side such as meters monitoring electricity (in kwh) delivered to the on-site batteries (which could be designed/applied to measure the kwh which a charger *consumes* in the EC parameter measurements which applies to the PE calculations).

Where the system's meters are located further "upstream", in order to not include any electricity lost to the EV charging system, any electricity sourced from associated infrastructure sources (notably from solar and the on-site battery) but delivered outside the EV charging system (e.g. delivered to the grid or the local building when the on-site battery is used as a back up generator source), must be sensibly taken into account for quantification. This includes the following examples:

1) Where the metered kwh to the on-site battery is located “upstream” on the grid side (rather than downstream of the on-site battery in the charger where electricity delivered to the EV is measured), any electricity that the on-site battery provides back to the grid, or its building in a given year must be measured and subtracted -- as LEC_{ijy} -- since these kwh represent losses to the overall charging system and do not result in EV miles driven.

2) Where the on-site battery is not connected to the grid or building (i.e., it does not serve as a power back up system), then the on-site battery does not need to be accounted for as a separate source, since it merely acts as a flow through for the grid and renewables sources. Any electricity received from the EV would also be returned to the EV. Therefore, the on-site battery would supply electricity consistent with the change in stored power between the year’s starting and end points which, compared to the kwh supplied by the grid and/or dedicated renewables, would be *de minimis*.

3) Any transfer of electricity from the EV to the onsite battery represent internal flows within the system and can be set aside since the electricity must either be returned downstream to the EV at a later date or tracked via LEC if subsequently delivered back to the grid via the on-site battery. Therefore, transfers of electricity from the EV to the onsite battery can be set aside.

4) Projects must be able to measure or sensibly estimate the electricity supplied from the grid and/or from dedicated renewable sources to the charger system and this may be a subset of the total electricity from this source. For example, the electricity delivered to the charging system may be less than the total electricity generated by the onsite renewables if these renewables also provide power back to the grid within a particular associated infrastructure system[43]. Similarly, the total grid electricity delivered to the system may be shared across both the EV charger if delivered directly while also supplying in parallel electricity to the on-site battery – the former contributing to NEC from the grid source and latter to NEC for the on-site battery.

Where the systems meters are located “downstream”, in order to not include any electricity lost to the EV charging system, any electricity sourced from associated infrastructure sources must be sensibly taken into account for quantification. This includes the following examples:

1) Although upstream-metering, (the measurement of kwh consumed by the chargers for parameter EC), typically applies for the PE calculations, the calculation of PE values can be made using downstream meters located in the chargers’ internal systems provided appropriate efficiency factors are applied to take account of chargers’ own electricity consumption. Where downstream measurement of PE is applied:

    - For PE calculations using downstream metering, consistent with the guidance in the parameter boxes for EC, ECTOD, NEC and NECT, efficiency factors must be applied to

[43] At a future date, projects may wish to consider issuing GHG credits for the subset of kwh delivered from the dedicated renewables to the grid (but not to the EV charger) using methodologies such as AMS-I.F https://cdm.unfccc.int/methodologies/DB/9KJWQ1G0WEG6LKHX21MLPS8BQR7242

account for potential efficiency losses due to the chargers' own kwh consumption. For L2s, such efficiency losses are de minimis[44] and so no efficiency factor is applied in the L2 EC, ECTOD, NEC and NECT parameter applications (since "downstream" meters would have de minimis variances with upstream meters). For DCFCs, if kwh data is sourced from "downstream" meters located within their own DCFCs internal smart meter systems (assuming as needed across these parameters that these smart meters are capable of differentiating inter alia the net kwh delivered to the EV's from each source s during time period t), then to establish the PE equation electricity *consumed* by the DCFC charger a DCFC default efficiency factor of 92.3% is applied to these internal smart DCFC metered kwh readings (i.e., using approach A in the parameter boxes)).

- Alternatively, DCFCs can use approach B applying "upstream" meter kwh measurements which are on the grid-side of the DCFC units/AI (e.g., for each source s and time period t).
- However, often relative to time-of-day periods *t* for NECT and ECTOD measurements, it is a DCFC's own "downstream" internal "smart" meters which have the most sophisticated metering capabilities for such time-of-day applications (whereupon approach A would be followed and the DCFC default efficiency factor applied).
- For DCFC using approach A, the default efficiency value applied would be the "downstream" smart meter's reading divided by the efficiency factor of 0.923 in order to estimate the kwh consumed by the DCFC fast charger on an "upstream kwh consumed" basis (as needed for the PE equations).
- If a project can demonstrate a more accurate efficiency factor for their particular DCFC systems (for example due to improvements in DCFC technology efficiencies over time), this updated accurate efficiency factor may be substituted for the 92.3% default efficiency value.

2) Where meters are located downstream for the measurement of NEC pertaining to the on-site battery, then the electricity measured must already be net of any LEC losses from the on-site battery to the grid – and thus LEC must be set at zero. This basis for such on-site battery net electricity measurements would be consistent with DCFC's measurement systems which track the electricity exchanges close the point of delivery to the EV. Additionally, for downstream metering, the electricity provided by the EV to the onsite battery must be measured for the calculation of NEC for the on-site battery (that is, it cannot be set aside for downstream metering).
3) Where the EV is delivering vehicle-to-grid (V2G) services where electricity from the car's on-board battery is returned directly to the grid, these EV-sourced electricity are netted out in the grid-sourced net-kwh (that is, in the calculation of NEC for the grid source *s*).
4) Where charging systems include simple associated infrastructure settings, such as residences using L1/L2 systems where "upstream" metering systems apply and where the associated infrastructure system elements can be limited (e.g. no on-site battery).

Note that the quantification of emissions from project associated infrastructure systems can be simplified using sensible estimates. For example, where a household residence has a solar panel

[44] Per INL: https://avt.inl.gov/evse-type/ac-level-2

that is grid-connected – which, while its total solar kwh production and grid-sales are metered, does not have a separate sub-meter to establish the solar kwh supplied to the EV charging system specifically -- it is acceptable to assume that the kwh delivered to the EV charger is the same weighted average as the solar/grid kwh mix the household itself consumed (i.e., sources whose electricity would have been separately metered). Utility-style modeling is also acceptable for settings where only the net electricity consumption/generation is measured for a household in order to establish the electricity delivered by both the grid and the on-site renewables and thus the required weighted average.

VCS Methodology

VM0039

Methodology for Use of Foam Stabilized Base and Emulsion Asphalt Mixtures in Pavement Application

Version 1.0

24 June 2019

Sectoral Scope 6

This methodology was developed by the Smart Construction Center at the University of Maryland, in collaboration with Emissionairy, Inc., Chamberlain Contractors, Inc., and Straughan Environmental, Inc.

Authors:

Qingbin Cui, Associate Professor (cui@umd.edu, +1 301 405 8104)

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1 SUMMARY DESCRIPTION OF THE METHODOLOGY

Additionality and Crediting Method	
Additionality	Performance Method
Crediting Baseline	Performance Method

This methodology provides a framework for the quantification of greenhouse gas (GHG) emission reductions associated with the production and installation of Foam Stabilized Base (FSB) and/or asphalt emulsions as substitutes for Hot Mix Asphalt (HMA) in road construction projects located in the United States[1].

For over 40 years, FSB and asphalt emulsions have been used in road projects around the world when natural resources for virgin aggregate or funding to construct and maintain roads using HMA have been limited. In North America, where virgin aggregate has historically been easily accessible within proximity to project sites, FSB has not been as widely implemented as it has in other parts of the world. FSB has, therefore, been used on a very limited basis in the United States for the last 10 to 15 years. Most projects using FSB and asphalt emulsions in the United States are pilot projects funded by various state highway agencies. While these projects have proven successful, state highway administrations have been slow to accept and develop the protocol and practices for this approach in North America. Presently there are no national or regional standards for the production or application of FSB and asphalt emulsions, which serves as a major impediment to the acceptance and application of FSB and asphalt emulsions beyond the testing phase.

GHG emission reductions are generated from producing and applying FSB and asphalt emulsions versus HMA as follows:

- FSB and asphalt emulsions consist of 50% less liquid asphalt/bitumen by weight and 2.5% less asphalt/bitumen by volume than required for HMA production, reducing the reliance on resources. No virgin aggregates are required, eliminating the energy and resources needed for excavating machines and trucking. In most applications, but especially in rural areas, the GHG emissions from trucking are significantly reduced. This is due to the fact that FSB and asphalt emulsions can be manufactured on or close to the project site.
- Aggregates in FSB and asphalt emulsions do not have to be heated, while HMA liquid, which is roughly 2.2% of the total weight of the mix, needs to be heated up to 310 ºF.

[1] Under this methodology, the project proponent may be the technology owner, FSB producer/manufacturer, road owner, contractor, or other party associated with the production of application/construction or development of paving segments paved with FSB. Given that the project proponent could be any one of entities listed above, clear project ownership must be demonstrated through contractual agreements, or other arrangements, in order to avoid the risk of double counting with other participants in the supply chain.

In this methodology, performance benchmarks have been established for the determination of additionality and the crediting baseline. These benchmarks are based on GHG emissions from the baseline scenario, which enables a measurement of emission reduction potentials through the substitution of FSB and asphalt emulsions for HMA. Data from hot mix facilities and placement projects in different geographic locations within the United States were surveyed to determine the levels of the performance benchmarks. Emission reductions of FSB and asphalt emulsions are the differences between actual project emissions and the crediting performance benchmark.

2 DEFINITIONS

Aggregate
A collective term for the mineral materials such as sand, gravel and crushed stone that are used with a binding medium to form asphalt. Aggregate can be from either natural or recycled sources, called virgin aggregate or recycled aggregate.

Asphalt
A cementitious material, ranging from a dark brown to black color, in which the predominating constituents are bitumens that occur in nature or are obtained by petroleum processing

Asphalt Emulsions
A dispersion of small droplets of one liquid into another liquid. Usually, asphalt emulsions contain small droplets of asphalt binder in water and emulsifying agent. Standard asphalt emulsions contain 40% to 75% asphalt binder, 0.1% to 2.5% emulsifier, and 25% to 60% water.

Asphalt Pavement
Asphalt concrete layer(s) on supporting courses such as concrete base, asphalt treated base, cement treated base, granular base, and/or granular sub-base placed over the subgrade

Bitumen
A black or dark colored organic material with adhesive properties derived from distillation of petroleum or natural asphalt. Bitumen is also called liquid asphalt, asphalt binder, and/or liquid asphalt cement.

Cold Central Plant Recycling (CCPR)
A method for producing FSB and asphalt emulsions which requires milled reclaimed asphalt pavement (RAP) to be transported from an existing jobsite to a central mixing plant. The unheated RAP is then blended with foamed asphalt and a small amount of Portland cement in a cold mixing process.

Cold In-Place Recycling (CIR)
The principal method for producing FSB and asphalt emulsions which uses one or more mobile recycling machines for milling, asphalt production, and placement in a continuous operation at the pavement site. Generally, CIR uses 100% RAP generated from the existing pavement, which is

blended with small amount of Portland cement with a treatment depth ranging from approximately 2 to 6 inches.

Foamed Asphalt
A mixture of air, water, and bitumen. When injected with a small quantity of cold water, the hot bitumen expands explosively to about fifteen times its original volume and forms a fine mist or foam. In this foamed state, the bitumen has a very large surface area and an extremely low viscosity. This expanded bitumen mist is then incorporated into the mixing drum where the bitumen droplets are attracted to and coat the finer particles of pavement material, thus forming a mastic that effectively binds the mixture together.

Foamed Stabilized Base (FSB)
A mixture of foamed asphalt binder and RAP, or a combination of RAP and recycled concrete. Unlike hot mix asphalt (HMA), the foamed binder does not coat the aggregate particles. Rather, it coats the fines (passing #200 sieve) in the aggregate, which helps serve as a bonding agent to keep the aggregate particles together. FSB is generally used as a base course layer in the pavement construction in lieu of conventional HMA in order to reduce the carbon footprint of construction operations.

Full-Depth Reclamation (FDR)
A technique in which the full thickness of the asphalt pavement and a pre-determined portion of the underlying material (base, sub base, and/or subgrade) is uniformly pulverized and blended to provide an upgraded, homogenous base material. FDR is performed on the roadway without the addition of heat, similar to CIR. Thus, the emissions from FDR can be quantified using the same method as CIR.

Hot Mix Asphalt (HMA)
A mixture of course aggregate, fine aggregate, and asphalt cement that is produced at a central facility at temperatures between 300 and 325°F. HMA can incorporate a small amount of RAP (usually 10% to 30%) into the mix.

Portland Cement
The most common type of generally used cement around the world. It is used as a basic ingredient of concrete, mortar, stucco, and most non-specialty grout. It usually originates from limestone. Portland cement is a fine powder that consists of more than 90% ground Portland cement clinker, a limited amount of calcium sulfate (which controls the set time), and up to 5% minor constituents as allowed by various standards.

Reclaimed Asphalt Pavement (RAP)
Material generated from milling existing asphalt pavement layers during the rehabilitation of paved surfaces. RAP consists of aggregates that are coated by asphalt.

Structural Layer Coefficient
The relative structural capacity of a material per inch of thickness.

Virgin Aggregate
Aggregate that has been quarried and not used in any prior asphalt applications.

Warm Mix Asphalt (WMA)
A subcategory of HMA that is produced within a target temperature discharge range using the applicable state Department of Transportation (DOT) approved WMA additives or processes. The WMA technologies may be used as coating and compaction aids without lowering the production temperature.

3 APPLICABILITY CONDITIONS

This methodology is applicable under the following conditions:

1) Project activities include the construction of any type of road and/or parking lot (including parking lot patching projects) in the United States.
2) Project activities must apply one or more of the following processes for road construction:
    a) FSB produced using the CCPR process
    b) FSB produced using the CIR process
    c) FSB produced using the FDR process
    d) Asphalt emulsions produced using the CCPR process
    e) Asphalt emulsions produced using the CIR process
    f) Asphalt emulsions produced using the FDR process
3) Production plants where the project activity occurs may serve multiple pavement types, including, but not limited to, roadways and parking lots.
4) Project activities may have an HMA or WMA surface layer, but must have at least one FSB or asphalt emulsions base layer.

This methodology is not applicable under the following conditions:

1) Project activities include only an HMA, WMA, or other non-FSB/asphalt emulsions paving material base layer.

4 PROJECT BOUNDARY

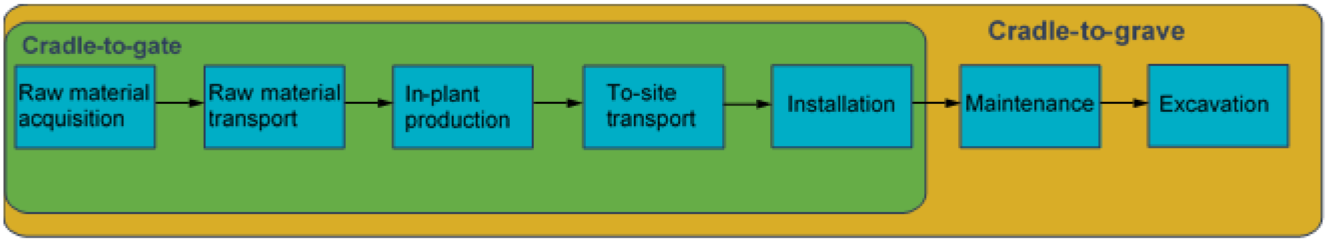
The spatial extent of the project boundary encompasses the stages from raw material acquisition to product installation and complies with the cradle-to-gate assessment principle (Sinden, 2008). As shown in Figure 1, the GHG impact of producing an asphalt mixture must be calculated by summing the following emission sources:

1) GHGs associated with manufacturing each of the constituent and ancillary materials;
2) GHGs from transporting materials from factory to mixing plant;

3) GHGs from all forms of energy involved in producing the asphalt at the mixing plant; and

4) GHGs from all forms of energy involved in milling the existing pavement and placing new pavement, including relevant transport activities.

Figure 1: Map of the Asphalt Life-Cycle

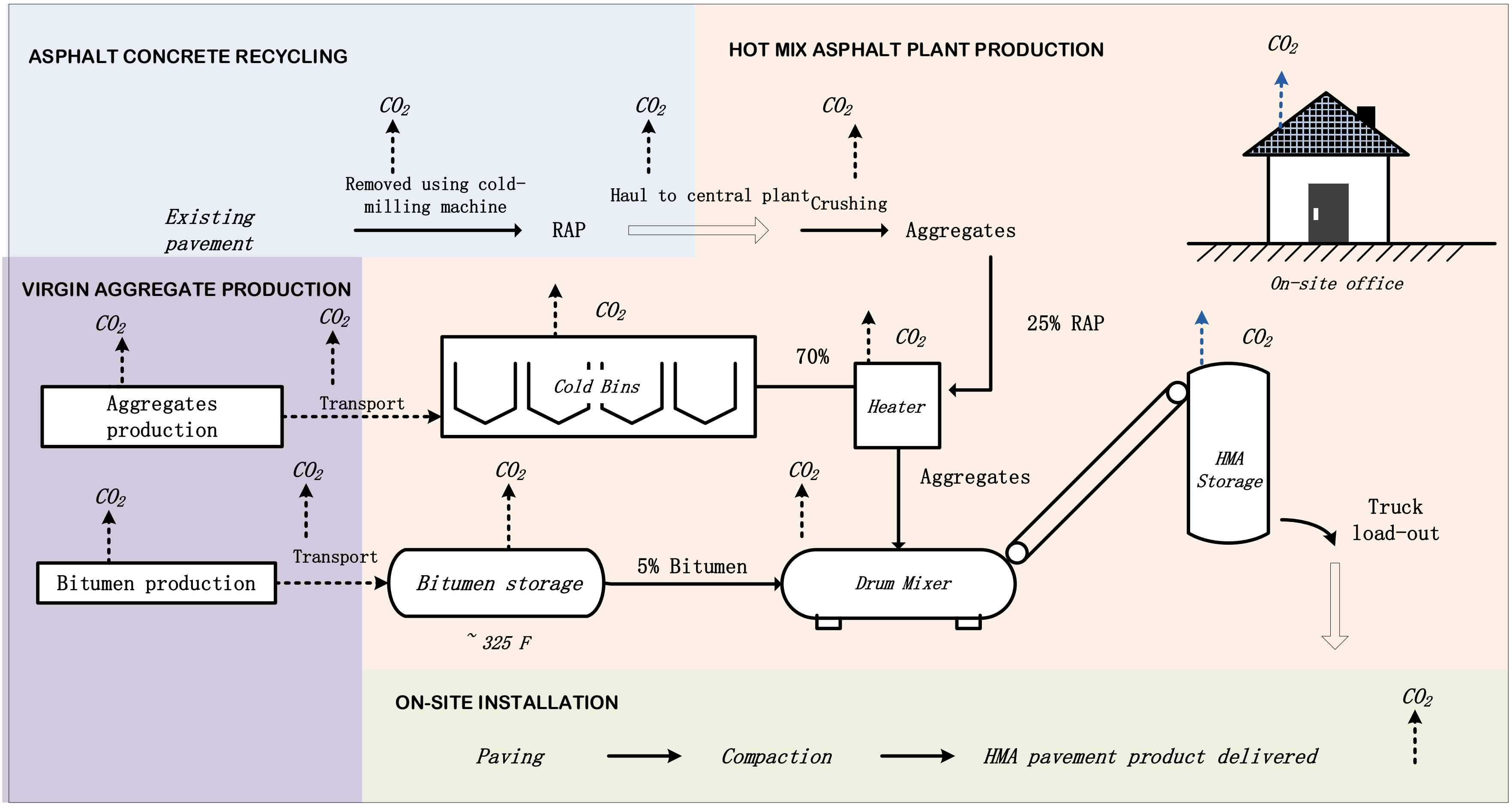


Maintenance and excavation of pavement is not included due to the high variability of maintenance practices in each region. Maintenance activities can be classified into preventive maintenance and structural improvement. Given the complexity of maintenance methods, material sources, and equipment use, associated GHG emissions vary significantly. The emission difference can only be captured after the maintenance activities are complete. As the structural performance of FSB and asphalt emulsions are comparable to the baseline HMA method, the frequency of pavement maintenance is generally the same (Bemanian et al., 2006; Morian et al., 2005). There is insignificant difference in post-installation emissions between FSB/asphalt emulsions and HMA. The boundary also excludes GHG emissions associated with the production of capital goods having lifetimes longer than one year and the transportation of employees to and from their normal place of work.

4.1 Boundary for Baseline Emissions

The estimation of baseline emissions for HMA projects begins with the production of raw materials at manufacturer sites and ends with the delivery of the final pavement product to the customer. It includes all energy-consuming activities of equipment and machinery at supplier sites, the hot mix facility, the job site, and associated transportation. The emission sources covered within the system boundary include production materials, manufacturing equipment/vehicles, operation of the plant office, and transport and storage of input materials (Sinden 2008). Specifically, the boundary for HMA systems consist of energy consumption for quarrying/producing the mineral aggregates and bitumen binder, transportation to and at the HMA production plant, storage, heating of the individual components (including aggregates and bitumen binder), mixing, and the transportation and installation of the mix at the job site, as shown in Figure 2.

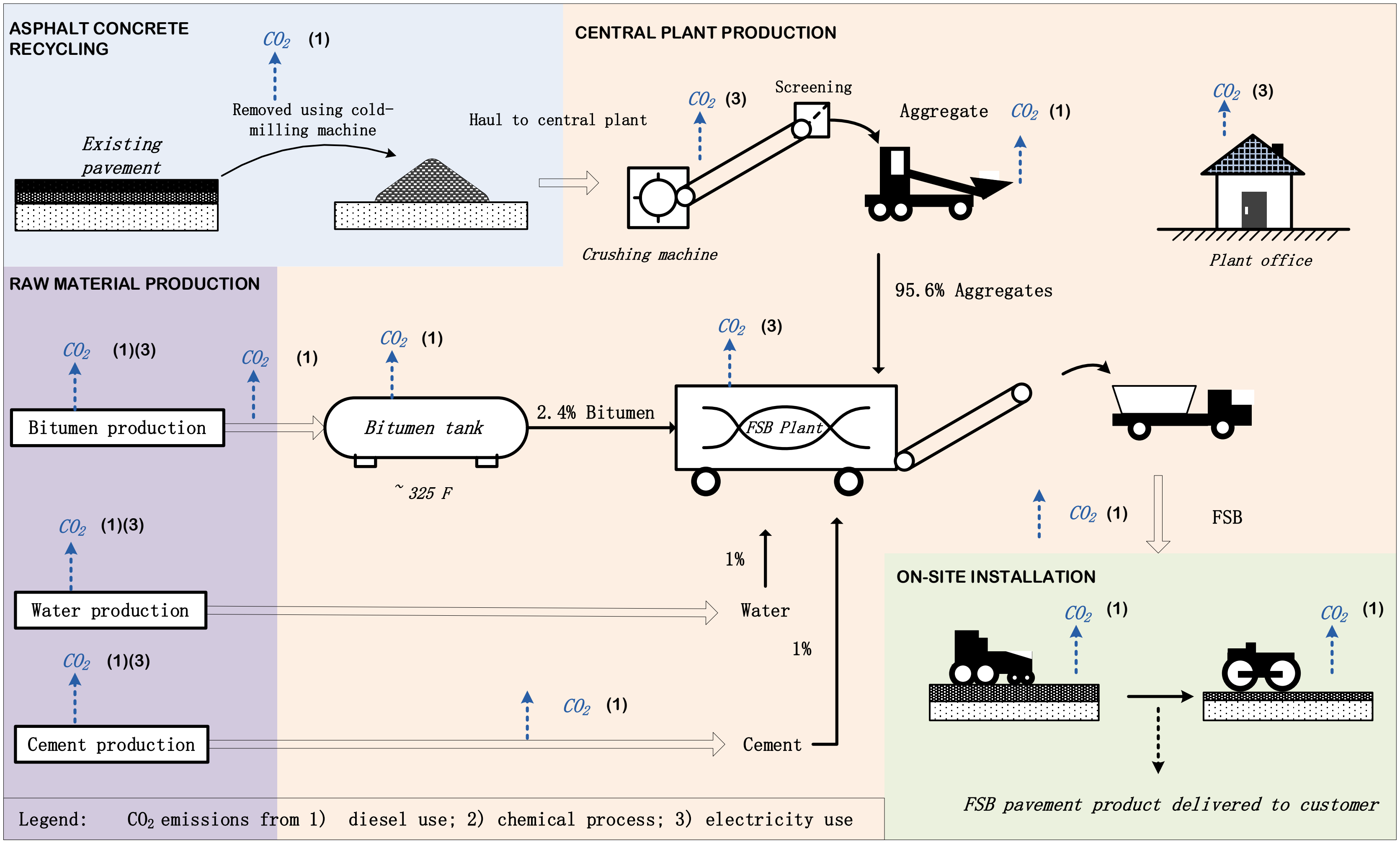
Figure 2: Diagram of HMA Production and Placement



4.2 Boundary for Project Emissions from CCPR Process

The estimation of project emissions for CCPR projects begins with the transportation of raw and recycled materials to a central plant and ends with the delivery of the final pavement product to the customer. CCPR projects transport milled materials from an existing jobsite to a central plant where FSB or asphalt emulsions are processed through a pug mill. Production of FSB begins with the crushing of RAP, which diverts waste from landfills. Once the crushed pavement is sized, the unheated RAP is then blended with foamed bitumen (or asphalt emulsions) and a small amount of Portland cement in a cold mixing process. Figure 3 shows the major processes included in a CCPR project. The boundary consists of the energy consumption for milling the existing pavement, producing bitumen binder and water, transportation to and at the FSB and asphalt emulsions production plant, heating of bitumen binder, mixing, transportation of materials and resources to the project site, and installation of the mix.

Figure 3: CCPR Project Activities and Associated GHG Sources

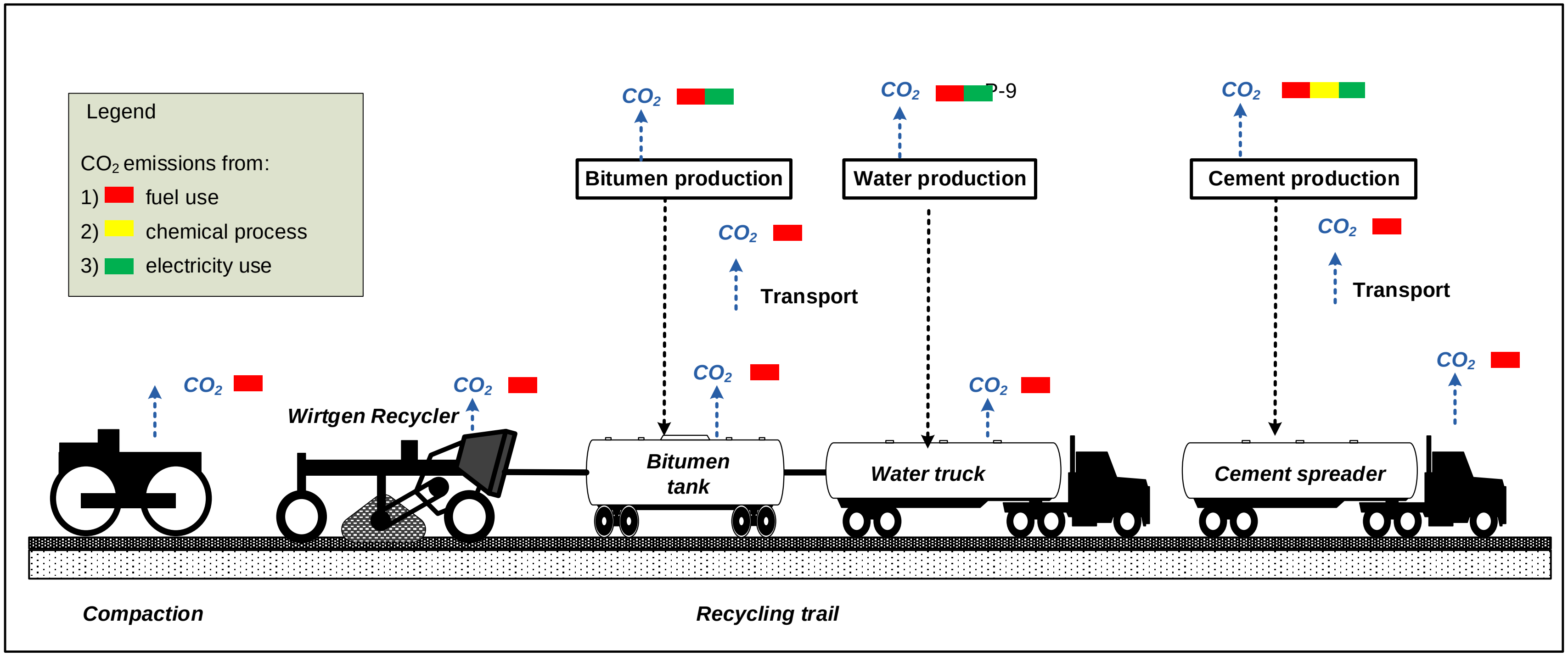


Note: Double-lined arrows signify included transportation; dashed-line arrows signify the separation of activities in different locations.

4.3 Boundary for Project Emissions from CIR and FDR Systems

The estimation of project emissions for CIR and FDR projects begins with the transportation of raw materials to a job site and ends with the delivery of the final pavement product to the customer. CIR and FDR use one or more mobile recycling machines for milling, production, and placement in a continuous operation at the pavement site. It reconstructs the roadways by using special equipment to mill up the existing pavement, mix it with hot bitumen oil (or asphalt emulsions) and additives, and then immediately place it back down on the road by permanent placement with a paver and rollers. CIR and FDR allows a paving contractor to use the aggregate from the existing road and, by adding liquid asphalt cement (consisting of under 3% of the total volume), it reduces the emissions of new aggregate materials and new liquid asphalt cement that must be shipped from the producer's plant site. Figure 4 shows the major activities included in CIR and FDR systems. The project boundary includes production of bitumen, water, and cement, operation of recycler and rollers, and transportation and storage of input materials.

Figure 4: CIR and FDR Project Activities and Associated GHG Sources



4.4 GHG Sources Included and Excluded from the Project Boundary

The greenhouse gases included in or excluded from the project boundary are shown in Table 1 below.

Table 1: GHG Sources Included or Excluded from the Project Boundary

Source		Gas	Included?	Justification/Explanation
HMA (Baseline)	Raw material acquisition	CO_2	Yes	GHGs are released from energy consumption in material manufacture process.
		CH_4	No	Not applicable
		N_2O	No	
	Raw material transport	CO_2	Yes	GHGs are released from fuel consumption for transporting materials from producers to central plant.
		CH_4	No	Not applicable
		N_2O	No	
	In-plant production	CO_2	Yes	GHGs are generated from the usage of natural gas by the drum mixer, plant electricity (including electricity for plant office), and diesel equipment/vehicles operated for producing HMA at the central plant.
		CH_4	No	Not applicable
		N_2O	No	
	To-site transport	CO_2	Yes	GHGs are released from fuel consumption for transporting materials from the central plant to construction site.
		CH_4	No	Not applicable
		N_2O	No	
	Installation	CO_2	Yes	GHGs are released from diesel consumption by construction equipment/vehicles, including asphalt paving machine, backhoe, bobcat/loader, sweeper/broom, air compressor, roller, trucks, etc.
		CH_4	No	Not applicable
		N_2O	No	

Source		Gas	Included?	Justification/Explanation
	Maintenance	CO_2	No	GHGs from maintenance and rehabilitation are excluded due to uncertain traffic volume, failure type and repair options.
		CH_4	No	Not applicable
		N_2O	No	
	Excavation	CO_2	No	GHGs from excavation are excluded due to the uncertainty in determining pavement disposal options (e.g., landfill, recycling, remain in place).
		CH_4	No	Not applicable
		N_2O	No	
CCPR (Project Scenario 1)	Raw material acquisition	CO_2	Yes	GHGs are released from energy consumption in material manufacture process.
		CH_4	No	Not applicable
		N_2O	No	
	Raw material transport	CO_2	Yes	GHGs are released from fuel consumption for transporting materials from producers to the central plant.
		CH_4	No	Not applicable
		N_2O	No	
	FSB/asphalt emulsions production	CO_2	Yes	GHGs are generated from the usage of electricity by plant office, bitumen heater and crusher and diesel equipment/vehicles operated for producing FSB/asphalt emulsions at the central plant.
		CH_4	No	Not applicable
		N_2O	No	
	To-site transport	CO_2	Yes	GHGs are released from fuel consumption for transporting materials from the central plant to the construction site.
		CH_4	No	Not applicable
		N_2O	No	
	Installation	CO_2	Yes	GHGs are released from fuel consumption by construction equipment/vehicles, including asphalt paving machine, backhoe,

Source		Gas	Included?	Justification/Explanation
				bobcat/loader, sweeper/broom, air compressor, roller, trucks, etc.
		CH_4	No	Not applicable
		N_2O	No	
	Maintenance	CO_2	No	GHGs from maintenance and rehabilitation are excluded due to uncertain traffic volume, failure type and repair options.
		CH_4	No	Not applicable
		N_2O	No	
	Excavation	CO_2	No	GHGs from excavation are excluded due to the uncertainty in determining pavement disposal options (e.g., landfill, recycling, remain in place).
		CH_4	No	Not applicable
		N_2O	No	
CIR or FDR (Project Scenario II)	Raw material acquisition	CO_2	Yes	GHGs are released from energy consumption in material manufacture process.
		CH_4	No	Not applicable
		N_2O	No	
	Raw material transport	CO_2	Yes	GHGs are released from fuel consumption for transporting materials from producers to the job site.
		CH_4	No	Not applicable
		N_2O	No	
	FSB/asphalt emulsions Production & Placement	CO_2	Yes	GHGs are released from fuel consumption by construction equipment/vehicles, including, but not limited to a cold recycler (e.g., Wirtgen 3800 CR), a cement spreader, a water truck, a bitumen truck, a vibratory roller and a pneumatic roller.
		CH_4	No	Not applicable
		N_2O	No	
	Maintenance	CO_2	No	GHGs from maintenance and rehabilitation are excluded due to uncertain traffic volume, failure type and repair options.

Source		Gas	Included?	Justification/Explanation
		CH_4	No	Not applicable
		N_2O	No	
	Excavation	CO_2	No	GHGs from excavation are excluded due to the uncertainty in determining pavement disposal options (e.g., landfill, recycling, remain in place).
		CH_4	No	Not applicable
		N_2O	No	

5 BASELINE SCENARIO

The baseline scenario for projects applying this methodology is the application of HMA, or the subcategory WMA, to both the surface and base layers. The emissions associated with the quarry, transportation, and production of HMA or WMA serve as performance benchmarks, which are identified in Table 3 of Section 6 below.[2]

CCPR, CIR, and FDR projects replace HMA or WMA base layers with FSB or asphalt emulsions. These processes typically outperform the performance benchmarks because they can reduce the emissions from producing bitumen and producing, transporting, and heating virgin aggregates.

6 ADDITIONALITY

Project proponents applying this methodology must determine additionality using the procedure described below:

Step 1: Regulatory Surplus

The project proponent must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the *VCS Standard.*

Step 2: Performance Benchmark

[2] More than 94% of U.S. roads are paved with HMA (EPA, 2015). The National Asphalt Pavement Association (NAPA) statistics show that approximately one third of HMA projects in the U.S. in 2014 used WMA technologies (NAPA 2017). HMA and WMA typically requires that more than 70% virgin aggregates are used in HMA production. They need to be quarried, transported to the hot mix plant, sorted into cold bins, dried by the heaters, blended with hot bitumen binders, and then fed into a mixer. The emissions associated with a series of these processes serve as performance benchmarks.

There are three strata of performance benchmarks for additionality based on project types and one-way distances between the HMA plant and job site.

Stratum 1 is for patching projects with hauling distance less than 40 miles, while Stratum 2 is for patching projects with hauling distance greater than 40 miles. Stratum 3 is for roadway projects. The performance benchmarks for all three strata are summarized in Table 2 below. Appendix A describes the calculation of the performance benchmark for additionality.

Where a project emits less than the relevant predetermined benchmark set out below, the project is deemed to be additional. This is determined by comparing the project emission intensity (derived from Section 7.2 below) to the additionality performance benchmark.

Table 2: Performance Benchmark for Patching Projects and Roadway Projects (2014)

Stratum	Project type	Hauling distance	Additionality performance benchmark
1	Patching	≤ 40 miles	121.9 kgCO_2e/t
2	Patching	> 40 miles	142.4 kgCO_2e/t
3	Roadway	Undefined	95.1 kgCO_2e/t

Note: 1 kgCO_2e per tonne of output = 0.001 tCO_2e per tonne of output

The additionality performance benchmark is adjusted annually based on the expected changes in the use of RAP[3]. Based on NAPA (2017), the use of RAP in HMA is expected to increase by 1.1% every year. This increase can reduce carbon emissions by 0.1kgCO_2e/t (NAPA, 2012). Therefore, as shown in Table 3, the performance benchmark decreases by 0.1kgCO_2e/t annually.

Table 3: Performance Benchmarks from 2014 to 2025

	Patching Project (<40mile)	Patching Project (>40mile)	Roadway Project
2014	121.9	142.4	95.1
2015	121.8	142.3	95.0
2016	121.7	142.2	94.9
2017	121.6	142.1	94.8
2018	121.5	142.0	94.7
2019	121.4	141.9	94.6
2020	121.3	141.8	94.5

3 An increased use of RAP can reduce GHG emissions due to the use of more recycled materials thus reducing the need for mining, processing, and transporting crushed stone and bitumen binder.

2021	121.2	141.7	94.4
2022	121.1	141.6	94.3
2023	121.0	141.5	94.2
2024	120.9	141.4	94.1
2025	120.8	141.3	94.0

Note: Unit is $kgCO_2e/t$, where 1 $kgCO_2e$ per tonne of output = 0.001 tCO_2e per tonne of output

7 QUANTIFICATION OF GHG EMISSION REDUCTIONS

7.1 Baseline Emissions

Baseline emissions have been predetermined by the performance benchmark for the crediting baseline, which is the same as the additionality performance benchmark. The crediting baselines from 2014 to 2025 are presented in Table 4 below.

Similar to the additionality benchmark, there are three strata of performance benchmarks based on project types and one-way distances between the HMA plant and job site. Appendix A describes the calculation of the performance benchmark for the crediting baseline.

Table 4: Crediting Baseline for Estimation of Emission Reductions

	Patching Project (<40mile)	Patching Project (>40mile)	Roadway Project
2014	121.9	142.4	95.1
2015	121.8	142.3	95.0
2016	121.7	142.2	94.9
2017	121.6	142.1	94.8
2018	121.5	142.0	94.7
2019	121.4	141.9	94.6
2020	121.3	141.8	94.5
2021	121.2	141.7	94.4
2022	121.1	141.6	94.3
2023	121.0	141.5	94.2
2024	120.9	141.4	94.1
2025	120.8	141.3	94.0

Note: Unit: $kgCO_2e/t$. 1 $kgCO_2e$ per tonne of output = 0.001 tCO_2e per tonne of output

7.2 Project Emissions

Project emissions are calculated in one of two ways, depending on production method. Where the project is performed using CCPR, the calculation of project emissions must follow the process in Section 7.2.1. Where the project is performed using CIR or FDR, the calculation of project emissions must follow the process in Section 7.2.2.

7.2.1 Emissions from CCPR

CCPR emission intensity (*CCPR EI*) represents the quantity of GHGs emitted from producing and installing one metric ton of FSB and asphalt emulsions using CCPR. It is the summation of raw material production emission intensity (EI_M), to-plant delivery emissions intensity (EI_{PD}), in-plant production emission intensity (EI_P), to-site delivery emissions intensity (EI_{SD}) and on-site installation emission intensity (EI_I). *CCPR EI* is calculated as follows:

$$CCPR\ EI = EI_M + EI_{PD} + EI_{SD} + EI_P + EI_I \quad (1)$$

Where:

CCPR EI	=	Emission intensity of CCPR (kgCO_2e/t)
EI_M	=	Emission intensity of raw material production (kgCO_2e/t)
EI_{SD}	=	Emission intensity of to-site delivery (kgCO_2e/t)
EI_P	=	Emission intensity of in-plant production (kgCO_2e/t)
EI_I	=	Emission intensity of pavement installation (kgCO_2e/t)

Raw material production emission intensity[4] (EI_M) must be calculated as follows:

$$EI_M = \frac{EF_M \times W_M}{Project\ amount} \quad (2)$$

Where:

EI_M	=	Emission intensity of raw material production (kgCO_2e/t)
EF_M	=	Material emission factor (kgCO_2e/kg)
W_M	=	Material weight (kg)
Project amount	=	Amount of FSB/asphalt emulsions manufactured (t)

To-plant delivery emissions intensity (EI_{PD}) and to-site delivery emissions intensity (EI_{SD}) must be calculated according to Equation 3 and Equation 4. Where hauling distance is not directly

[4] It is reasonable to assume zero leakage because there is no difference in site preparation activities between baseline and project scenarios. Replacing HMA with FSB or asphalt emulsions for the pavement base layer does not entail a change in carbon efflux or carbon sink at the construction site.[5] It is reasonable to assume zero leakage because there is no difference in site preparation activities between baseline and project scenarios. Replacing HMA with FSB or asphalt emulsions for the pavement base layer does not entail a change in carbon efflux or carbon sink at the construction site.

monitored, the distance can be estimated using a map distance calculator. The addresses of the start point and destination must be documented. For conservativeness, a discount factor (DF) of 0.1 must be applied when a map distance calculator is used to estimate hauling distance (Hauling distance = Map distance × (1+DF)). DF is equal to 0 where using actual logged miles.

$$EI_{PD} = \frac{Trip_p \times Distance_P \times (1+DF) \times EF_T}{Project\ amount} \quad (3)$$

Where:

EI_{PD}	=	Emission intensity of to-plant delivery ($kgCO_2e/t$)
$Trip_P$	=	Number of trips from material manufacture to production plant
$Distance_P$	=	Distance to plant (mile)
DF	=	Discount factor
EF_T	=	Truck emission factor ($kgCO_2e$/mile)
Project amount	=	Amount of FSB/asphalt emulsions manufactured (t)

$$EI_{SD} = \frac{Trip_S \times Distance_S \times (1+DF) \times EF_T}{Project\ amount} \quad (4)$$

Where:

EI_{SD}	=	Emission intensity of to-site delivery ($kgCO_2e/t$)
$Trip_S$	=	Number of trips from production plant to job site
$Distance_S$	=	Distance to site (mile)
DF	=	Discount factor
EF_T	=	Truck emission factor ($kgCO_2e$/mile)
Project amount	=	Amount of FSB/asphalt emulsions manufactured (t)

In-plant production emission intensity (EI_P) includes the emissions from diesel and electricity consumption by plant equipment, vehicles, and the plant office.

Diesel users are often mixing machines, loaders, and dump trucks. Their emissions are calculated using Equations 5 and 6. Relevant emission factors are provided in Appendix B. Equipment operating hours must be logged to determine the amount of time it was used in the plant.

Electricity users are often the bitumen heater, RAP crusher, and plant office. Their emissions are calculated using Equation 8. Electricity emission factors can be found at the eGRID default emission factor database provided by the EPA. The electricity consumption must be recorded according to the electric meter.

$$EI_P = EI_D + EI_E \quad (5)$$

Where:

EI_P	=	Emission intensity of in-plant production ($kgCO_2e/t$)

EI_D	=	Emission intensity of diesel-consuming activities ($kgCO_2e/t$)
EI_E	=	Emission intensity of electricity-consuming activities ($kgCO_2e/t$)

$$EI_D = \frac{EF_{EQ} \times HR_{EQ}}{Project\ amount} \quad (6)$$

Where:

EI_D	=	Emission intensity of diesel-consuming activities ($kgCO_2e/t$)
EF_{EQ}	=	Equipment emission factor ($kgCO_2e/hour$)
HR_{EQ}	=	Equipment operation hours (hour)
Project amount	=	Amount of FSB/asphalt emulsions manufactured (t)

$$EI_E = \frac{EF_{EL} \times C_{EL}}{Project\ amount} \quad (7)$$

Where:

EI_E	=	Emission intensity of electricity-consuming activities ($kgCO_2e/t$)
EF_{EL}	=	Electricity emission factor ($kgCO_2e/kWh$)
C_{EL}	=	Electricity consumption (kWh)
Project amount	=	Amount of FSB/asphalt emulsions manufactured (t)

On-site installation emission intensity (EI_I) is due to diesel consumption from the equipment used for the installation project. The equipment includes milling machines, backhoes, loaders, sweepers, pavers, rollers, and trucks. Equipment emissions must be calculated using Equation 8. Relevant emission factors are provided in Appendix B. Where equipment operation hours are not available, labor hours can be used to approximate equipment operation hours according to Equation 10. Labor hours must be documented in the project daily log for verification. Conversion factors (CF) for commonly used equipment are listed in Section 9.1.1.

$$EI_I = \frac{EF_{EQ} \times HR_{EQ}}{Project\ amount} \quad (8)$$

Where:

EI_I	=	Emission intensity of pavement installation ($kgCO_2e/t$)
EF_{EQ}	=	Equipment emission factor ($kgCO_2e/hour$)
HR_{EQ}	=	Equipment operation hours (hour)
Project amount	=	Amount of FSB/asphalt emulsions installed (t)

$$HR_{EQ} = HR_{LA} \times CF \quad (9)$$

Where:

HR_{EQ}	=	Equipment operation hours (hour)

HR_{LA}	=	Labor hours (hour)
CF	=	Conversion factor

Note that CCPR projects may include more than one installation project because FSB and asphalt emulsions produced in central plants could be placed in a number of road areas. Where there are *i = 1,…, N* installation projects using FSB and asphalt emulsions from the same manufacturing process, the emission intensity of multiple CCPR projects (MCCPR EI) must be calculated as follows:

$$MCCPR\ EI = EI_M + EI_{PD} + EI_P + \frac{\sum_i^N EI_{SD,i} \cdot project\ amount_i + \sum_I^N EI_{I,i} \cdot project\ amount_i}{\sum_I^N project\ amount_i} \quad (10)$$

Where:

MCCPR EI	=	Emission intensity of multiple CCPR projects ($kgCO_2e/t$)
EI_M	=	Emission intensity of raw material production ($kgCO_2e/t$)
EI_{PD}	=	Emission intensity of to-plant delivery ($kgCO_2e/t$)
EI_P	=	Emission intensity of in-plant production ($kgCO_2e/t$)
EI_{SD}	=	To-site delivery emission intensity ($kgCO_2e/t$)
EI_I	=	On-site installation emission intensity ($kgCO_2e/t$)
Project amount	=	Amount of FSB and asphalt emulsions manufactured (t)

7.2.2 Emissions from CIR or FDR

CIR or FDR emission intensity (*CIR EI or FDR EI*) represents the quantity of GHGs emitted from producing and installing one metric ton of FSB or asphalt emulsions using CIR or FDR. *CIR EI* or *FDR EI* must calculated as follows:

$$CIR\ EI\ (or\ FDR\ EI) = EI_M + EI_{SD} + EI_I \quad (11)$$

Where:

CIR EI	=	Emission intensity of CIR ($kgCO_2e/t$)
FDR EI	=	Emission intensity of FDR ($kgCO_2e/t$)
EI_M	=	Material emissions intensity ($kgCO_2e/t$)
EI_{SD}	=	To-site delivery emission intensity ($kgCO_2e/t$)
EI_I	=	On-site installation emission intensity ($kgCO_2e/t$)

Material emissions intensity (EI_M) must be calculated using Equation 3 above.

To-site delivery emissions intensity (EI_{SD}) must be calculated using Equation 5 above.

On-site installation emissions intensity (EI_I) is derived from diesel consumption from the equipment used for the installation project. This equipment typically includes a cold recycler (e.g., Wirtgen 3800 CR), cement spreader, water truck, bitumen truck, vibratory roller, pneumatic roller, etc. The equipment emissions must be calculated using Equation 9 above. Relevant emission factors are provided in Appendix B.

Where project proponents cannot record the operating hours of all the equipment, the hours must be estimated using equipment running speeds according to Equation 13. The running speed of the cold recycler can be read from the screen on the machine. The water truck and bitumen truck are connected to the cold recycler to supply it with binding agents, and the rollers normally follow the train of equipment to compact the newly produced layer. Therefore, they can be assumed to run at the same speed as the cold recycler.

$$HR_{CR} = \frac{L}{S} \qquad (12)$$

Where:

HR_{CR}	=	Operation hours of cold recycler (hour)
S	=	Running speed of cold recycler (mile/hour)
L	=	Project length (mile)

Note that CIR and FDR projects may include more than one installation project because FSB and asphalt emulsion produced from CIR or FDR could be placed in a number of road sections. Where there are *i = 1,…, N* road sections using FSB and asphalt emulsion from the same CIR or FDR machinery, the emission intensity of multiple CIR or FDR projects (*MCIR EI* or *MFDR EI*) must be calculated as follows:

$$MCIR\ EI\ (or\ MFDR\ EI) = EI_M + \frac{\sum_i^N \boldsymbol{EI_{SD,i} \cdot project\ amount_i} + \sum_I^N \boldsymbol{EI_{I,i} \cdot project\ amount_i}}{\sum_I^N \boldsymbol{project\ amount_i}} \qquad (13)$$

Where:

MCIR EI	=	Emission intensity of multiple CIR projects ($kgCO_2e/t$)
MFDR EI	=	Emission intensity of multiple FDR projects ($kgCO_2e/t$)
EI_{SD}	=	To-site delivery emission intensity ($kgCO_2e/t$)
Project amount	=	Amount of FSB and asphalt emulsions manufactured (t)
EI_I	=	On-site installation emission intensity ($kgCO_2e/t$)

7.3 Leakage

Leakage is not considered an issue under this methodology, and is therefore set at zero.[5]

[5] It is reasonable to assume zero leakage because there is no difference in site preparation activities between baseline and project scenarios. Replacing HMA with FSB or asphalt emulsions for the pavement base layer does not entail a change in carbon efflux or carbon sink at the construction site.

7.4 Net GHG Emission Reductions and Removals

Net GHG emission reductions for FSB and asphalt emulsions are the emission intensity differences adjusted by the weight differences. The emission reductions must be calculated according to Equations 15 through 27.

A correction factor[6] (θ) of 1.02 for FSB and 1.17 for asphalt emulsions is applied. For projects that have a different structural layer coefficient and material density, the correction factor must be calculated as follows:

$$\theta = 0.0025\ DE\ /\ LC \tag{14}$$

Where:

DE	=	Density of FSB or asphalt emulsions, lb/cu.ft
LC	=	Layer coefficient of FSB or asphalt emulsions

Net GHG emission reductions for a single FSB project must be calculated as follows:

$$ER_{FSB-CCPR} = \left(\frac{CB}{\theta_{FSB}} - CCPR\ EI\right) \cdot \frac{project\ amount}{1{,}000} \tag{15}$$

Where:

$ER_{FSB\text{-}CCPR}$	=	Net emission reductions of FSB using CCPR (tCO_2e)
CB	=	Crediting baseline ($kgCO_2e/t$)
Θ_{FSB}	=	Correction factor for FSB (default value is 1.02)
CCPR EI	=	Emission intensity of CCPR project ($kgCO_2e/t$)
Project amount	=	Amount of FSB manufactured (t)

$$ER_{FSB-CIR} = \left(\frac{CB}{\theta_{FSB}} - CIR\ EI\right) \cdot \frac{project\ amount}{1{,}000} \tag{16}$$

Where:

$ER_{FSB\text{-}CIR}$	=	Net emission reductions of FSB using CIR (tCO_2e)

[6] The American Association of State Highway Transportation Officials (AASHTO) Design Guide is the recommended reference for the thickness design of cold in-place recycled asphalt mixes. The composition and structural properties of central plant recycled cold mix and cold in-place recycled paving materials are virtually the same; the range of structural layer coefficients recommended for recycled cold mixes (0.25 to 0.35) is also applicable for cold in-place recycled mixes. On average, various Departments of Transportation are considering a structural layer coefficient of 0.32 for FSB and of 0.30 for asphalt emulsion mixes (Schwartz and Khosravifar, 2013). The structural layer coefficient for a 0.75 inch HMA base mix is 0.40 (AASHTO, 1998). Accordingly, substituting FSB and asphalt emulsions for HMA on a project would, on average, require the FSB and asphalt emulsions layer to be approximately 25% (or 33%) thicker than the HMA layer. The densities of FSB, asphalt emulsions, and HMA are 130 lb/cu.ft, 140 lb/cu.ft and 160 lb/cu.ft, respectively. After factoring in these density differences, the use of FSB and asphalt emulsions must be 2% and 17% more than the HMA base by weight for the same length of paved road.

CB	=	Crediting baseline ($kgCO_2e/t$)
Θ_{FSB}	=	Correction factor for FSB (default value is 1.02)
CIR EI	=	Emission intensity of CIR project ($kgCO_2e/t$)
Project amount	=	Amount of FSB manufactured (t)

$$ER_{FSB-FDR} = \left(\frac{CB}{\theta_{FSB}} - FDR\ EI\right) \cdot \frac{project\ amount}{1{,}000} \quad (17)$$

Where:

$ER_{FSB\text{-}FDR}$	=	Net emission reductions of FSB using FDR (tCO_2e)
CB	=	Crediting baseline ($kgCO_2e/t$)
Θ_{FSB}	=	Correction factor for FSB (default value is 1.02)
FDR EI	=	Emission intensity of FDR project ($kgCO_2e/t$)
Project amount	=	Amount of FSB manufactured (t)

Net GHG emission reductions for multiple FSB projects must be calculated as follows:

$$ER_{FSB-CCPR} = \left(\frac{CB}{\theta_{FSB}} - MCCPR\ EI\right) \cdot \Sigma\ \frac{project\ amount_i}{1{,}000} \quad (18)$$

Where:

$ER_{FSB\text{-}CCPR}$	=	Net emission reductions of FSB using CCPR (tCO_2e)
CB	=	Crediting baseline ($kgCO_2e/t$)
Θ_{FSB}	=	Correction factor for FSB (default value is 1.02)
MCCPR EI	=	Emission intensity of multiple CCPR projects ($kgCO_2e/t$)
Project amount	=	Amount of FSB manufactured (t)

$$ER_{FSB-CIR} = \left(\frac{CB}{\theta_{FSB}} - MCIR\ EI\right) \cdot \Sigma\ \frac{project\ amount_i}{1{,}000} \quad (19)$$

Where:

$ER_{FSB\text{-}CIR}$	=	Net emission reductions of FSB using CIR (tCO_2e)
CB	=	Crediting baseline ($kgCO_2e/t$)
Θ_{FSB}	=	Correction factor for FSB (default value is 1.02)
MCIR EI	=	Emission intensity of multiple CIR projects ($kgCO_2e/t$)
Project amount	=	Amount of FSB manufactured (t)

$$ER_{FSB-FDR} = \left(\frac{CB}{\theta_{FSB}} - MFDR\ EI\right) \cdot \Sigma\ \frac{project\ amount_i}{1{,}000} \quad (20)$$

Where:

$ER_{FSB\text{-}FDR}$	=	Net emission reductions of FSB using FDR (tCO_2e)
CB	=	Crediting baseline ($kgCO_2e/t$)
Θ_{FSB}	=	Correction factor for FSB (default value is 1.02)
MFDR EI	=	Emission intensity of multiple FDR projects ($kgCO_2e/t$)
Project amount	=	Amount of FSB manufactured (t)

Net GHG emission reductions for a single asphalt emulsion project must be calculated as follows:

$$ER_{AE-CCPR} = \left(\frac{CB}{\theta_{AE}} - CCPR\ El\right) \cdot \frac{project\ amount}{1{,}000} \qquad (21)$$

Where:

$ER_{AE\text{-}CCPR}$	=	Net emission reductions of asphalt emulsions using CCPR (tCO_2e)
CB	=	Crediting baseline ($kgCO_2e/t$)
θ_{AE}	=	Correction factor for asphalt emulsion (default value is 1.17)
CCPR EI	=	Emission intensity of CCPR project ($kgCO_2e/t$)
Project amount	=	Amount of asphalt emulsions manufactured (t)

$$ER_{AE-CIR} = \left(\frac{CB}{\theta_{AE}} - CIR\ El\right) \cdot \frac{project\ amount}{1{,}000} \qquad (22)$$

Where:

$ER_{AE\text{-}CIR}$	=	Net emission reductions of asphalt emulsions using CIR (tCO_2e)
CB	=	Crediting baseline ($kgCO_2e/t$)
θ_{AE}	=	Correction factor for asphalt emulsion (default value is 1.17)
CIR EI	=	Emission intensity of CIR project ($kgCO_2e/t$)
Project amount	=	Amount of asphalt emulsions manufactured (t)

$$ER_{AE-FDR} = \left(\frac{CB}{\theta_{AE}} - FDR\ El\right) \cdot \frac{project\ amount}{1{,}000} \qquad (23)$$

Where:

$ER_{AE\text{-}FDR}$	=	Net emission reductions of asphalt emulsions using FDR (tCO_2e)
CB	=	Crediting baseline ($kgCO_2e/t$)
θ_{AE}	=	Correction factor for asphalt emulsion (default value is 1.17)
FDR EL	=	Emission intensity of FDR project ($kgCO_2e/t$)
Project amount	=	Amount of asphalt emulsions manufactured (t)

Net GHG emission reductions for multiple asphalt emulsion projects must be calculated as follows:

$$ER_{AE-CCPR} = \left(\frac{CB}{\theta_{AE}} - MCCPR\ El\right) \cdot \frac{project\ amount}{1{,}000} \tag{24}$$

Where:

$ER_{AE\text{-}CCPR}$	=	Net emission reductions of asphalt emulsions using CCPR (tCO_2e)
CB	=	Crediting baseline ($kgCO_2e/t$)
θ_{AE}	=	Correction factor for asphalt emulsion (default value is 1.17)
MCCPR EI	=	Emission intensity of multiple CCPR projects ($kgCO_2e/t$)
Project amount	=	Amount of asphalt emulsions manufactured (t)

$$ER_{AE-CIR} = \left(\frac{CB}{\theta_{AE}} - MCIR\ El\right) \cdot \frac{project\ amount}{1{,}000} \tag{25}$$

Where:

$ER_{AE\text{-}CIR}$	=	Net emission reductions of asphalt emulsions using CIR (tCO_2e)
CB	=	Crediting baseline ($kgCO_2e/t$)
θ_{AE}	=	Correction factor for asphalt emulsion (default value is 1.17)
MCIR EI	=	Emission intensity of multiple CIR projects ($kgCO_2e/t$)
Project amount	=	Amount of asphalt emulsions manufactured (t)

$$ER_{AE-FDR} = \left(\frac{CB}{\theta_{AE}} - MFDR\ El\right) \cdot \frac{project\ amount}{1{,}000} \tag{26}$$

Where:

$ER_{AE\text{-}FDR}$	=	Net emission reductions of asphalt emulsions using FDR (tCO_2e)
CB	=	Crediting baseline ($kgCO_2e/t$)
θ_{AE}	=	Correction factor for asphalt emulsion (default value is 1.17)
MFDR EI	=	Emission intensity of multiple FDR projects ($kgCO_2e/t$)
Project amount	=	Amount of asphalt emulsions manufactured (t)

8 MONITORING

The data parameters available at validation and those to be monitored are introduced and background information is provided in Sections 8.1 and 8.2, respectively. Section 8.3 describes general guidance for collecting and reporting all data and parameters listed in Section 8.2.

8.1 Parameters Available at Validation

8.1.1 Parameters available at validation for HMA and CCPR

Data / Parameter:	EF_M
Data unit	$kgCO_2e/kg$
Description	Material emission factor
Equations	2
Source of data	CMUGDI (2008)
Value applied	RAP: 0 Cement: 0.83 Bitumen: 0.48 Water: 0 Crushed rock: 0.056 Sand: 0.005 Manufactured aggregates: 0.006
Justification of choice of data or description of measurement methods and procedures applied	CMUGDI (2008) is comprised of national economic input-output models and publicly available resources use and emission data, which has been accessed over 1 million times by researchers or business users.
Purpose of Data	Calculation of material production emissions
Comments	Data to be updated when the material emissions factor is updated

Data / Parameter:	EF_T
Data unit	$kgCO_2e/mile$
Description	Truck's emission per mile travelled
Equations	3, 4
Source of data	TCR (2015)
Value applied	10.2
Justification of choice of data or description of measurement methods and procedures applied	Emission factors from TCR are compiled from publicly available data sources and updated each year to ensure that project proponents have the most accurate and up-to-date greenhouse gas data.
Purpose of Data	Calculation of baseline delivery emission Calculation of CCPR delivery emission
Comments	Data to be updated when the diesel emissions factor is updated

Data / Parameter:	EF_{EQ}

Data unit	$kgCO_2e/hr$
Description	Equipment emissions per hour
Equations	6, 8
Source of data	EPA (2012). "Engine Certification Data for Heavy Truck, Buses, and Engines."<http://www.epa.gov/oms/certdata.htm#largeng>.
Value applied	Appendix B
Justification of choice of data or description of measurement methods and procedures applied	The engine emission information is obtained from the EPA off-road engine certification database and further stratified equipment types by engine maker and horsepower rating. The database created for equipment emission estimation is presented in Appendix B
Purpose of Data	Calculation of baseline emission Calculation of CCPR emission
Comments	Data was collected one time and must be updated when more strict emission standard is implemented nationwide

Data / Parameter:	EF_{EL}
Data unit	$kgCO_2e/kWh$
Description	Electricity emission factor
Equations	7
Source of data	EPA (2017)
Value applied	Refer to EPA's eGRID summary tables for electricity emission factors for different regions
Justification of choice of data or description of measurement methods and procedures applied	Emission factors from eGRID summary tables are compiled by the EPA and updated each year to ensure that project proponents have the most accurate and up-to-date greenhouse gas data. The calculation of electricity emission must use region-specific emission factors.
Purpose of Data	Calculation of baseline emission Calculation of CCPR emission
Comments	The project proponent must use the most recent eGRID summary tables available.

Data / Parameter:	CF
Data unit	Between 0 and 1
Description	Conversion factor: the percentage of equipment operating time in the total labor time
Equations	9
Source of data	Liu et al. (2016)

Value applied	Milling machine: 0.66 Backhoe: 0.33 Loader: 0.33 Sweeper: 0.55 Paver: 0.50 Roller: 0.59 Truck: 1
Justification of choice of data or description of measurement methods and procedures applied	Three projects were observed on-site to count the effective operation time of each piece of equipment. The percentage utilization (PU) was calculated using the effective operation time divided by the total labor hours. The average *PU* values are 0.55 for the asphalt-milling machine; 0.10 for the backhoe; 0.10 for the bobcat/loader; 0.4 for the sweeper/broom; 0.10 for the excavator; 0.33 for the paver and 0.45 for the roller. Different *PU*s will produce different amounts of GHG emissions. According to a study by Lewis et al. (2009), the emission rate of idling equipment is about one quarter of the emission rate of the operating equipment. This difference is simplified and incorporated into the emission calculation as an average conversion factor (CF), which equals *PU+0.25(1-PU)*.
Purpose of Data	Calculation of baseline equipment emissions Calculation of CCPR equipment emissions
Comments	Data does not need to be updated

Data / Parameter:	DF
Data unit	Between 0 and 1
Description	For conservativeness, a discount factor (DF) must be applied when a map distance calculator is used to estimate hauling distance. DF is equal to 0 if using actual logged miles.
Equations	3, 4
Source of data	On-site observations
Value applied	0.1
Justification of choice of data or description of measurement methods and procedures applied	Ten projects were observed on site to count the distance between map and equipment odometer. Hauling distance = Map distance × (1+DF)
Purpose of Data	Calculation of baseline equipment emissions Calculation of CCPR equipment emissions
Comments	Data does not need to be updated

8.1.2 Parameters available at validation for CIR or FDR

Data / Parameter:	EF_T
Data unit	$kgCO_2e/mile$
Description	Truck's emission per mile travelled
Equations	3, 4
Source of data	TCR (2015)
Value applied	10.2
Justification of choice of data or description of measurement methods and procedures applied	Emission factors from TCR are compiled from publicly available data sources and updated each year to ensure that project proponents have the most accurate and up-to-date greenhouse gas data.
Purpose of Data	Calculation of CIR or FDR delivery emissions
Comments	Data to be updated when the diesel emissions factor is updated

Data / Parameter:	EF_M
Data unit	$kgCO_2e/kg$
Description	Material emission factor
Equations	1
Source of data	CMUGDI (2008)
Value applied	RAP: 0 Cement: 0.83 Bitumen: 0.48 Water: 0
Justification of choice of data or description of measurement methods and procedures applied	CMUGDI (2008) is comprised of national economic input-output models and publicly available resources use and emission data, which has been accessed over 1 million times by researchers or business users.
Purpose of Data	Calculation of material production emissions
Comments	Data to be updated when the material emissions factor is updated

Data / Parameter:	EF_{EQ}
Data unit	$kgCO_2e/hr$
Description	Equipment emission per hour
Equations	6, 7
Source of data	EPA (2012). "Engine Certification Data for Heavy Truck, Buses, and Engines."<http://www.epa.gov/oms/certdata.htm#largeng>.

Value applied	Appendix B
Justification of choice of data or description of measurement methods and procedures applied	The engine emission information is from the EPA off-road engine certification database and stratified by equipment type, engine make, and horsepower rating. The database created for equipment emission estimation is presented in Appendix B.
Purpose of Data	Calculation of CIR or FDR emission
Comments	Data was collected one time and must be updated when more strict emissions standards are implemented nationwide

8.2 Data and Parameters Monitored

8.2.1 Data and Parameters Monitored for HMA and CCPR

Data / Parameter	W_M
Data unit	Kg
Description	Quantity of each raw material used to produce HMA or FSB or asphalt emulsions
Equations	2
Source of data	Data source acquired through monitoring
Description of measurement methods and procedures to be applied	The data can be obtained from plant production records
Frequency of monitoring/recording	Once per project
QA/QC procedures to be applied	Cross-checking of reported quantity versus trucking manifests to confirm quality measurement.
Purpose of Data	Calculation of HMA material emissions Calculation of CCPR material emissions
Comments	

Data / Parameter	$Distance_P$
Data unit	Miles
Description	The total miles that trucks travelled to supply raw materials to HMA plant or FSB plant
Equations	3
Source of data	Data derived from monitoring
Description of measurement methods and procedures to be applied	Distance can be obtained from the daily report of truck drivers or measured by approximation

Frequency of monitoring/recording	Once per project
QA/QC procedures to be applied	Cross-checking of reported mileage versus trucking manifests to confirm quality measurement.
Purpose of Data	Calculation of HMA to-plant delivery emissions Calculation of CCPR to-plant delivery emission
Comments	

Data / Parameter	$Distance_S$
Data unit	Miles
Description	The total miles that trucks travelled to supply products to the job site
Equations	4
Source of data	Data derived from monitoring
Description of measurement methods and procedures to be applied	Distance can be obtained from the daily report of truck drivers or measured by approximation
Frequency of monitoring/recording	Once per project
QA/QC procedures to be applied	Cross-checking of reported mileage versus trucking manifests to confirm quality measurement.
Purpose of Data	Calculation of HMA to-site delivery emissions Calculation of CCPR to-site delivery emission
Comments	

Data / Parameter	C_{EL}
Data unit	*kWh*
Description	Electricity consumption of the whole plant
Equations	7
Source of data	Data derived through monitoring
Description of measurement methods and procedures to be applied	The use of electricity can be obtained from plant's utility bills
Frequency of monitoring/recording	Utility bills must be collected monthly or quarterly
QA/QC procedures to be applied	Cross-checking of reported consumption versus utility bills to confirm quality measurement.
Purpose of Data	Calculation of CCPR in-plant production emissions

Comments	

Data / Parameter	Project amount
Data unit	t
Description	Output quantity of FSB and asphalt emulsions
Equations	2, 3, 4, 6, 7, 8
Source of data	Data derived through monitoring
Description of measurement methods and procedures to be applied	Data can be reported according to plant production records
Frequency of monitoring/recording	Once per project
QA/QC procedures to be applied	Cross-checking of reported amount versus production logs to confirm quality measurement.
Purpose of Data	Calculation of CCPR emission
Comments	

Data / Parameter	HR_{EQ}
Data unit	Hour
Description	Total operating hours of on-site use of equipment
Equations	8
Source of data	Data derived through monitoring
Description of measurement methods and procedures to be applied	Data can be obtained from daily report of on-site contractors
Frequency of monitoring/recording	Once per project
QA/QC procedures to be applied	Cross-checking of reported data versus labor hours to confirm quality measurement.
Purpose of Data	Calculation of HMA equipment emissions Calculation of CCPR equipment emissions
Comments	Data does not need to be updated

Data / Parameter	HR_{LA}
Data unit	Hour
Description	Total labor hours of on-site use of equipment
Equations	9

Source of data	Data derived from monitoring
Description of measurement methods and procedures to be applied	Labor hours can be obtained from the daily reports of contractors
Frequency of monitoring/recording	Once per project
QA/QC procedures to be applied	Cross-checking of reported hours versus daily reports to confirm quality measurement.
Purpose of Data	Calculation of HMA installation emissions Calculation of CCPR installation emission
Comments	

Data / Parameter	DE
Data unit	lb/cu.ft
Description	Density of FSB or asphalt emulsions
Equations	14
Source of data	Data derived from monitoring
Description of measurement methods and procedures to be applied	Density data can be obtained from project specifications
Frequency of monitoring/recording	Once per project
QA/QC procedures to be applied	Cross-checking of reported data versus theoretical density to confirm quality measurement.
Purpose of Data	Calculation of CCPR emission reduction
Comments	

Data / Parameter	LC
Data unit	
Description	Layer coefficient of FSB or asphalt emulsions
Equations	14
Source of data	Data derived from monitoring
Description of measurement methods and procedures to be applied	Layer coefficient can be obtained from project specifications
Frequency of monitoring/recording	Once per project

QA/QC procedures to be applied	Cross-checking of reported data versus DOT commonly used coefficients to confirm quality measurement.
Purpose of Data	Calculation of CCPR emission reduction
Comments	

8.2.2 Data and Parameters Monitored for CIR or FDR

Data / Parameter:	W_M
Data unit	Kg
Description	The weight of each raw material used to produce FSB or asphalt emulsions
Equations	2
Source of data	Data derived from monitoring
Description of measurement methods and procedures to be applied	The data can be obtained from project records.
Frequency of monitoring/recording	Once per project
QA/QC procedures to be applied	Cross-checking of reported quantity versus trucking manifests to confirm quality measurement.
Purpose of Data	Calculation of CIR or FDR material emissions
Comments	Data does not need to be updated

Data / Parameter	Project amount
Data unit	T
Description	Output quantity of FSB and asphalt emulsions
Equations	2, 4, 6
Source of data	Data derived through monitoring
Description of measurement methods and procedures to be applied	The data can be reported according to plant production records
Frequency of monitoring/recording	Once per project
QA/QC procedures to be applied	Cross-checking of reported quantity versus trucking manifests to confirm quality measurement.
Purpose of Data	Calculation of CIR or FDR emission
Comments	

Data / Parameter:	L
Data unit	Miles
Description	Length of damaged pavement
Equations	11
Source of data	Data derived from monitoring
Description of measurement methods and procedures to be applied	The data can be obtained from project records
Frequency of monitoring/recording	Once per project
QA/QC procedures to be applied	Cross-checking of reported mileage versus map distance to confirm quality measurement.
Purpose of Data	Calculation of CIR or FDR installation emissions
Comments	

Data / Parameter:	Distance
Data unit	Miles
Description	The total miles that trucks travelled to supply raw materials to the job site
Equations	6
Source of data	Data derived from monitoring on site
Description of measurement methods and procedures to be applied	Distance can be obtained from the daily report of truck drivers or measured by approximation
Frequency of monitoring/recording	Once per project
QA/QC procedures to be applied	Cross-checking of reported mileage versus trucking manifests to confirm quality measurement.
Purpose of Data	Calculation of CIR or FDR to-site delivery emissions
Comments	

Data / Parameter:	S
Data unit	Mph
Description	Running speed of cold recycler
Equations	11

Source of data	Data derived from monitoring project site
Description of measurement methods and procedures to be applied	The data can be obtained from project records
Frequency of monitoring/recording	Once per project
QA/QC procedures to be applied	Cross-checking of reported speed versus driver's log to confirm quality measurement.
Purpose of Data	Calculation of CIR or FDR installation emissions
Comments	

Data / Parameter	DE
Data unit	lb/cu.ft
Description	Density of FSB or asphalt emulsions
Equations	14
Source of data	Data derived from monitoring
Description of measurement methods and procedures to be applied	Density data can be obtained from project specifications
Frequency of monitoring/recording	Once per project
QA/QC procedures to be applied	Cross-checking of reported data versus theoretical density to confirm quality measurement.
Purpose of Data	Calculation of CIR or FDR emission reduction
Comments	

Data / Parameter	LC
Data unit	
Description	Layer coefficient of FSB or asphalt emulsions
Equations	14
Source of data	Data derived from monitoring
Description of measurement methods and procedures to be applied	Layer coefficient can be obtained from project specifications
Frequency of monitoring/recording	Once per project
QA/QC procedures to be applied	Cross-checking of reported data versus DOT commonly used coefficients to confirm quality measurement.

Purpose of Data	Calculation of CIR or FDR emission reduction
Comments	

8.3 Description of the Monitoring and Quality Assurance Plan

Project proponents must detail the procedures for collecting and reporting all data and parameters listed in Section 8.2. Input data must be checked for typical errors, including inconsistent physical units, unit conversion errors, transcription errors, and missing data for specific time periods or physical units.

All data collected as a part of monitoring process must be archived electronically and be kept at least for two years after the end of the last project crediting period. All direct measurements must be conducted with calibrated measurement equipment according to relevant industry standards. Where direct measurements are not applied, project proponents must demonstrate that the values used for the project are reasonably conservative, considering the uncertainty associated with these values.

Quality assurance/quality control procedures must also be applied to add confidence that all measurements and calculations have been made correctly. These may include, but are not limited to:

- Protecting records of monitored data (hard copy and electronic storage)
- Checking data integrity on a regular and periodic basis (manual assessment, comparing redundant metered data, and detection of outstanding data/records)
- Comparing current estimates with previous estimates to identify any abnormal readings
- Providing sufficient training to project participants to install and maintain project devices
- Establishing minimum experience and requirements for operators in charge of project and monitoring
- Performing recalculations to make sure no mathematical errors have been made.

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APPENDIX A: DETERMINATION OF PERFORMANCE BENCHMARK FOR ADDITIONALITY AND CREDITING BASELINE

Quantification of Baseline Emissions

The performance benchmark determined for use in this methodology represents the quantity of GHGs emitted from producing and installing one metric ton of HMA. This was calculated based on emission intensities that sum the material emission intensity, to-plant delivery emissions intensity, in-plant production emission intensity, to-site delivery emissions intensity, and on-site installation emission intensity.

The component materials of HMA include bitumen binders, crushed rock, sand, gravel, RAP and manufactured aggregates. GHG emissions from material production and transportation include:

1) The embodied GHG emissions of construction materials, which are primarily from energy consumption and chemical combustion associated with material production; and,

2) GHG emissions from fuel consumption for transporting materials to production facilities.

Primary equipment/vehicles used for placing HMA include asphalt paving machines, backhoes, bobcat/loaders, sweeper/brooms, air compressors, rollers, trucks, etc. Equipment operation information was gathered from projects sampled using HMA. For each project, the operation information for trucks, which deliver the hot mix to the job site and carry the RAP from the job site to the hot mix plant, was obtained from truck driver reports. The truck driver reports record time in and out from the job site for each truck, the total mileage travelled, and the gallons of diesel used by each truck. The recorded information was then used for estimating the GHG emissions from the trucks when transporting the raw materials/products and loading/dumping the materials at both the job site and the hot mix plant. The operation of the rest of the equipment/vehicles was obtained from the contractor’s daily report in terms of total labor hours.

The emissions associated with materials, to-plant delivery, and in-plant production were estimated through the survey of sixteen hot mix producers from Maryland, Virginia, and Pennsylvania in 2013. The six hot mix producers included in the survey were WMA certified. The average WMA output percentage was 19%. The average percentage of RAP in our survey is 23%, higher than 2011 statistic nationwide average value of 19% reported by NAPA (2013). Higher percentage of RAP implies a more conservative benchmark. In addition, this survey covered typical fuel types for HMA facilities and the proportion of each fuel type approximately represented fuel structure of HMA plants (EPA, 2000). Out of sixteen plants in the survey, ten plants consumed natural gas, three consumed oil, and three consumed propane. This proportion is aligned with the number published by EPA that natural gas fuel is used to produce 70% to 90% of the HMA.

Each producer reported raw material consumption, delivery distance, and fuel use by the rotary dryer plus additional fuels used inside the gate by equipment and vehicles on a quarterly basis in 2013. GHG emission intensity was determined following Equations A1 to A5 below. A calculation example for an individual HMA facility is displayed in Table A1 and a summary result for the sixteen facilities is displayed in Table A2.

Raw material production:

$$EI_M = \frac{EF_M \times W_M}{Project\ amount} \quad \text{(A1)}$$

Where:

EI_M	=	Emission intensity of raw material production (kgCO_2e/t)
EF_M	=	Material emission factor (kgCO_2e/kg)
W_M	=	Material weight (kg)
Project amount	=	Amount of HMA manufactured (t)

Plant production:

$$EI_P = EI_D + EI_E \quad \text{(A2)}$$

Where:

EI_P	=	Emission intensity of in-plant production (kgCO_2e/t)
EI_D	=	Emission intensity of diesel-consuming activities (kgCO_2e/t)
EI_E	=	Emission intensity of electricity-consuming activities (kgCO_2e/t)

$$EI_D = \frac{EF_{EQ} \times HR_{EQ}}{Project\ amount} \quad \text{(A3)}$$

Where:

EI_D	=	Emission intensity of diesel-consuming activities (kgCO_2e/t)
EF_{EQ}	=	Equipment emission factor (kgCO_2e/hour)
HR_{EQ}	=	Equipment operation hours (hour)
Project amount	=	Amount of HMA manufactured (t)

$$EI_E = \frac{EF_{EL} \times C_{EL}}{Project\ amount} \quad \text{(A4)}$$

Where:

EI_E	=	Emission intensity of electricity-consuming activities (kgCO_2e/t)
EF_{EL}	=	Electricity emission factor (kgCO_2e/kWh)
C_{EL}	=	Electricity consumption (kWh)
Project amount	=	Amount of HMA manufactured (t)

Raw material delivery:

$$EI_{PD} = \frac{Distance_P \times EF_T}{Project\ amount} \quad \text{(A5)}$$

Where:

EI_{PD}	=	Emission intensity of to-plant delivery ($kgCO_2e/t$)
$Distance_P$	=	Distance to plant (mile)
EF_T	=	Truck emission factor ($kgCO_2e$/mile)
Project amount	=	Amount of HMA manufactured (t)

Table A1: Example Calculation of GHG Emissions from Hot Mix Facility

HMA Plant 1	Operation period: 7/1/2013 to 9/30/2013					
HMA output	83,612 t		**Type:** Drum			
Raw Material Production						
	Quantity		Mix design		$kgCO_2$/kg	tCO_2e
Crushed Rock	68562.4	t	82%		0.056	3839.50
Sand	6689.0	t	8%		0.005	33.45
Gravel	0.0	t			0.017	0.00
Rap	4180.6	t	5%		0	0.00
Other Recycled Aggregates	0.0	t			0.006	0.00
Bitumen	4180.6	t	5%		0.48	2006.70
Water	0.0	t				0.00
Subtotal						**5879.65**
Plant Production						
		Usage	Unit	Emission factor		tCO_2e
Plant Combustion	Fuel oil	158614	GAL	10.18	kg/gal	1614.69
	Natural gas		DTH	53.02	kg/MMBtu	0.00
	Recycled oil		GAL	9.99	kg/gal	0.00
Equipment & Vehicles	Diesel fuel	5336	GAL	10.21	kg/gal	54.48

	Gasoline		GAL	8.78	kg/gal	0.00
Line Power	Electricity	297000	kWh	0.51	kg/kWh	150.80
Subtotal						**1819.98**
Raw Material Delivery						
	Distance	Round	Fuel use	Emission factor		tCO_2e
Bitumen Fleet Delivery	65 km	185.8	1 gal/mi	10.2	kg/gal	153.00
Crushed Rock Fleet Delivery	11 km	3047.2	1 gal/mi	10.2	kg/gal	424.64
Sand Rock Fleet Delivery	31 km	297.3	1 gal/mi	10.2	kg/gal	116.75
Subtotal						**694.39**
Total emissions, tCO_2e	*8394.01*		**Emission intensity**, $kgCO_2e/t$			*99.39*

Table A2: Summary of GHG Emissions from Hot Mix Facilities and Their Upstream Raw Material Productions

	GHG emissions from sampling facilities, $kgCO_2e/t$ HMA															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Raw material	69.6	68.1	65.6	56.8	56.3	47.8	44.8	48.9	42.4	44.7	53.3	60.1	55.9	54.4	48.6	47.2
In-plant	21.6	18.6	25.3	14.5	17.5	20.8	15.4	2.4	10.4	16.7	17.4	17.5	19.9	22	19.5	14.7
Delivery	8.2	5.2	8.4	40.7	2.8	12.7	15.9	8.1	8.2	11.6	11.8	11.0	21.2	33.6	22.1	18.1
Total	99.4	91.9	99.3	111.9	76.8	81.3	76.2	59.4	60.8	72.9	82.4	88.5	96.9	110.1	90.2	80.0

The emissions associated with to-site delivery and on-site installation were estimated through the survey of patching and roadway projects. Ten HMA patching projects were surveyed to calculate baseline emissions for patching projects. For each project, the operation information for trucks, which deliver the hot mix to the job site and carry the RAP from the job site to the central plant, was obtained from truck driver reports. The truck driver reports recorded the time in and out from the job site for each truck, total mileage travelled, and gallons of diesel used by each truck. The recorded information was then used for estimating the GHG emissions from the trucks when transporting the recycled materials/products and loading/dumping the materials at both the job site and the central plant. The operation of the rest of the equipment/vehicles was obtained from the contractor’s daily report in terms of total labor hours.

Three out of ten projects were selected for a manual assessment of the utilization rate of each individual piece of equipment[7]. The percentage utilization (PU) was calculated using the effective operation time divided by the total labor hours. The average *PU* values are 0.55 for the asphalt-milling machine; 0.10 for the backhoe; 0.10 for the bobcat/loader; 0.4 for the sweeper/broom; 0.10 for the excavator; 0.33 for the paver and 0.45 for the roller. Different equipment utilization levels will produce different amounts of GHG emissions. According to a study by Lewis et al. (2009), the emission rate of idling equipment is about one quarter of the emission rate of the operating equipment. This difference was simplified and incorporated into the emission calculation as an average conversion factor (CF), which equals *PU+0.25(1-PU)*. Calculation equations for equipment emissions during on-site installation are provided below, and the estimation results are displayed in Table A3.

The on-site installation EI (EI_I) is calculated as follows:

$$EI_I = \frac{EF_{EQ} \times HR_{EQ}}{Project\ amount} \quad (A6)$$

Where:

EI_I	=	Emission intensity of pavement installation ($kgCO_2e/t$)
EF_{EQ}	=	Equipment emission factor ($kgCO_2e/hour$)
HR_{EQ}	=	Equipment operation hours (hour)
Project amount	=	Amount of HMA installed (t)

$$HR_{EQ} = HR_{LA} \times CF \quad (A7)$$

Where:

HR_{EQ}	=	Equipment operation hours (hour)
HR_{LA}	=	Labor hours (hour)
CF	=	Conversion factor

Baseline emissions for roadways are generated from the Project Emission Estimator (PE-2). PE-2 collected and organized construction and rehabilitation data from 11 Michigan Department of Transportation HMA pavement, re-construction, rehabilitation, and maintenance projects throughout the State of Michigan in 2011. The amount of GHG emissions from each project is summarized in Table A4.

Results show that the emissions from the hot mix facility and its upstream raw material production range from 59.4$kgCO_2e/t$ HMA to 111.9$kgCO_2e/t$ HMA with an average value of 86.1$kgCO_2e/t$ HMA; the emissions from HMA installation in patching projects range from 42.7 $kgCO_2e/t$ to 135.2 $kgCO_2e/t$ with an average value of 64.6 $kgCO_2e/t$; the emissions from HMA installation projects performed on roadways range from 4.5 $kgCO_2e/t$ to 145.1 $kgCO_2e/t$ with an average value of 55.7 $kgCO_2e/t$.

[7] The patch work was located at the Howard Crossing Apartment, Ellicott City, MD. The sizes of the three patches were 884 square feet, 6,969 square feet and 10,080 square feet.

Table A3: GHG Emissions from HMA Installation in Patching Projects

	EF(g/hr/hp)	hp	Conversion factor	Operation hours of sampled projects									
				1	2	3	4	5	6	7	8	9	10
Milling	887.1	150	0.66	7.2	31.8	8.9	0	7.9	10.9	0	0	5.3	6.2
Backhoe	1025.8	80	0.33	3.5	0	4.3	0	3.9	5.3	3.4	3.9	2.6	3.0
Loader	1025.8	142	0.33	7.1	31.0	8.7	11.7	7.8	10.7	6.8	3.9	5.2	6.1
Sweeper	940.9	115	0.55	12.1	12.1	14.8	19.8	13.2	18.1	11.5	13.2	4.4	10.4
Paver	984.7	130	0.50	5.4	9.7	6.7	17.9	5.9	8.2	10.4	5.9	3.9	4.7
Roller	1025.6	45	0.59	6.4	11.4	15.8	42.3	14.1	19.3	18.5	14.1	9.4	5.5
Truck (on-site)	886.6	255	1	15.5	99.8	0.1	0.1	4	8	0.1	0.17	10.6	0.1
Truck (off-site)	10.2kg/mi	mile	1	530	0	410	731	898	372	838	1008	956	657
Placed HMA, t				100	727	195	291	195	218	245	329	339	140
Delivery distance, mile				66	23	26	31	58	21	43	38	35	59
GHG ($kgCO_2e/t$)				135.2	47.3	52.6	53.3	79.1	59.6	54.3	42.7	45.0	76.5

Table A4: GHG Emissions from HMA Replacement on Roadways

		US-131	US-31	US-41	I-69	M-20	M-55	M-28	US-41
Asphaltic materials	t	20428	74784	19512	23250	23250	10939	891	13261
Equip. emission	tCO_2	252.1	874.7	1287.5	3373	303.3	48.9	127.1	592
GHG	**$kgCO_2/t$**	**12.3**	**11.7**	**66.0**	**145.1**	**18.8**	**4.5**	**142.6**	**44.6**

Note:

- US-131 Asphalt Crack Relief Layer; Reconstruction; Crush and Shape, 6 lane miles
- US-31 HMA Reconstruct, 13.08 lane miles
- US-41 HMA Reconstruct and Roadway Realignment, 6.04 lane miles
- I-69 Concrete Reconstruct, 40.56 lane miles
- M-20 HMA Cold Milling and Overlay, 16.64 lane miles

- M-55 HMA Cold Milling and Resurfacing, 13.66 lane miles
- M-28 Concrete Patch Repairs and HMA Resurfacing, 9.26 lane miles
- US-41 Road Reconstruction HMA and Concrete, 4.4 lane miles

Determination of Performance Benchmark for Additionality and Crediting Baseline

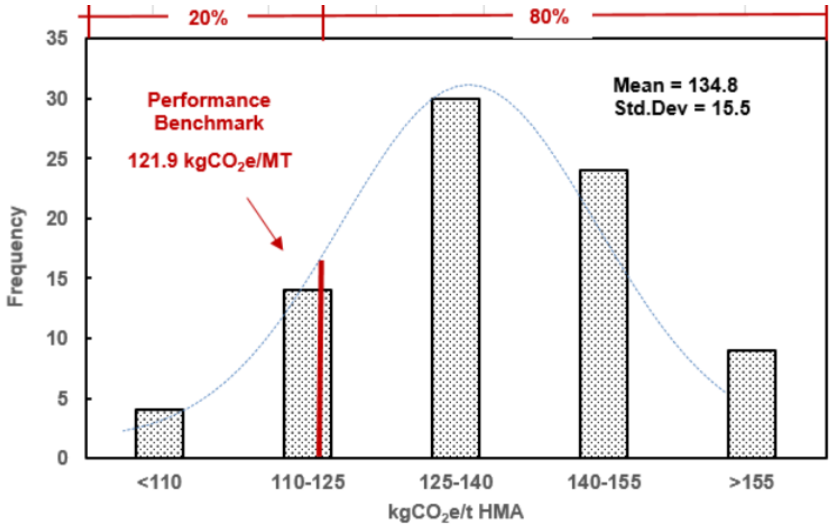
Once the baseline emissions were determined based on a sample of HMA producers and projects were surveyed to represent the sectoral emission performance, this estimation was then applied to determine the performance benchmark which is the same for both additionality and the crediting baseline.

Due to the significant impact of project type and delivery distance on the total amount of GHG emissions, performance benchmarks are proposed for specific project types and the one-way distances between a HMA plant and a job site. Out of a total of ten surveyed projects, six have a hauling distance of less than 40 miles, while four have a hauling distance of greater than 40 miles. Combined with sixteen facilities, the total sampling points were 96 (=16×6) for HMA projects (< 40mi) and 64 (=16×4) for HMA projects (>40mi). The combination covers all the possible values of emission intensities of the sampled projects. Statistical analysis of the sampling population shows that when the distance is less than 40 miles, the average baseline emission (μ) is 134.8 kgCO_2e/t HMA and the standard deviation (σ) is 15.5 kgCO_2e/t HMA, as represented in Figure A1 below. When the distance is larger than 40 miles, the average baseline emission (μ) is 170.3 kgCO_2e/t HMA and the standard deviation (σ) is 33.6 kgCO_2e/t HMA. According to UNFCCC (2006), performance benchmarks may be defined as an emission level that is exceeded by 80% of existing HMA projects. Given the sampled projects approximate a normal distribution, the performance benchmark must be 121.9 kgCO_2e/t HMA (equals to μ- 0.84σ) for HMA projects (< 40mi), which is illustrated in Figure A1. The calculation follows a standard cumulative distribution function using normal distribution mean and standard deviation. The performance benchmark is 142.4 kgCO_2e/t HMA for HMA projects (>40mi) as calculated as follows:

Performance benchmark = Average baseline emission – 0.84 × Standard deviation (A9)

For roadway projects, the average baseline emission (μ) is 141.8 kgCO_2e/t HMA and the standard deviation (σ) is 56.2 kgCO_2e/t HMA., and therefore the performance benchmark of roadway projects is 95.1kgCO_2e/t HMA.

Figure A1: Illustration of performance benchmark for hauling distance less than 40 miles


20%
80%
Performance Benchmark
121.9 kgCO2e/MT
Mean = 134.8
Std.Dev = 15.5
Frequency
35
30
25
20
15
10
5
0
<110
110-125
125-140
140-155
>155
kgCO2e/t HMA

APPENDIX B: EMISSIONS FACTORS FOR CONSTRUCTION EQUIPMENT

Equipment catalog	Manufacturer	hp	Emission rate (g/hp/hr)	Emission factor (kg CO_2e/hr)
Air Compressors	Emglo	5.0	1301.3	6.5
Air Compressors	Mi-T-M	5.5	1301.3	7.2
Air Compressors	Sullair	61.0	948.8	57.9
Air Compressors	Others	19.5	1183.8	23.8
Cement and Mortar Mixers	MultiQuip	13.0	1301.3	16.9
Cement and Mortar Mixers	Others	13.0	1301.3	16.9
Cold recycler	Wirtgen 7'	429.0	948.8	407.0
Cold recycler	Wirtgen 9'	580.0	948.8	550.3
Cold recycler	Wirtgen 12'	950.0	948.8	901.4
Cold recycler	Other	NA	NA	535.9
Dumpers/Tenders	Terex	300.0	824.4	247.3
Dumpers/Tenders	Ford	210.0	948.8	199.3
Dumpers/Tenders	Others	255.0	886.6	226.1
Excavators	JCB	128.0	1030.9	132.0
Excavators	John Deere	141.0	1020.7	143.9
Excavators	Kobelco	112.0	1067.5	119.6
Excavators	Others	127.0	1039.7	132.0
Forklifts	JCB	76.0	1030.9	78.3
Forklifts	John Deere	73.0	1020.7	74.5
Forklifts	Others	74.0	1025.8	75.9
Off-Highway Trucks	Terex	260.0	863.6	224.5
Off-Highway Trucks	Caterpillar	210.0	948.8	199.3
Off-Highway Trucks	John Deere	265.0	1020.7	270.5
Off-Highway Trucks	Others	150.7	984.0	148.3
Milling machine	Others	150.0	881.7	132.3

Equipment catalog	Manufacturer	hp	Emission rate (g/hp/hr)	Emission factor (kg CO_2e/hr)
Paver	Barber-Greene	115.0	1020.7	117.4
Paver	Wheeler Machinery	142.0	948.8	134.7
Paver	Others	128.5	984.7	126.5
Plate Compactors	Bomag	3.9	1471.1	5.7
Plate Compactors	MultiQuip	4.0	1301.3	5.2
Plate Compactors	Wacker	9.0	1301.3	11.7
Plate Compactors	Others	5.6	1357.9	7.6
Pressure Washers	Honda	9.0	1301.3	11.7
Pressure Washers	Mi-T-M	13.0	1301.3	16.9
Pressure Washers	Shark-Karcher	11.0	1301.3	14.3
Pressure Washers	Others	11.0	1301.3	14.3
Pumps	Gorman-Rupp	72.0	1301.3	93.7
Rollers	Bomag	44.0	1063.2	46.8
Rollers	Dynapac	85.0	824.4	70.1
Rollers	MultiQuip	18.0	1189.1	21.4
Rollers	Others	45.2	1025.6	46.3
Rough Terrain Forklifts	Case	73.0	824.4	60.2
Rough Terrain Forklifts	JCB	76.0	1014.7	77.1
Rough Terrain Forklifts	John Deere	73.0	1020.7	74.5
Rough Terrain Forklifts	Others	74.0	953.3	70.5
Rubber Tired Dozers	John Deere	90.0	1020.7	91.9
Rubber Tired Dozers	Others	90.0	1020.7	91.9
Rubber Tired Loaders	JCB	150.0	1030.9	154.6
Rubber Tired Loaders	John Deere	134.0	1020.7	136.8
Rubber Tired Loaders	Others	142.0	1025.8	145.7
Skid Steer Loaders	Bobcat	46.0	1179.4	54.3

Equipment catalog	Manufacturer	hp	Emission rate (g/hp/hr)	Emission factor (kg CO_2e/hr)
Skid Steer Loaders	John Deere	76.0	1020.7	77.6
Skid Steer Loaders	Toro	20.0	1189.1	23.8
Skid Steer Loaders	Others	47.3	1129.7	53.5
Sweepers/Scrubbers	Schwarz Industries	115.0	1020.7	117.4
Sweepers/Scrubbers	Schwarz Industries	250.0	824.4	206.1
Sweepers/Scrubbers	Victory	190.0	977.6	185.7
Sweepers/Scrubbers	Others	185.0	940.9	174.1
Track Loaders	John Deere	90.0	1020.7	91.9
Track Loaders	Takeuchi	81.0	1137.2	92.1
Track Loaders	Others	85.5	1078.9	92.2
Backhoes	JCB	86.0	1030.9	88.7
Backhoes	John Deere	86.0	1020.7	87.8
Backhoes	Others	81.7	1025.8	83.8
Trenchers	DitchWitch walk-behind	17.5	1020.7	17.9
Trenchers	DitchWitch ride-on	42.0	1063.2	44.7
Trenchers	Vermeer Walk-behind	23.0	1189.1	27.3
Trenchers	Vermeer ride-on	46.0	1063.2	48.9
Trenchers	Others	28.9	1084.1	31.3
Water Trucks	Ford	240.0	824.4	197.9
Water Trucks	Kenworth	475.0	948.8	450.7
Water Trucks	Freightliner	300.0	948.8	284.6

Data source: EPA (2012)

APPENDIX C: EXPERT REVIEW PANEL FOR PERFORMANCE BENCHMARKS

Expert Review Panel

An expert panel met on June 23, 2014 at the University of Maryland to review and provide feedback on the levels of performance benchmarks. Experts in attendance included the following:

- Tuncer Edil – Professor Emeritus, Geological Engineering and Civil & Environmental Engineering, University of Wisconsin-Madison
- Gerardo Flintsch – Professor of Civil and Environmental Engineering, Virginia Polytechnic Institute
- Jeff Graf – Executive Vice President, Maryland Paving Inc.
- Luke Wisniewski – Chief Climate Change, Maryland Department of Environment

Other Participants

Other participants included the following:

- Harold Green, GRR
- Dan Shaw, GRR
- Chandra Akisetty PE, GRR
- Qingbin Cui, University of Maryland
- Xiaoyu Liu, University of Maryland
- Sara Berman, Straughan Environmental
- Deborah Sward, Straughan Environmental
- Andrew Beauchamp, Verra
- John Holler, Verra

The meeting included introductions from members of the team, Verra staff, and a summary of the methodology development process. The Expert Review Panel members then asked questions, provided their feedback, and had a discussion with the methodology development team. The following is a summary of the discussion.

Expert Review Panel Discussion

Q1 Luke Wisniewski: Does the use of a thicker base cause any issues matching it to existing roads or cause logistical issues?

Response: No, usually when doing a road rehabilitation –milling out the existing pavement and constructing foam and hot mix—a project will have to mill out an inch deeper in order to compensate for the use of the FSB. If a project is removing 4” of HMA base for replacement with a 5” thick FSB layer, the road will be milled down further to compensate. It also depends on how and where the project occurs and the restrictions and specifications on the grade. If the grade is not to be changed the road will be milled deeper. If the grades can be changed, a transition will be made between the existing pavement and the sections with a layer of FSB. Each project will specify whether the grades need to match or a transition can be made.

Q2 Gerardo Flintsch: The structural layer coefficient of bitumen for cold mix being used is 0.32. Where did this value come from? Please provide further references, and I have a reference I can add (shared with the team through email).

Response: The methodology is being revised to clearly identify how the structural coefficient of 0.32 was developed. The value came from a study conducted by the University of Maryland (UMD) for the Maryland State Highway Administration (MD SHA). UMD collected core samples and had them tested at a lab. The Team conducted some falling weight deflectometer (FWD) tests to determine the resilient modulus (M_r). From the core samples tested and the FWD test the team calculated the layer coefficient. The results of the structural layer coefficient from the samples ranged from 0.38 to 0.4. The Team also conducted a Nomograph test following the Wirtgen Core Recycling Mix Manual and examined the values for the asphalt cold mix. Comparing the results allowed for a broader data source to review. In order to be more conservative in our value and to accurately represent all conditions, the team averaged the results from studies conducted throughout the world and developed 0.32 as the structural layer coefficient.

A clarification to the methodology will be made to clearly identify that FSB uses only 1.5-2% more material per cubic foot than HMA. This is because the densities are different. The density for HMA is 160 lbs per cubic ft and for FSB it is 130 lbs per cubic ft. FSB’s layer coefficient is lower than HMA, thus requiring 25% more volume while only requiring 1.5-2% more material to maintain the required specification layer coefficient. The differences between volume and weight will be clarified further within the methodology for calculating emission savings.

The methodology team will include further references supporting the methodology findings. A report by Charles Schwartz (team member) and Sadaf Khosravifar for “State Highway Administration Research Report: Design and Evaluation of Foamed Asphalt Base Materials” outlines the role of FSB.

Q3 Gerardo Flintsch: One discussion in a lifecycle assessment (LCA) is how do we address the physical stock energy of the asphalt binder? The LCA can be very high. How does the team address this?

Response: The comment is being considered and taken into account in the methodology. Materials emissions factors are coming from Environmental Protection Agency’s database Department of Energy’s, EIO-LCA and other databases publicly available and referenced in the methodology. The equipment emission factors are coming from EPA tier emission standards, and the assembly emission factors come from the Inventory of Carbon and Energy developed by University of Bath, UK. This reference provides material emission factors.

Q4 Tuncer Edil: Considering the maintenance stage produces a considerable amount of emissions, it is important to include this stage in the project boundary. The difference between HMA, CCPR CIR has a high impact on GHG emission levels and the choice of maintenance regime can extend the service life of a road thus considerably reducing GHG emissions over its lifespan.

Response: Maintenance was not included within the project boundary given the great variability of road maintenance requirements due to geographic location and ownership protocol. LCA can take a cradle to grave or a cradle to gate approach. The team decided on a cradle to gate in order to reduce potential variability of GHG emissions due to the broad range of road maintenance schedules/strategies over the 50 year lifespan of a road. Including maintenance over a 50-year period will in turn skew the calculation due to the significant amount of emissions associated with a project boundary of 50 years. 50 years would also prove difficult to monitor for a project boundary. The current project boundary meets with ISO standards and guidance. The initial designs have considered the differences between structural layer coefficients of two materials – 4 inch base using HMA and 5 inch base using FSB. The structural performance must be the same when road is constructed (or reconstructed) using the two materials. The maintenance schedule can be reasonably assumed to be same frequency and activity, accordingly.

Q5 Tuncer Edil: Is the service life of FSB the same as HMA?

Response: The service life of FSB and HMA are similar. FSB is used as base a layer with HMA as a surface layer. Under this circumstance the service life is dictated by HMA surface layer performance. The performance of roads with and without FSB as a base layer are very similar. The structural integrity was found to be the same by Schwartz & Khosravifar. The National Center for Asphalt Technology (NCAT) in their Spring 2014 (Volume 26 Number 1) report evaluates structural integrity and maintenance over a two-year period. They have completed 80% of the study. The results to date have been positive with10 million Equivalent Single Axle Load (ESALs) with no significant cracking or rutting reported in the interim report.

Q6 Gerardo Flintsch: The methodology reference data from 2002. There has been much development in the construction equipment manufacturing industry. Equipment used in manufacturing has become efficient over the past 12 years reducing GHG emissions level. However the research studies referenced date back to 2002 for EIO-LCA. However, the HMA equipment data is from 2009. Why do you continue to use data from 2002?

Response: The 2002 data is for the materials side. The 2002 data used in the model comes from the Department of Commerce. The current version of the model they developed is based on 2002 data. The team will confirm and provide further documentation within the methodology to explain why the methodology includes data from 2002.

Q7 Sara Berman: Does the Additionality threshold accurately represent the industry? Does the expert review panel believe there to be false negatives or false positives within the threshold? Is the threshold too stringent or too lenient?

Response from team: The team averaged data from HMA plants surveyed throughout MD and VA. 80% was a threshold found throughout other methodologies. Taking the survey of HMA plants conducted by the team into account and the 80% threshold used by other methodologies made sense given the industry.

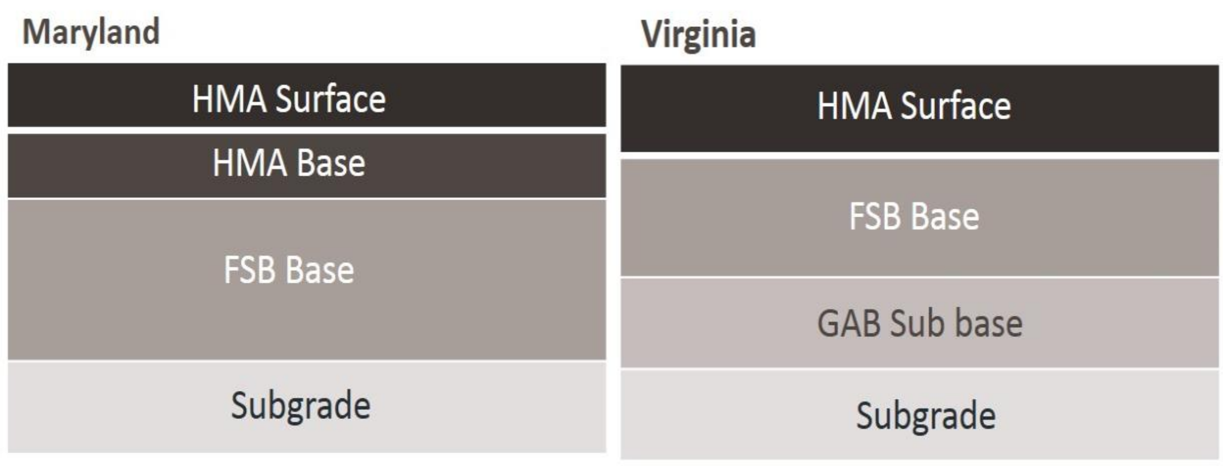
Q8 Sara Berman: Luke Wisniewski do you think there is sufficient regulatory support and/or guidance, which will allow for a market for the methodology to move forward? Could MDE support this moving forward from a regulatory standpoint?

Luke Wisniewski: There is sufficient information for the methodology to move forward. The protocol would have to be validated by an independent organization. If there is a market for offsets it can move forward. MDE will accept the use of FSB. MDE can accept it as the protocol or as an offset credit if it is approved and used appropriately.

Q9 Sara Berman: How significant is the difference between the Maryland and Virginia specifications for the use of FSB in road construction?

Response: There is a considerable difference between Maryland and Virginia FSB use specifications. The following diagram outlines the two specifications. It is important to note the use and location of FSB in relation to the other materials.

Figure C1: FSB Specification for Maryland and Virginia



Q10 Sara Berman: Are there financial incentives to use FSB?

Response: Presently, there are no financial incentives to use FSB rather than HMA.

Q11 Sara Berman: Is there a rationale for why the experts support the methodology?

Response: Tuncer Edil finds that once the team addresses the comments from this meeting the methodology will be ready to move forward. Other reviewers support the methodology moving forward.

Q12 Tuncer Edil: There has been much improvement in incorporating RAP and RAS in recent years into HMA mix designs. The methodology references 3% RAS in the HMA mix, which is surprisingly low. On page 25 change 2006 to 2010 in footnote 3.

Response: The usage of 3% RAS was found to be representative of the HMA plants surveyed in the development of the methodology. The methodology will provide further documentation supporting the use of 3% and include an additional footnote for clarification.

Q14 Gerardo Flintsch: Although the methodology is focused on FSB, emulsion is included in several places. Is emulsion going to be considered? If so, emulsion needs further clarification and documentation. Will this impact the structural layer coefficient?

Response: Emulsion will be included in the methodology. It is a similar process to foam. The difference between foam and emulsion is when the mix occurs. The methodology will be adapted to accurately represent this in the methodology. The model will address emulsion moving forward.

Questions from Jeff Graf

Jeff Graf was unable to attend the meeting. His comments and questions with the team response are listed below.

Q1: Jeff would like the group to take into account the nascent industry trend of using warm mix rather than hot mix. Warm mix allows roads to cool faster in warmer climates, and thus enables roads to open sooner to traffic and shorten project time. This would alter the baseline and change the overall accounting of GHG savings.

Response: Warm-mix is an upcoming technology and we have used warm-mix data from various plants in our calculations. Our data points include warm mix data from HMA plants and the corresponding GHG response includes warm-mix.

Q2: Jeff asked why the boundary was set as cradle-to-gate rather than cradle to grave. He believes we need to identify that in the use of the RAP the ownership remains with the construction of the road and not with the individual who ground up the road for a CCPR project.

Response: The boundary setting was discussed earlier in the report in order to feasibly observe the project lifespan and eliminate broad variability of road maintenance schedules, which are geographically specific.

Q3: Jeff indicated that CIR projects are often based on the space available to stage the project and size of project area being resurfaced. He recommends further clarification within the methodology as to when CIR projects are feasible.

Response: Three types of recycling methods are being used in pavement industry. First HIR (hot in-place recycling), which is feasible for only top 2 inches of HMA pavement. Second CCPR (cold central plant recycling), which is feasible if the HMA pavement is cracked and rutted up to 4 to 6 inches. Last one is CIR (cold in-place recycling), which is generally preferable if the pavement has to be rehabilitated until the top one inch of base course (severely cracked and rutted pavements up to 4 to 12 inches). The choice of which type to apply is dependent on the area where the recycling project is located and existing drainage conditions of the pavement and economic feasibility. Some projects without proper drainage or existing paving fabric or poor base course condition are not suitable for CIR projects, even if it is economical to do so. It will then have to be replaced with CCPR process.

Q4: Was Maryland Department of Environment's AP 42 referenced for emissions calculations?

The Economic Input-Output LCA Model was adopted to calculate material GHG emissions, which was developed by Carnegie Mellon University. The EPA engine certification database was adopted to calculate equipment GHG emissions. We used nationwide emission factor database, as opposed to state-specific emission factor database.

Q5: The methodology mentions cement in the FSB mix. Is this used across the board? Does it vary based on different State Planning and Research offices (SPR)? With new construction will you have to add more cement to the mix in order for it to adhere properly?

Response: Cement is added in FSB mixes, because it helps to increase the moisture susceptibility resistance. Each project will comply with SPR, project requirements based on specifications and road conditions.

Q6: On a new construction project using FSB, will additional binder or cement be needed to achieve the structural integrity required? If so, will this impact your calculations?

Response: No additional binder or cement is required for new projects. For either new projects or rehabilitation projects, the project team will collect the RAP samples from stockpiles or job sites respectively and develop mix design in the laboratory. Usually the binder content requires varies between 2.1% to 2.3% and cement content always stays at 1%. Portland cement helps the mix to increase the moisture susceptibility resistance and increase its wet ITS (indirect tensile strength) value in FSB mix. It also helps to add extra fines, which are required very often in RAP samples to absorb the expanded asphalt binder. If the cement content increases, the mix loses flexibility and it will become counterproductive.

Verified Carbon Standard

VCS Methodology

VM0040

Methodology for Greenhouse Gas Capture and Utilization in Plastic Materials

Version 1.0

23 July 2019

Sectoral Scope 3

This methodology was developed by:

Newlight Technologies

TABLE OF CONTENTS

1 SOURCES

This methodology was informed primarily by CDM methodology AMS-III.BA, *Recovery and recycling of materials from E-Waste*, particularly the principle of using recycled materials to displace virgin materials production.

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology is globally applicable to project activities that convert carbon dioxide and/or methane, which would have otherwise been emitted into the atmosphere, into a useful plastic material for sale into the plastics market. Such project activities reduce greenhouse gas emissions in two ways. First, project activities sequester carbon dioxide and/or methane into plastic material. Second, the process for manufacturing plastic material from sequestered carbon dioxide and/or methane can be less emission-intensive than the traditional process for manufacturing plastic material.

Additionality and Crediting Method	
Additionality	Activity Method
Crediting Baseline	Project Method

3 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions apply to this methodology:

Additives
Materials that are added in the middle of the production process to provide certain qualities or attributes to the final product. The incorporation of additives must be considered and accounted for when quantifying the total amount of GHG feedstocks used in the final product.

Biodegradable
A material that will decompose in less than 100 years due to the activity of bacteria or other living organisms

DMM (Direct Measurement Method)
The direct measurement method is a method used to calculate the amount of GHGs sequestered into plastic materials. It uses volumetric or mass-flow meters to measure the GHG input as it enters the production process.

Feedstock
The greenhouse gases (i.e., CO_2 and/or CH_4) which are captured as part of project activities to be used along with other materials to produce plastic material

MFR (Molecular Formula Ratio)
The Molecular Formula Ratio is a method used to calculate the amount of GHGs sequestered into plastic materials. It refers to the stoichiometric ratio method, which calculates the quantity of GHGs sequestered based on the chemical formula and weight of the final plastic material.

Non-Qualifying CH_4
Methane which is part of the GHG feedstock, but which would have been captured and destroyed in the baseline scenario (e.g., via a landfill collection system)

Plastic Material
Resins or pelletized material that can be molded into useful products. These materials directly displace conventional plastics such as polypropylene (PP), polystyrene (PS), polyethylene (PE), thermoplastic urethane (TPU), acrylonitrile butadiene styrene (ABS), polycarbonate (PC) and polyethylene terephthalate (PET).

Qualifying CH_4
Methane which is part of the GHG feedstock that would have been emitted into the atmosphere in the baseline scenario

Thermopolymer
Also known as thermoplastic polymers, which form when repeating units called monomers link into chains or branches. Because they soften when heated, thermoplastic polymers are easy to mold into a variety of shapes.

Virgin plastic
Plastic material that is manufactured for the first time and used in products that the project activity would be displacing. Virgin plastic is typically made from petroleum-based materials.

4 APPLICABILITY CONDITIONS

This methodology is globally applicable to project activities that convert carbon dioxide and/or methane, which would have otherwise been emitted into the atmosphere, into a useful plastic material for sale into the plastics market.

Project activities must meet the following conditions:

1) Project activities must produce a useful plastic material through a carbon capture and utilization technology which converts CO_2 and/or CH_4 into a long-chain thermopolymer. Such plastic material must:

    a) Have an expected lifetime (period of non-degradation) of at least 100 years[1], or

    b) Be biodegradable. However, in such cases the project may only calculate emission reductions related to the displacement of virgin plastic, and must NOT account for the

[1] Plastic materials produced by projects must permanently sequester carbon (i.e., sequester carbon for a period of at least 100 years) in order to claim emission reductions for the capture and sequestration of GHGs. Many plastic materials are well-known to have degradation times significantly greater than 100 years. Please refer to the following articles, which are cited in Section 10 of this methodology: Andrady (2003); Barnes et al. (2009); Browne et al. (2007); Thompson et al. (2004); Thompson et al. (2005).

capture and sequestration of GHGs, which would be re-released to the atmosphere in the case of biodegradable materials.

2) Project activities must produce a plastic material that will be used to produce useful plastic products that are sold in the commercial market.

3) Project activities must produce PHA (polyhydroxyalkanoates) directly from CO_2 or CH_4 through a process in which the resultant material displaces one of the following plastic materials:

   - Polypropylene (PP)
   - Polystyrene (PS)
   - Polyethylene (PE), including high-density and low-density polyethylene (HDPE, LDPE) and linear low-density polyethylene (LLDPE)
   - Thermoplastic urethane (TPU)
   - Acrylonitrile butadiene styrene (ABS)
   - Polycarbonate (PC)
   - Polyethylene terephthalate (PET)
   - Polyvinyl Chloride (PVC)

4) Project activities cannot combine CO_2 and CH_4 as feedstock to create a single plastic material.

5) Where CO_2 is used as a feedstock, it must be derived from a source that would have otherwise emitted it to the atmosphere (i.e., the CO_2 is not processed/produced specifically for this project activity) or it must be derived from direct air capture technology.

6) Where CH_4 is used as feedstock, the project proponent must demonstrate whether the CH_4 is qualifying or non-qualifying, as further defined in Section 8.3 below.

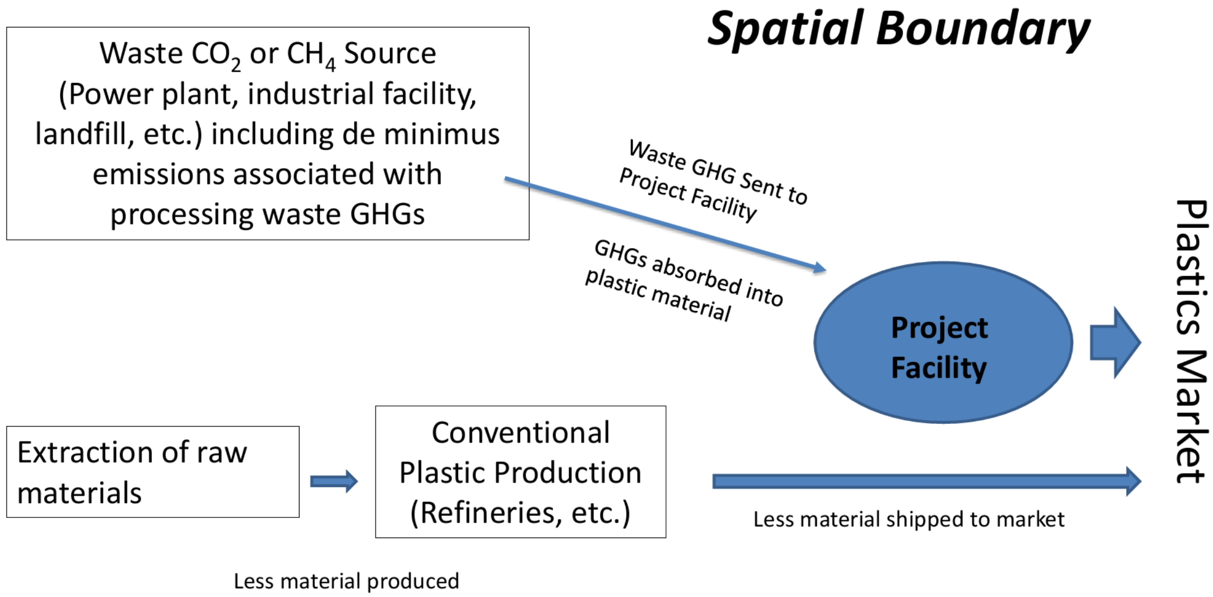
7) Where CH_4 is used as feedstock, the CH_4 used in the project activity cannot be displaced by a more carbon-intensive fuel, as demonstrated by meeting one or more of the conditions set out in Section 8.3 below.

5 PROJECT BOUNDARY

As illustrated below, the spatial extent of the project boundary encompasses:

- The project facility where plastic materials are produced;
- The facilities from which the GHG feedstock is sourced (if not direct air capture);
- The facilities where displaced conventional plastic material is manufactured.

Figure 1. Spatial Boundary of the Project Activity



The greenhouse gases included in or excluded from the project boundary are shown in Table 1 below.

Table 1: GHG Sources Included In or Excluded From the Project Boundary

Source		Gas	Included?	Justification/Explanation
Baseline	Captured GHGs	CO_2	Optional	CO_2 is one of the main gases that can be captured by carbon capture and utilization technology. Note that some projects may use only CH_4 and not CO_2, in which case CO_2 may be excluded from the project boundary. Either CO_2 and/or CH_4 must be included within the project boundary.
		CH_4	Optional	CH_4 is one of the main gases that can be captured by carbon capture and utilization technology. Note that some projects may use only CO_2 and not CH_4, in which case CH_4 may be excluded from the project boundary. Either CO_2 and/or CH_4 must be included within the project boundary.
		N_2O	No	N_2O and any other GHGs are not gases that would be captured and utilized in plastic material with current technology.
		Other	No	N/A
	GHGs from displacement of traditional	CO_2	Yes	The use and combustion of fossil fuels is the primary source of emissions from the traditional process of manufacturing plastics,

Source		Gas	Included?	Justification/Explanation
	plastics production			including the refining of raw materials and process energy for production of plastics. See Appendix II for further detail. Note – transportation of plastic materials is not considered in either the baseline or project scenario because it is assumed that under either scenario, conventional plastics or GHG-captured plastics would require similar means of transport.
		CH_4	No	Excluded for simplicity
		N_2O	No	Excluded for simplicity
		Other	No	N/A
Project	GHGs from the project facility	CO_2	Yes	Use of electricity and combusted natural gas or liquid/solid fuels are the primary energy sources that would be used to power a facility capturing GHGs and manufacturing plastic material, and thus CO_2 would be the primary emission from that combustion.
		CH_4	No	Excluded for simplicity
		N_2O	No	Excluded for simplicity
		Other	No	Excluded for simplicity
	GHGs from burning of plastic material that previously captured and sequestered CO_2 and CH_4	CO_2	Yes	Incineration of plastic material, re-releasing CO_2 into the atmosphere
		CH_4	No	Excluded for simplicity
		N_2O	No	Excluded for simplicity
		Other	No	Excluded for simplicity
	Upstream emissions associated with processing waste GHGs	CO_2	No	Excluded since project upstream emissions are negligible compared to the baseline upstream emissions associated with traditional plastic production.
		CH_4	No	
		N_2O	No	
		Other	No	

6 BASELINE SCENARIO

The baseline scenario is the continuation of manufacturing plastic material through traditional processes (i.e., not through the use of GHG capture and utilization technology). This methodology uses a project method to determine the crediting baseline.

7 ADDITIONALITY

This methodology uses an activity method for the demonstration of additionality.

Step 1: Regulatory Surplus

Project proponents must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the *VCS Standard*.

Step 2: Positive List

The applicability conditions of this methodology represent the positive list. The project must demonstrate that it meets all applicability conditions, and in so doing, it is deemed as complying with the positive list and as being additional.

The positive list was established using the activity penetration option (Option A in the *VCS Standard*). Justification for the activity method is provided in Appendix I.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

Emissions in the baseline scenario are comprised of two components. The first component is the emissions associated with traditional plastic materials production processes. The second component is the emissions from the GHG feedstock which would remain in the atmosphere or be released to the atmosphere in the absence of the project.

Component 1: Plastic production

Emissions associated with the production of virgin plastic through traditional processes that are displaced by the plastic material manufactured by the project must be accounted for in the baseline scenario. Appendix II provides default factors for GHG emissions per metric ton of virgin or new plastic (note that virgin plastic may have some recycled plastic as indicated in Appendix II, Table 3b) produced using traditional plastic production processes for different types of plastic materials. It may be assumed that for every metric ton of plastic material manufactured at a project facility, a metric ton of plastic material produced through traditional processes is displaced.

Component 2: GHG feedstock

Where the project captures CO_2 from flue gases to produce plastics, CO_2 emissions in the baseline scenario are simply those that would otherwise be released to the atmosphere.

Where the project uses CH_4 as feedstock for plastic production, the CH_4 may be derived from two types of sources:

1) **Non-qualifying CH_4:** Methane that comes from a landfill or other source where it is required to be flared or otherwise destroyed in the baseline scenario. Where non-qualifying CH_4 is captured as part of project activities, emissions in the baseline scenario must only be attributed to the CO_2 that is released as a result of the CH_4 flaring or destruction process.

2) **Qualifying CH_4:** Methane that comes from a source where it is not required to be flared or otherwise destroyed in the baseline scenario (e.g., a small landfill or biogas facility). Where qualifying CH_4 is captured as part of project activities, emissions in the baseline scenario are attributed to the release of such CH_4 to the atmosphere.

Baseline emissions in year *y* of the project crediting period (BE_y) is therefore expressed as follows:

$$BE_y = BE_{tp,y} + BE_{cg,y} \quad (1)$$

Where:

BE_y	= Baseline emissions in year y
$BE_{tp,y}$	= Baseline emissions from plastic material production via traditional manufacturing processes (tCO_2e) in time period *y*
$BE_{cg,y}$	= Baseline emissions from the GHG feedstock which would remain in, or be released to, the atmosphere in the absence of the project (tCO_2e) in time period *y*

Baseline emissions from plastic material production via traditional manufacturing processes is calculated as follows:

$$BE_{tp,y} = \sum_i (Q_{p,i,y} * EF_i) \quad (2)$$

Where:

$BE_{tp,y}$	= Baseline emissions from plastic material production via traditional manufacturing processes (tCO_2e) in time period *y*
$Q_{p,i,y}$	= Net quantity of plastic type *i* produced by the project in year *y* (metric ton)
EF_i	= Emission factor associated with the production of virgin plastic materials via traditional manufacturing processes (tCO_2e/metric ton of plastic for plastic type *i*)

The net quantity of plastic type *i* produced by the project in year *y* ($Q_{p,i,y}$) is calculated as follows:

$$Q_{p,i,y} = Q_{gross,i,y} - Q_{add,i,y} \quad (3)$$

Where:

$Q_{p,i,y}$	= Net quantity of plastic type *i* produced by the project in year *y* (metric ton)
$Q_{gross,i,y}$	= Gross quantity of plastic type *i* produced by the project in year *y* (metric tons)

$Q_{add,i,y\ i}$ = Quantity (mass) of any additives or supplemental material that may be added to the plastic resin for plastic type *i* produced by the project in year *y* (metric tons)

Guidance regarding the calculation of EF_i is given in the parameter tables in Section 9.1 and further details for the calculation of the default values for EF_i can be found in Appendix II. Different types of plastic material have different emission factors, and therefore, where a project produces more than one type of plastic material, the emissions from each type of plastic material must be calculated separately, and then summed.

Baseline emissions from the GHG feedstock which would remain in, or be released to, the atmosphere in the absence of the project is calculated as follows:

$$BE_{cg,y} = Q_{CO2.seq,y} + Q_{CH4.ADJ,y} \qquad (4)$$

Where :

$BE_{cg,y}$ = Baseline emissions from the sequestration of GHGs into plastic materials

$Q_{CO2,seq,y}$ = Amount of CO_2 captured in year *y* to produce plastic material *i* by the project (metric tons per year)

$Q_{CH4,ADJ,y}$ = Adjusted amount of CH_4 captured in year *y* to produce plastic material *i* by the project (metric tons per year)

Note – Where the plastic produced by the project activity is biodegradable, then it is assumed that all quantities of GHGs captured will eventually be released, in which case $BE_{cg,y} = 0$.

$Q_{CO2,seq,y}$ and $Q_{CH4,ADJ,y}$ must be determined using the molecular formula ratio (MFR), which determines the quantity of CO_2 or CH_4 captured, based on the molecular formula of the final plastic material. For each type of plastic *i*, the project proponent must provide the molecular formula, as well as the formula for the conversion from the GHGs which convert to the plastic material. An example of how to determine the MFR is provided in Appendix III.

Where CO_2 is used as a feedstock, the quantity of CO_2 sequestered is calculated as follows:

$$Q_{CO2.seq,y} = \sum_i \{[Q_{p,i,y} * (MW_C / MW_{p,i})] / RCM_{CO2}\} \qquad (5)$$

Where:

$Q_{CO2,seq,y}$ = Amount of CO_2 captured in year *y* to produce plastic material *i* by the project (metric tons per year)

$Q_{p,i,y}$ = Net quantity of plastic type *i* produced by the project in year *y* (metric ton)

MW_C = Molecular weight of the carbon in the plastic material *i* (g/mol)

$MW_{p,i}$ = Total molecular weight of the plastic material *i* (g/mol)

RCM_{CO2} = Fraction of carbon as part of the carbon dioxide molecule (% carbon in carbon dioxide by molar weight or 27.27%)

Where CH_4 is used as a feedstock, the quantity of CH_4 sequestered is calculated as follows:

$$Q_{CH4.seq,y} = \sum_i [Q_{p,i,y} * (MW_{C,CH4} / MW_{p,i})] / RCM_{CH4} \quad (6)$$

Where:

$Q_{CH4,seq,y}$ = Amount of CH_4 captured in year *y* to produce plastic material *i* by the project (metric tons per year)

$Q_{p,i,y}$ = Net quantity of plastic type *i* produced by the project in year *y* (metric ton)

$MW_{C,CH4}$ = Molecular weight of the total number of carbon molecules in the plastic material *i* (g/mol)

$MW_{p,i}$ = Total molecular weight of the plastic material *i* (g/mol)

RCM_{CH4} = Fraction of carbon as part of the methane molecule (% carbon in methane by molar weight, or 75%[2])

Where CH_4 is used as a feedstock, adjustments must be made because some of the CH_4 may be non-qualifying, as follows:

$$Q_{CH4.ADJ,y} = (Q_{CH4.seq,y} * GWP_{CH4} * QF_{Per,y}) + [Q_{CH4.seq,y} * 44/16 * (1-QF_{Per,y})] \quad (7)$$

Where:

$Q_{CH4,ADJ,y}$ = Adjusted amount of CH_4 captured in year *y* to produce plastic material *i* by the project (tCO_2e per year)[3]

$Q_{CH4.seq,y}$ = Amount of CH_4 captured in year *y* to produce plastic material *i* by the project (metric tons per year)

GWP_{CH4} = Global warming potential of methane

$QF_{Per,y}$ = Percentage of methane captured that is qualifying methane

44/16 = Ratio of the molecular weight of CO_2 to CH_4

[2] Carbon (12) + 4 hydrogen (4) = a molecular weight of 16 g/mol. And 12/16 = 75%

[3] Note that the quantity of any GHG captured in the process must be measured at the very point in which the GHGs are sequestered. In other words, in a multi-step process, GHGs may be captured but some may escape throughout each stage of the process. The meter for captured GHGs should be at the point where as much of the GHGs will be captured as possible.

Projects cannot combine CO_2 and CH_4 as feedstock.[4]

In addition to determining the weight from the molecular formulas, a cross-check must be applied based on the direct monitoring of GHG capture[5]. In this case, directly monitoring the amount of CO_2 and CH_4 going into the process will provide validation of the left side (input) of the molecular formula (the direct measurement method (DMM)). The equation to use for the cross-check is as follows:

$$Q_{GHG,seq,check,y} = Q_{CO2,meter,y} + Q_{CH4,meter,y} \quad (8)$$

Where:

$Q_{GHG,seq,check,y}$	= The cross check of $Q_{CO2,seq,y}$ and $Q_{CH4,ADJ,y.}$ (metric tons)
$Q_{CO2,meter,y}$	= Amount of CO_2 captured in year *y* to produce plastic material by the project, as determined by a flow meter (metric tons)[6]
$Q_{CH4,meter,y}$	= Amount of CH_4 captured in year *y* and used to produce long-lived plastic products (metric tons)

Note that $Q_{CO2,seq,y}$ and $Q_{CH4,ADJ,y}$ will be the variables actually used for baseline emission calculations (metric tons of GHG/year), unless $Q_{GHG,seq,check,y} < Q_{CO2.seq,y} + Q_{CH4.seq,y}$. Where $Q_{GHG,seq,check,y} < Q_{CO2.seq,y} + Q_{CH4.seq,y}$, an explanation and correction must be provided. Where no reasonable explanation or correction can be provided, then the lower, metered values must be used in order to be conservative (i.e., $Q_{CO2.seq,y} = Q_{CO2,meter,y}$ and $Q_{CH4.seq,y} = Q_{CH4,meter,y}$).

8.2 Project Emissions

Project emissions include emissions from electricity use and fossil fuel combustion at the project production facility, and emissions from the amount of plastic made by the project activity that is eventually destroyed by incineration.

Project emissions are calculated as follows:

$$PE_y = PE_{inc,y} + PE_{elec,y} + PE_{ffc,y} \quad (9)$$

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[4] CO_2 and CH_4 cannot be combined together to form a single plastic material because determining the source of the carbon atom in the molecular formula of the plastic, and whether it came from CO_2 or CH_4 would be difficult. A project may use both CO_2 and CH_4 to produce different plastic materials, but there must always be separate reactions each using *either* CO_2 *or* CH_4 or as a feedstock.

[5] Determining GHG input by direct measurement is intended to be used as a validation of the molecular formula ratio because a validation/verification body (VVB) cannot directly measure or test the exact molecular formula of the plastic resin. Because no process is 100% efficient, it would be expected that some GHGs that enter the process are lost at some point before the final plastic is produced. Thus, the measurements of GHGs via the meter should be greater than what is determined to be sequestered into the plastic through the molecular formula ratio for $Q_{p,i,y}$. Thus, where the meter measurements are less than what is determined via the molecular formula ratio, an explanation or corrective action would need to be provided by the project proponent. Where no explanation or correction can be provided by the project proponent, then the project must use the lower, metered values in order to be conservative (i.e., $Q_{CO2.seq,y} = Q_{CO2,meter,y}$ and $Q_{CH4.seq,y} = Q_{CH4,meter,y}$).

[6] Note that the quantity of any GHG captured in the process must be measured at the very point in which the GHGs are sequestered. In other words, in a multi-step process, GHGs may be captured but some may escape throughout each stage of the process. The meter for captured GHGs should be at the point where as much of the GHGs will be captured as possible.

Where:

PE_y	= Project emissions for year *y* of the project crediting period (tCO_2e)
$PE_{inc,y}$	= Project emissions from the eventual incineration of a portion of plastic that sequestered GHGs, which are then re-emitted (tCO_2e)
$PE_{elec,y}$	= Project emissions from the use of electricity at the project production facility (tCO_2e)
$PE_{ffc,y}$	= Project emissions from the combustion of fossil fuels at the project production facility (tCO_2e)

Project emissions from the incineration of plastic are calculated as:

$$PE_{inc,y} = (Q_{CO2.seq,y} * DF_{EL}) + (Q_{CH4.seq,y} * DF_{EL} * 44/16) \quad (10)$$

Where:

$PE_{inc,y}$	= Project emissions from the eventual incineration of a portion of plastic that sequestered GHGs, which are then re-emitted (tCO_2e)
$Q_{CO2,seq,y}$	= Amount of CO_2 captured in year *y* to produce plastic material *i* by the project (metric tons per year)
DF_{EL}	= Discount factor applied for volume of end-of-life plastic material that can be expected to be incinerated, thus releasing the CO_2 or CH_4 that was originally sequestered.
$Q_{CH4,seq,y}$	= Amount of CH_4 captured in year *y* to produce plastic material *i* by the project (metric tons per year)

Further guidance for calculating DF_{EL}, including a default factor for projects located in the United States and a conservative global default factor, are included in the parameter tables in Section 9.1 and in Appendix II, below.

Project emissions from the use of electricity at the project production facility are calculated as:

$$PE_{elec,y} = Q_{elec,y} * EF_{elec} \quad (11)$$

Where:

$PE_{elec,y}$	= Project emissions from the use of electricity at the facility in year *y*
$Q_{elec,y}$	= Quantity of electricity from the grid in year *y* used to power the project production facility in year *y* (MWH)
EF_{elec}	= Emissions intensity of the electricity in tCO_2/MWH.

Project emissions from the combustion of fossil fuels at the project production facility are calculated as follows:

$$PE_{ffc,y} = Q_{ff,y} * FC_y * EF_{a,y} \quad (12)$$

Where:

$PE_{ffc,y}$	= Project emissions from the combustion of fossil fuel in year y
$Q_{ff,y}$	= Quantity of fossil fuel used in year *y*
FC_y	= Energy content of fuel type a combusted the year *y* (terajoule or TJ).
$EF_{a,y}$	= Emission factor of fuel in year *y* (tCO_2e/TJ).

8.3 Leakage

There is one potential source of leakage to consider under this project activity. Specifically, where methane was supplied from a landfill to be used as a feedstock for this project activity in sufficient quantities, it is conceivable that the facility previously using that methane would turn to other, potentially more carbon-intensive fuels as a substitute. In order to deal with this potential issue, the project proponent cannot count for qualifying methane any biogas that was already contracted for by another entity to be used for energy production. As indicated in the applicability conditions of this methodology, where methane is to be used as a feedstock, the project proponent must demonstrate whether the methane is qualifying or non-qualifying (e.g., through a representation with the methane supplier or other evidence to the satisfaction of the validation/verification body (VVB)). In addition, in situations where an existing source of methane is supplying feedstock to the project facility, the project proponent must:

- Demonstrate that the methane for the project is coming from an expansion of the methane source where methane was previously being vented (e.g., a landfill that is expanding its gas collection system). In such case, it can be assured that no methane is being diverted from another fuel use because the ability to collect biogas is being increased; or

- Demonstrate there is excess gas supply potential that is not being utilized by the landfill or other methane source. For example, if projections of gas availability (to be provided by the landfill operator) show gas supply should be higher than what was actually being used, it would indicate that there is *potential* for more biogas to be used than is actually the case; or

- Provide other evidence to the satisfaction of the VVB that the methane source is supplying biogas which is not being diverted to another user.

Where the project proponent can demonstrate that one or more of these conditions exist for the project activity, then leakage does not need to be taken into consideration. Where these conditions cannot be definitively confirmed, the methane provided from the facility cannot count towards baseline emissions.

8.4 Net GHG Emission Reduction and Removals

Net GHG emission reductions and removals are calculated as follows:

$$ER_Y = BE_Y - PE_y \quad (13)$$

Where:

ER_Y = Net GHG emissions reductions and removals in year y (tCO_2e)

BE_Y = Baseline emissions in year y (tCO_2e)

PE_y = Project emissions in year y (tCO_2e)

9 MONITORING

9.1 Data and Parameters Available at Validation

Data / Parameter	EF_i
Data unit	tCO_2e/metric ton of plastic material type i produced
Description	Emission factor for GHG's caused by the production of virgin plastic materials in tCO_2e/metric ton of plastic material
Equations	2
Source of data	Use values from credible international or national government sources, such as the U.S. EPA (see Appendix II, below, for more information on the data used to calculate this variable in the U.S.).
Value applied	See Appendix II
Justification of choice of data or description of measurement methods and procedures applied	National environmental agencies or similar government and research institutions have accurate data on energy requirements for each segment of the plastic production process including raw materials extraction and the production process itself. To be updated each crediting period if new data exists.
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	MW_C
Data unit	g/mol
Description	Molecular weight of CO_2
Equations	5 and 6
Source of data	Periodic Table of Elements
Value applied	44

Justification of choice of data or description of measurement methods and procedures applied	Molecular weights as provided for in the Periodic Table of Elements.
Purpose of Data	Calculation of baseline emissions
Comments	For each type of plastic *i*, the project proponent must provide the molecular formula, as well as the conversion from the original compounds (including the GHGs) which convert to the plastic material. Taking into account the molecular weight of each compound, the project proponent can then illustrate that for each ton of plastic (eg: $C_4H_6O_2$) produced, X tons of CO_2 are required.

Data / Parameter	$MW_{C,CH4}$
Data unit	g/mol
Description	Molecular weight of CH_4
Equations	5 and 6
Source of data	Periodic Table of Elements
Value applied	16
Justification of choice of data or description of measurement methods and procedures applied	Molecular weights as provided for in the Periodic Table of Elements.
Purpose of Data	Calculation of baseline emissions
Comments	For each type of plastic *i*, the project proponent must provide the molecular formula, as well as the conversion from the original compounds (including the GHGs) which convert to the plastic material. Taking into account the molecular weight of each compound, the project proponent can then illustrate that for each ton of plastic (eg: $C_4H_6O_2$) produced, X tons of CO_2 are required.

Data / Parameter	$MW_{p,i}$
Data unit	g/mol
Description	Molecular weight plastic material
Equations	5 and 6
Source of data	Project proponent must provide formula for plastic material
Value applied	N/A

Justification of choice of data or description of measurement methods and procedures applied	Molecular weights as provided for in the Periodic Table of Elements.
Purpose of Data	Calculation of baseline emissions
Comments	For each type of plastic *i*, the project proponent must provide the molecular formula, as well as the conversion from the original compounds (including the GHGs) which convert to the plastic material. Taking into account the molecular weight of each compound, the project proponent can then illustrate that for each ton of plastic (eg: $C_4H_6O_2$) produced, X tons of CO_2 are required.

Data / Parameter	RCM_{CO2} and RCM_{CH4}
Data unit	Percentage
Description	Fraction of carbon as part of the CH_4 and CO_2 molecule (% carbon in CH_4 and CO_2 by molar weight)
Equations	5 and 6
Source of data	Calculated based on molecular weights of carbon, CO_2 and CH_4.
Value applied	RCM_{CO2} = 27.27% RCM_{CH4} = 75%
Justification of choice of data or description of measurement methods and procedures applied	N/A
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	GWP of CH_4
Data unit	tCO_2/tCH_4
Description	Global warming potential of methane
Equations	7
Source of data	IPCC
Justification of choice of data or description of measurement methods and procedures applied	The *IPCC Guidelines for National Greenhouse Gas Inventories* are internationally recognized, and the data provided in the guidelines is peer reviewed
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	DF_{EL}
Data unit	Unitless
Description	Discount factor applied to account for the end of life of plastic material that is incinerated, releasing CO_2
Equations	10
Source of data	U.S. EPA or similar source in other countries (see Appendix II)
Value applied	For projects located in the U.S.: 0.15 For projects located outside of the U.S.: 1) Determine value from credible national government sources (see Appendix II) 2) Global default value: 0.40
Justification of choice of data or description of measurement methods and procedures applied	National environmental agencies or similar government and research institutions have accurate data on the percentage of plastic materials in conventional waste streams and what percentage of those waste stream that is incinerated.
Purpose of Data	Calculation of project emissions – where plastic is incinerated, the captured CO_2 is released, and reductions cannot be credited for this portion of the baseline emissions.
Comments	Discount factor applied to account for the end of life of plastic material that is expected to be incinerated, releasing CO_2. For example, where 20% of plastics in a particular country can be expected to be incinerated instead of recycled or landfilled, then the discount factor is 0.20. To be updated each crediting period if new data exists. Additional Guidance: Projects must apply a discount factor, DF_{EL}, to account for plastics that are destroyed (e.g., through incineration if they enter municipal waste streams), thus releasing the captured CO_2 prior to the end of their lifetime. Accurate data as to the amount of plastic material that is incinerated versus landfilled is well documented in many countries. In the U.S., the Environmental Protection Agency (EPA) estimates that 15% of plastic materials, regardless of type, will eventually be incinerated, with the rest being landfilled or recycled (see Appendix II for further detail). This percentage must be discounted from the calculations of emission reductions, to account for the volume of CO_2 that can be expected to be re-emitted. Where similar data exists in the country where the project is located, this data may be used to inform the discount factor. Appropriate data and data sources include host country officially

	published data, research studies or industry data. Any data or analysis used to inform the discount factor must be explained in the project documentation and assessed by the validation/verification body. The discount factor must distinguish between different types of plastics and/or be conservative for the type of plastic(s) that the project is producing. Where no similar data exists in the country where the project is located, a conservative global default factor may be used, as set out in Appendix II.

Data / Parameter	$FC_{,y}$
Data unit	TJ
Description	Energy content per unit of fuel type y
Equations	12
Source of data	IPCC
Justification of choice of data or description of measurement methods and procedures applied	The *IPCC Guidelines for National Greenhouse Gas Inventories* is internationally recognized and the data provided in the guidelines is peer reviewed.
Purpose of Data	Calculation of project emissions
Comments	N/A

Data / Parameter	$EF_{a,y}$
Data unit	tCO_2e/TJ
Description	Emission factor of fuel type y
Equations	12
Source of data	IPCC
Justification of choice of data or description of measurement methods and procedures applied	The *IPCC Guidelines for National Greenhouse Gas Inventories* is internationally recognized and the data provided in the guidelines is peer reviewed.
Purpose of Data	Calculation of project emissions
Comments	N/A

9.2 Data and Parameters Monitored

Data / Parameter	$Q_{gross,i,y}$
Data unit	metric tons of plastic type *i*
Description	Quantity of total plastic type *i* sold by the project into the market in time period y from eligible feedstocks
Equations	2 and 3
Source of data	Measurements at project facility
Description of measurement methods and procedures to be applied	Plastic material and additives must be weighed on scales that have available calibration procedures from the manufacturer.
Frequency of monitoring/recording	Daily or monthly
QA/QC procedures to be applied	Calibration of scales must be conducted according to the equipment manufacturer's specifications.
Purpose of data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	$Q_{add,i,y}$
Data unit	metric tons of additive
Description	Quantity of any additives weighed before being put into the process.
Equations	2 and 3
Source of data	Measurements at project facility
Description of measurement methods and procedures to be applied	Additives must be weighed on scales that have available calibration procedures from the manufacturer. Additives may be added to the process to make the plastic more flexible or provide other desirable attributes. This supplemental material must be weighed prior to entering the process and subtracted out from the gross weight to obtain the net weight of plastic that has sequestered the GHGs.
Frequency of monitoring/recording	Daily or monthly
QA/QC procedures to be applied	Calibration of scales must be conducted according to the equipment manufacturer's specifications.
Purpose of data	Calculation of baseline emissions

Comments	N/A

Data / Parameter	$QF_{Per,y}$
Data unit	Percentage
Description	The percent of CH_4 during a specific production run of plastic which is qualifying (i.e., the percent of CH_4 that would have been vented to the atmosphere in the absence of the project).
Equations	7
Source of data	Project proponent, based on information from gas suppliers.
Description of measurement methods and procedures to be applied	Project proponent must obtain such information from the gas supplier about the source and baseline status (venting or destruction) of CH_4. The project proponent must interview each gas supplier for the project activity and present survey results to the validation/verification body (VVB), who may wish to interview gas supplier as well. The survey will include the following questions: • Is the gas supplier required by regulation to destroy the methane that is being provided to the project activity? Please describe and provide references to any applicable regulations. • Please provide historical data on any methane destroyed in previous years – including as a percentage of total methane output of the source.[7] Data should be provided from the last three years if available or for the operating history of the methane source if less than three years.
Frequency of monitoring/recording	Once per verification
QA/QC procedures to be applied	Project proponent must obtain information from the gas supplier about the source of methane. That documentation must be provided to the VVB for review.
Purpose of data	Calculation of baseline emissions. For qualifying methane, the GWP of methane is calculated in baseline emissions. For non-qualifying methane, the baseline emission is CO_2. But because that methane was captured instead of destroyed, the

[7] For example, if in the last three years, the methane source has destroyed an average of 25% of the estimated total output of the source, such data should be provided and $QF_{Per,y}$ would thus be 0.75.

	CO_2 associated with the combustion of CH_4 was not emitted and can therefore be counted as a baseline emission.
Comments	Where the captured and sequestered methane was sourced from a landfill that already has a landfill gas collection system, or where LFG is required to be captured and destroyed, that amount of methane must be assumed to be destroyed and emitted as CO_2. For example, where 60% of the methane for a project facility was sourced from a landfill with an LFG collection system and 40% from an anaerobic digestion facility on a farm that is not required to capture methane, $QF_{Per,y}$ equals 0.4.

Data / Parameter	$Q_{CO2,meter,y}$
Data unit	tCO_2
Description	Amount of CO_2 captured in year *y* to produce plastic material by the project, as determined by a flow meter
Equations	8
Source of data	Measurements at project facility
Description of measurement methods and procedures to be applied	Use calibrated flow meters. Calibration must be conducted according to the equipment manufacturer's specifications. The amount of CO_2 must be metered before entering the plastic production process and must be subject to standard calibration and QA/QC procedures for the measurement of critical data variables. This data must be crosschecked with a pre-production estimate of GHG-to-product ratios to ensure that GHG feedstock is not released during the production process. For example, a process may take two pounds of CO_2 to manufacture one pound of plastic. The project proponent must keep a record of all methane inputted into the process and provide an estimated percentage of qualifying and non-qualifying methane.
Frequency of monitoring/recording	Data must be monitored continuously and recorded on at least a daily basis.
QA/QC procedures to be applied	Calibration of meters must be conducted according to the equipment manufacturer's specifications.
Purpose of data	Calculation of baseline emissions
Comments	Project proponents may use a mass-flow meter to measure mass of CO_2. Project proponents may also use a volumetric meter to determine cubic feet or meters of gas collected, but this number

	must be converted to mass by multiplying the measured volume by the density of CO_2 or CH_4 at normal temperature and pressure (20 degrees C at 1 atmosphere). The density of CO_2 at NTP is 1.842 kg/m3.[8] The density of CH_4 at NTP is 0.668 kg/m3. Determining GHG input by direct measurement is intended to be used as a cross-check of the molecular formula ratio because a verifier cannot directly measure or test the exact molecular formula of the plastic resin. Because no process is 100% efficient, it would be expected that some GHGs that enter the process are lost at some point before the final plastic is produced. Thus, the measurements of GHGs via the meter should be greater than what is determined to be locked into the plastic through the molecular formula ratio for $Q_{p,i,y}$. Where the meter measurements are less, this situation should be explained or corrected to the satisfaction of the VVB

Data / Parameter	$Q_{CH4,meter,y}$
Data unit	tCH_4
Description	Amount of CH_4 captured in year *y* to produce plastic material by the project, as determined by a flow meter
Equations	8
Source of data	Measurements at project facility
Description of measurement methods and procedures to be applied	Use calibrated flow meters. Calibration must be conducted according to the equipment manufacturer's specifications. The amount of CH_4 must be metered before entering the plastic production process and must be subject to standard calibration and QA/QC procedures for the measurement of critical data variables. This data must be crosschecked with a pre-production estimate of GHG-to-product ratios to ensure that GHG feedstock is not released during the production process. For example, a process may take two pounds of CH_4 to manufacture one pound of plastic. The project proponent must keep a record of all methane inputted into the process and provide an estimated percentage of qualifying and non-qualifying methane.
Frequency of monitoring/recording	Data must be monitored continuously and recorded on at least a daily basis.
QA/QC procedures to be applied	Calibration of meters must be conducted according to the equipment manufacturer's specifications.

[8] www.engineeringtoolbox.com/gas-density-d_158.html

Purpose of data	Calculation of baseline emissions
Comments	Project proponents may use a mass-flow meter to measure mass of methane. Project proponents may also use a volumetric meter to determine cubic feet or meters of gas collected, but this number must be converted to mass by multiplying the measured volume by the density of CO_2 or CH_4 at normal temperature and pressure (20 degrees C at 1 atmosphere). The density of CH_4 at NTP is 0.668 kg/m3. Determining GHG input by direct measurement is intended to be used as a cross-check of the molecular formula ratio because a verifier cannot directly measure or test the exact molecular formula of the plastic resin. Because no process is 100% efficient, it would be expected that some GHGs that enter the process are lost at some point before the final plastic is produced. Thus, the measurements of GHGs via the meter should be greater than what is determined to be locked into the plastic through the molecular formula ratio for $Q_{p,i,y}$. Where the meter measurements are less, this situation should be explained or corrected to the satisfaction of the VVB

Data / Parameter	$Q_{elec,y}$
Data unit	MWh
Description	Quantity of electricity used by project facility supplied by the grid in year y
Equations	11
Source of data	Measurements at project facility or electric utility bills
Description of measurement methods and procedures to be applied	Use calibrated electricity meters. Calibration must be conducted according to the equipment manufacturer's specifications. Alternatively, utility billing data can be used.
Frequency of monitoring/recording	Data must be monitored continuously and recorded on at least a daily basis. If utility data is used, monthly bills are acceptable
QA/QC procedures to be applied	The consistency of metered electricity generation should be cross-checked with receipts from electricity purchases where applicable
Purpose of data	Calculation of project emissions
Comments	N/A

Data / Parameter	EF_{elec}
Data unit	tCO_2e/MWH
Description	Emission intensity of electricity

Equations	11
Source of data	US eGrid or utility data or similar source if the project is in another country.
Description of measurement methods and procedures to be applied	In developing countries, project proponents may use the "Tool to calculate the emission factor for an electricity system" to calculate this parameter. In the US, eGrid emissions factor for the sub-region where the facility is located (latest available information) may be used.
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	As per "Tool to calculate the emission factor for an electricity system"
Purpose of data	Calculation of project emissions
Comments	N/A

Data / Parameter	$Q_{ff,y}$
Data unit	Gallons (oil fuels), cubic meters (natural gas), metric tons (solid fuels)
Description	Quantity of fossil fuel used by the project facility in year y
Equations	12
Source of data	Measurements at project facility
Description of measurement methods and procedures to be applied	Use calibrated flow or gas meters. Calibration must be conducted according to the equipment manufacturer's specifications.
Frequency of monitoring/recording	Data must be monitored and recorded monthly.
QA/QC procedures to be applied	The consistency of metered fuel use should be cross-checked with receipts from fuel suppliers where applicable
Purpose of data	Calculation of project emissions
Comments	N/A

9.3 Description of the Monitoring Plan

The project must monitor all key variables, including the following:

- Quantity of CO_2 captured from the atmosphere as a GHG feedstock (where CO_2 is part of the GHG feedstock) for the plastic material. The capture process will capture CO_2, which will then be run through a meter to measure the amount of CO_2 captured in pounds or kg.

- Quantity of methane that is collected (if CH_4 is part of the GHG feedstock) must be piped or shipped into the production facility. The amount of methane captured must be measured through traditional metering methods.

  Note that both the CO_2 and CH_4 captured must be crossed checked with pre-defined, estimated ratios of GHG input to plastic output, which must be included in the quality control section of the monitoring tables. In addition, the project proponent is required to account for any GHGs that escape during the manufacturing process (although the point of measurement should be the latest point just prior to when the GHG feedstock combines with other materials to form the plastic material and is thus sequestered). To confirm the level of baseline emissions from the capture of the GHGs for sequestration into the plastic material, the project proponent must calculate both the MFR and the DMM (the stoichiometric ratio method and direct measurement method).

- Production of plastic material, as monitored through appropriate weighing techniques.
- In cases where methane is used as a feedstock, an analysis of whether that methane would be qualifying or non-qualifying.
- An analysis of the potential for leakage as described in Section 8.3 above.
- Quantities of electricity and any fossil fuel used at the facility (for project emissions). Gas and electricity meter readings shall be the primary method for monitoring these data parameters. Utility-supplied data (gas and electricity bills) are acceptable.

The project proponent must establish, maintain and apply a monitoring plan and GHG information system that includes criteria and procedures for obtaining, recording, compiling and analyzing data, parameters and other information important for quantifying and reporting GHG emissions relevant for the project and baseline scenarios. Monitoring procedures must address the following:

- Types of data and information to be reported;
- Units of measurement;
- Origin of the data;
- Monitoring methodologies (e.g., estimation, modeling, measurement and calculation);
- Type of equipment used;
- Monitoring times and frequencies;
- QA/QC procedures;
- Monitoring roles and responsibilities, including experience and training requirements;
- GHG information management systems, including the location, back up, and retention of stored data.

Where measurement and monitoring equipment is used, the project proponent must ensure the equipment is calibrated according to current good practice (e.g., relevant industry standards).

All data collected as part of monitoring must be archived electronically and kept at least for 2 years after the end of the last project crediting period. QA/QC procedures must include, but are not limited to:

- Data gathering, input and handling measures;
- Input data checked for typical errors, including inconsistent physical units, unit conversion errors;
- Typographical errors caused by data transcription from one document to another, and missing data for specific time periods or physical units;
- Input time series data checked for large unexpected variations (e.g., orders of magnitude) that could indicate input errors;
- All electronic files to use version control to ensure consistency;
- Physical protection of monitoring equipment;
- Physical protection of records of monitored data (e.g., hard copy and electronic records);
- Input data units checked and documented;
- All sources of data, assumptions and emission factors documented.

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APPENDIX I: JUSTIFICATION OF THE ACTIVITY METHOD

Background

The concept of using greenhouse gases (GHGs) as a raw material for the production of useful products is only a few years old. A number of start-up companies are developing technologies that use captured GHGs to produce tangible products, with what has been termed “Carbon Capture and Utilization” (CCU). Products created through CCU processes can act as long-term storage of the captured GHGs used in their production and displace products created through conventional processes. The level of commercial activity for CCU products is very low, as it is a new technology. This is particularly true for the use of CCU to create plastic materials that could displace plastics produced through conventional processes in the commercial market.

As of the writing of this methodology, there is no large-scale commercial application of CCU technology to capture and sequester GHGs in plastic materials, and there is only limited activity in using CCU to produce concrete and other similar building materials. As of 2018, the company closest towards commercialization of CCU technology in the plastics sector has only a small plant that could provide materials for commercial customers, operated by a start-up company called Newlight Technologies, Inc. As a result, essentially 100 percent of all plastic materials in any market are produced using conventional, petroleum-based materials and processes, with the exception of some niche plastics made from food crops like corn or sugarcane, which do not sequester GHGs long-term.

In addition, it should be noted that as of the writing of this methodology, Newlight’s technology for CCU in plastic materials has been available for more than three years, demonstrating that while the project is commercially available at a modest scale, its growth has been limited – indicating barriers to penetration in the wider market.

Approach

The activity penetration option requires that the total amount of plastic production from this alternative, GHG-capturing process, does not amount to more than five percent of total plastic production worldwide. Activity penetration is equal to: Observed Activity (OA) divided by the Maximum Adoption Potential (MAP).

In this case, as mentioned above, this project activity has not reached commercial scale. The one company, Newlight Technologies, Inc., which produces the only known plastic material from GHG feedstock, has only a small pilot facility which has produced plastic for a few clients. However, this particular plastic used shipped CO_2 from another source, not a waste source like the flue gas from a power plant. Thus, the “total number of instances installed at a given date in year *y*” is zero, and OA can be considered to be zero.

Given the early stage of CCU technology, it is difficult to say exactly what the resource and other constraints are to adoption of this technology. The feedstocks, CO_2 and CH_4, are ubiquitous, and there are no particular barriers (e.g., market access or customer acceptance) that would limit the adoption of this technology. Thus, for the purposes of this methodology, the MAP is the entire market for each specific type of plastic the project facility will produce, within the country where that facility is located.

Therefore, clearly the activity penetration level of the project activity covered by this methodology is below the five percent threshold, and the project activity may be deemed additional.

Additionally, given the low penetration of this activity, the only baseline scenarios that are reasonable to consider are: 1) the continued manufacturing of traditional plastic material with no plastic production involving GHG sequestration or perhaps; 2) the large-scale adoption of this technology many years into the future, at which point the five percent threshold for activity penetration would be exceeded and the activity would no longer be eligible for crediting.

APPENDIX II: EMISSION FACTORS

Introduction

This appendix provides additional information about the calculation of the following emission factors:

1) EF_i: the emission factor for GHGs caused by the production of virgin plastic materials; and
2) DF_{EL}: the discount factor applied to account for the end of life of plastic material that is incinerated, releasing CO_2

Emission Factor for the Production of Plastic Material (EF_i)

Introduction and Background

This methodology relies on emission factors for each type of plastic produced by the project activity in order to calculate baseline emissions associated with the displacement of virgin plastic production (EF_i). This appendix provides additional information about how EF_i is determined, including default factors for projects located in the United States and the process that must be used by projects located outside of the United States to calculate EF_i.

Emissions associated with the manufacture of plastic materials through conventional processes include the extraction and processing of raw materials, which are primarily petroleum products, emissions associated with the manufacturing process itself, and emissions associated with the transportation of plastic materials. These emissions vary depending on the type of plastic material – the production of polypropylene, for example, generates almost 40% fewer emissions than the production of polystyrene.

Calculation of Default Factors for Projects in the United States

Projects located in the United States may use a default value for EF_i, based on the United States Environmental Protection Agency (U.S. EPA) Waste Reduction Model (WARM), which was created to calculate the GHG emissions of waste management practices in the United States, including from the recycling and landfilling of plastic materials.

The WARM model disaggregates the different sources of emissions associated with plastic production and includes process energy from the petroleum refining process, process non-energy emissions, and transportation emissions, as shown in Table 3a below[9]. For the purposes of this methodology, only process and process non-energy emissions are included because emissions from the transportation of plastic materials are not expected to be different in the baseline and project scenarios (e.g., because traditional plastic or GHG-containing plastic both must be transported to their final destination).

Note – The tCO_2e in Table 3a and Table 3b, below, are expressed in short tons. For the purposes of calculating baseline emissions in Equation 2, the default values included in Table 4, below, have been converted into metric tCO_2e.

[9] https://www.epa.gov/sites/production/files/2016-03/documents/warm_v14_containers_packaging_non-durable_goods_materials.pdf

Table 3a: Source Reduction Emission Factors for Plastic

Material (a)	Process Energy (b)	Transportation Energy (c)	Process Non-Energy (d)	Net emissions (e) [e=b+c+d]
HDPE	1.18	0.15	0.20	1.53
LDPE	1.40	0.15	0.21	1.76
PET	1.74	0.07	0.39	2.20
LLDPE	1.14	0.15	0.25	1.54
PP	1.17	0.13	0.21	1.51
PS	1.86	0.15	0.45	2.46
PVC	1.68	0.08	0.14	1.90

The WARM model takes into account that some plastic is created from recycled materials, and therefore not all plastic materials on the market are from 100% raw materials, in its calculation of net emissions from plastic production. Table 3b, below, includes the emissions from “raw material acquisition” for the current mix of recycled vs. virgin plastic in the market (column “b”), as opposed to column “c” which calculates the emission factor for 100% virgin inputs. Note that the values in Table 3b are negative because this section of the WARM model is referencing reductions in emissions for every ton of plastic where its use is avoided.

Note that the figures in column “e” in Table 3a do not match column “b” in Table 3b below. This is because the transportation energy in the WARM model does not include retail transportation, which is 0.04 tCO_2/t of plastic for all plastic types[10]. The values in column “e” of Table 3a are equal to: [net emissions from 100% virgin inputs, Table 3b] – [0.04].

10 See Table 5-4 on page 5-5: https://www.epa.gov/sites/production/files/2016-03/documents/warm_v14_containers_packaging_non-durable_goods_materials.pdf.

Table 3b: Raw Material Acquisition and Manufacturing Emission Factor for Virgin Production of Plastics (tCO_2e/Short Ton)

Material (a)	Raw Material Acquisition and Manufacturing for Current Mix of Inputs (b)	Raw Material Acquisition and Manufacturing for 100% Virgin Inputs (c)	Net Emissions for Current Mix of Inputs (d)	Net Emissions for 100% Virgin Inputs (e)
HDPE	-1.47	-1.57	-1.47	-1.57
LDPE	-1.80	-1.80	-1.80	-1.80
PET	-2.20	-2.24	-2.20	-2.24
LLDPE	-1.58	-1.58	-1.58	-1.58
PP	-1.55	-1.55	-1.55	-1.55
PS	-2.50	-2.50	-2.50	-2.50
PVC	-1.95	-1.95	-1.95	-1.95
Mixed Plastics	-1.92	-1.98	-1.92	-1.98

The net emission factor (EF_i) for each type of plastic is calculated as:

[(net emissions for current mix of inputs (Table 3b)) – (transportation energy (Table 3a)) – (retail transportation)] x (conversion factor from short tons to metric tons, equal to 1.102)

For example, the net emissions factor for HDPE would be equal to:

[(1.47) – (0.15) – (0.04)] x (1.102) = 1.41

There are a few types of plastic material eligible to be produced through project activities, but not included in the U.S. EPA WARM model report. These forms of plastic are:

- Thermoplastic urethane (TPU)
- Acrylonitrile butadiene styrene (ABS)
- Polycarbonate (PC)

Emission factors for these plastic materials were derived from a report prepared for the City of Winnipeg[11]. The emission factors included in this report are inclusive of emissions associated with transportation. Therefore, to calculate emission factors for ABS, TPU and PC that are equivalent to the emission factors for other eligible plastic materials, an estimate of transportation emissions was subtracted from the total emissions. The EPA data from the WARM model specifies 0.19 metric tons of CO_2/per short ton of plastic (equal to 0.21 metric ton of CO_2/per metric ton of plastic) as the highest (and therefore most conservative) value for emissions from transportation. This value was subtracted from total emissions for the emission factors for ABS, TPU and PC included in Table 4 below. It is reasonable to

11 https://www.winnipeg.ca/finance/findata/matmgt/documents/2012/682-2012/682-2012_Appendix_H-WSTP_South_End_Plant_Process_Selection_Report/Appendix%207.pdf

infer that transporting ABS, TPU and PC would be similar in cost and energy to all other types of plastics, a point reinforced by the fact that the transport figures in the WARM model (except for PVC) are all in a very small range. The emission factors for TPU and PC were derived from the "Other Plastics" emission factor.

Table 4: Default Emission Factors for EF_i for projects located in the United States

Plastic Type	Emission Factor (tCO_2e/metric ton of plastic material produced)
HDPE	1.41
LDPE	1.77
PET	2.30
LLDPE	1.53
PP	1.52
PS	2.55
PVC	2.02
ABS	3.25
TPU	2.49
PC	2.49

Note that project proponents must use the latest version of the WARM model (or similar sources of data in other countries) when developing a new project.

Discount Factor for Incinerated Plastic Material (DF_{EL})

Introduction

DF_{EL} is the discount factor that is applied to account for the fact that a certain amount of GHGs captured as part of the project may be re-released when plastic is incinerated. Where plastic materials that are made through project activities are incinerated, CO_2 would be released to the atmosphere through the combustion process, and therefore the incinerated plastic materials would not represent a permanent sequestration of the GHG feedstock used in the production process. DF_{EL} represents the proportion of incinerated plastic to non-incinerated plastic.

This section sets out in more detail the three ways that DF_{EL} can be determined: 1) a default value for U.S.-based projects; 2) criteria for projects to determine DF_{EL} where appropriate data is available, and; 3) a conservative global default value.

Default Factor for Projects Located in the United States

The U.S. Environmental Protection Agency (U.S. EPA) has collected and reported data on the generation and disposition of waste in the United States for more than 30 years. This information is used to measure the success of waste reduction and recycling programs across the country and characterize the U.S. national waste stream, and can be used to determine DF_{EL} in the United States.

Based on the information included in the U.S. EPA *Advancing Sustainable Materials Management: 2014 Fact Sheet Assessing Trends in Material Generate, Recycling, Composting, Combustion with Energy Recovery and Landfilling in the United States* (November 2016)[12], 15% of total plastics are incinerated in the U.S. Therefore, the default factor for DF_{EL} in the U.S. is: 0.15.

Procedure for Projects Located Outside of the United States

Where projects are located outside of the United States, they must determine the percent of plastic incinerated in the country or geographic region of the project in order to determine $DF_{EL.}$ Independent market estimates from government, academic or trade association sources may be used to determine the level of plastic incineration in a particular country. Where a single source does not include sufficient information to determine the percent of plastic incinerated in a particular country, multiple sources of data may be used. For example, where 5 million tons of waste is incinerated in a country and 10% of such waste is plastic products, then 500,000 tons of plastic may be assumed to be incinerated in that country. Where another source shows that 1.5 million tons of plastics is consumed in that country, then the default factor may be set at 30% (equal to: (plastic products incinerated) / (total plastic consumed) = (500,000) / (1,500,000)).

The project proponent must calculate DF_{EL} in terms of tCO_2e/metric ton of plastic material produced and apply this calculated discount factor to determine emissions in Equation 2.

Global Default Value

Where data is not available to determine a specific default factor for the percent of plastic that is incinerated in a particular country, a conservative global default value must be used. The conservative global default for DF_{EL} is: 0.40.

This conservative global default value for DF_{EL} is based on an estimate of the percent of plastic that is incinerated in Europe, which has the highest level of plastics incineration of any known country or region. According to a report from Plastics Europe[13], 36% of post-consumer plastic produced in Europe was incinerated for energy generation. Therefore, for the purposes of the methodology, where a project proponent cannot find data on the level of baseline plastics incineration in a country where a project facility is located, the global default value for DF_{EL} is conservatively set at 40%.

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12 See *Table 1. Generation, Recycling, Composting, Combustion with Energy Recovery and Landfilling of Materials in MSW, 2014*,* in the column for “combustion as a percent of generation” in the *Advancing Sustainable Materials Management: 2014 Fact Sheet Assessing Trends in Material Generate, Recycling, Composting, Combustion with Energy Recovery and Landfilling in the United States* (U.S. EPA November 2016), which refers to the percent combusted as a percent of total waste generation for that category. and can be accessed at: https://www.epa.gov/sites/production/files/2016-11/documents/2014_smmfactsheet_508.pdf

13 http://vitalsigns.worldwatch.org/sites/default/files/vital_signs_trend_plastic_full_pdf.pdf, the original source is PlasticsEurope, *Plastics–The Facts 2014: An Analysis of European Plastics Production, Demand and Waste Data* (Brussels: 2014).

APPENDIX III: EXAMPLE CALCULATION FOR MOLECULAR FORMULA RATIO (MFR)

The molecular formula ratio (MFR) determines the quantity of CO_2 or CH_4 captured by observing the molecular formula of the final plastic material. As set out in Section 8 above, the project proponent must provide the molecular formula for each type of plastic *i*, and the formula for the conversion from the GHGs which convert to the plastic material. This appendix sets out an example of how to determine the MFR.

For example, where the plastic material has the molecular formula $C_4H_6O_2$, the project proponent will provide the following molecular formula:

$$33H_2 + 12O_2 + 4CO_2 \rightarrow C_4H_6O_2 + 30H_2O$$

The following calculations are used to derive the amount of CO_2 sequestered in a given quantity of the example plastic material above. The example calculation is based on the following conditions:

1) The plastic production process produces 27.7 metric tons of a plastic material;

2) The plastic has a molecular formula of $C_4H_6O_2$, with a molar weight of 86[14] grams per mole, equal to 55.8% carbon by weight; and

3) The carbon in the plastic material is 100% derived from sequestered CO_2, and CO_2 is 27.27%[15] carbon.

Therefore, to calculate the amount of CO_2 embodied in the final plastic material, the equation is as follows:

1) 27.7 MT of plastic material x 55.81% carbon in the material = 15.46 MT carbon in material.

2) If 100% of the carbon comes from CO_2, that means that of 15.46 MT carbon in the material, it would take 56.6 MT of CO_2 to provide enough carbon for the 15.46 MT. This is because the carbon in the CO2 is 27.27% of the weight of the CO_2 molecule[16]. If there are 56.6 MT of CO_2 required to produce 27.7 MT of plastic, the ratio of CO_2 embodied in the plastic material is 2.043:1 sequestered CO_2:plastic by weight.

3) Thus, the project proponent (and the validation/verification body (VVB)) would know that for every 100 metric tons of plastic produced, 204.33 metric tons of CO_2 is sequestered.

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14 Molecular weight of carbon is 12, oxygen is 16 and hydrogen is 1. Therefore, $C_4H_6O_2$=12*4 + 1*6 + 16*2 = 86. The four carbon atoms amount to 48, and 48/86 = 55.8%.

15 The molecular weight of carbon is 12, oxygen is 16 and thus CO_2 = 44. The percentage of weight that is carbon is 12/44 or 27.27%.

16 15.46 MT / 0.2727 = 56.6 MT

Example of quantifying GHGs sequestered when CO_2 is used as a feedstock:

As Equation 5 states:

$$Q_{CO2.seq,y} = \sum_i \{[Q_{p,i,y} * (MW_C / MW_{p,i})] / RCM_{CO2}\}$$

Where:

$Q_{CO2,seq,y}$	= amount of CO_2 captured in year *y* to produce plastic material *i* by the project (metric tons per year)
$Q_{p,i,y}$	= Net quantity of plastic type *i* produced by the project in year *y* (metric ton)
MW_C	= the molecular weight of the carbon in the plastic material *i* (g/mol)
$MW_{p,i}$	= the total molecular weight of the plastic material *i* (g/mol)
RCM_{CO2}	= the fraction of carbon as part of the carbon dioxide molecule (% carbon in carbon dioxide by molar weight or 27.27%)

If $Q_{p,i,y}$ were 27.7 tons, using the numbers from the above example would yield the following:

$$Q_{CO2.seq,y} = [Q_{p,i,y} * (MW_C / MW_{p,i})] / RCM_{CO2}$$

$Q_{CO2.seq,y}$ = [27.7 * (48/86)] / 0.2727 = 56.6 metric tons of CO_2 sequestered

VCS Methodology

VM0041

METHODOLOGY FOR THE REDUCTION OF ENTERIC METHANE EMISSIONS FROM RUMINANTS THROUGH THE USE OF 100% NATURAL FEED SUPPLEMENT

Version 1.0

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Sectoral Scope 15

This methodology was developed by

MOOTRAL

Document Prepared by MOOTRAL SA

Author: Elsa Zoupanidou (Mootral SA)

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1 SOURCES

This methodology was developed based on the requirements and guidelines of the following:

- *VCS Standard, v4.0*
- *VCS Methodology Requirements, v4.0*
- *VCS Guidance: Guidance for Standardized Methods, v3.3*
- *2006 IPCC Guidelines for National GHG Inventories. Volume 4: Agriculture, Forestry and Other Land Use. Chapter 10: Emissions from livestock and manure management*

The following have informed the development of this methodology:

- *VCS module VMD0027: Estimation of domesticated animal populations, v1.0*
- *VCS module VMD0028: Estimation of emissions from domesticated animals, v1.0*
- *"Quantification Protocol" approved by the Alberta Offset System: Quantification protocol for reducing greenhouse gas emissions from fed cattle (version 3.0)*
- *ACR Methodology for Grazing Land and Livestock Management, v1.0*

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology provides procedures to estimate enteric methane (CH_4) emission reductions generated from the inhibition of methanogenesis due to the introduction of a natural feed supplement into ruminants' diets. This methodology considers only emission reductions from enteric fermentation.

Feed supplements applicable under this methodology reduce CH_4 emissions by directly acting on the population of methanogenic archaea in the rumen. This methodology focuses on application of natural plant-based feed supplements, which along with inhibiting methanogenesis, may also have advantageous effects on rumen bacteria, thereby improving fermentation in the rumen.

Depending on the location where a project is implemented and data availability, this methodology provides three approaches for the quantification of baseline emissions and two approaches for the quantification of project emissions. Specifically, the quantification of baseline emissions may be performed using data from either on-site direct measurements, or by applying one of two different Intergovernmental Panel on Climate Change (IPCC)-approved methods to model emissions using country-specific or peer-reviewed biometric data. The quantification of project emissions may be performed using data from either on-site direct measurements, or by applying an empirically-derived regional emission reduction factor provided by the feed supplement manufacturer.

Table 2: Additionality and Crediting Baseline Methods

Additionality and Crediting Method	
Additionality	Activity method
Crediting Baseline	Project Method

3 DEFINITIONS

In addition to the definitions set out in VCS document *Program Definitions*, the following definitions apply to this methodology:

Animal Group
Animals at each farm grouped based on a homogenous ruminant population characterization such as animal type, weight, production phase (e.g., pregnant or lactating cow) and feed type

Diet
Feed ingredients or mixture of ingredients including water, which is consumed by animals

Dry Matter Intake (DMI)
All nutrients contained in the dry portion of the feed consumed by animals

Emission Reduction Factor
Percent reduction of enteric methane emissions per animal due to project feed supplement

Enteric Methane
Methane emissions from ruminants, due to enteric fermentation, as part of the digestion of feed materials

Enteric Fermentation
A natural part of the digestive process of ruminants where microbes decompose and ferment food present in the digestive tract or rumen. Enteric methane is one by-product of this process and is expelled by the animal through burping.

Feed(s)
Edible material(s) which are consumed by animals and contribute energy and/or nutrients to the animal's diet

Feed Supplement
A feed added to an animal's regular diet to improve the nutritive balance of the total mixed ration (or any other purpose, such as reduction of methane emissions) and intended to be (i)

fed undiluted as a supplement to other feeds; (ii) offered free-choice with other parts of the feed; or (iii) further diluted and mixed to produce a complete feed

Gross Energy
The total caloric energy contained in feed

Livestock Production Operation
An agricultural setting, permanent or semi-permanent facility or non-grazing area, where domesticated animals are kept or raised either indoors or outdoors to provide traction or for livestock commodities purposes1

Methanogenesis
The formation of methane in the rumen by microbes known as methanogens

Neutral Detergent Fiber (NDF)
A measure of total structural components (i.e., lignin, hemicellulose, cellulose, tannins and cutins) within the cells of plants that provides an estimate of fiber constituents of feedstuffs and indicates maturity; the higher the value, the more mature and lower quality the forage

Rumen
The large first compartment of the stomach of a ruminant where fermentation occurs, which allows for the digestion of fiber and other feeds

Ruminant
A mammal that has a different digestive system to monogastric (single stomach) animals. The primary difference is that ruminants' "stomach" consists of four compartments. The ruminants are able to acquire nutrients from plant-based food by fermenting it in the biggest compartment, the rumen, prior to digestion. Ruminating mammals include species like cattle, goat, sheep, deer, giraffes and antelopes.

4 APPLICABILITY CONDITIONS

This methodology applies to project activities which reduce enteric methane (CH_4) emissions through the inhibition of methanogenesis due to the introduction of a natural feed supplement into ruminants' diets.

The methodology is applicable under the following conditions:

1. Livestock producers must feed their animals a natural feed supplement which reduces enteric CH_4 emissions by direct inhibition of methanogens in the rumen.

1 FAO. Shaping the Future of Livestock. Berlin, 18–20 January 2018 http://www.fao.org/3/i8384en/I8384EN.pdf

2. Only ruminant animals shall be included in the project.

3. The project feed supplement must meet the following conditions:

    a. The active ingredients of the feed supplement must be 100% natural plant-based or macroalgae-based and non-GMO. This includes extracted components of plants. The feed manufacturer must provide a non-GMO certificate based on lab analysis.

    b. The feed supplement must have been demonstrated to comply with all feed and food regulations in each national or subnational (including local) jurisdiction in which it is consumed. Where conflict arises between regulations, the most stringent standard must apply.

    c. The feed supplement must have no significant negative health or performance impacts on the animal to which it is fed. Where conflict arises between regulations, the most stringent standard must apply.

    d. The feed supplement must be used as per feeding instructions provided by the manufacturer. The instructions provide critical defining conditions to secure the default level of reduction of the enteric methane emissions, such as the feeding routine and dose of supplement per kg of DMI to the animal.

4. Emission reductions generated by the use of other feed supplements and/or activities (e.g., improving animal productivity or nutritional and management strategies), the objective of which does not lead to the inhibition of methanogenesis, cannot be claimed through this methodology. This is to prevent overestimation of emission reductions achieved.

5. The implementation of project activities must confirm that the herd of ruminants in a given operation is fed the project feed supplement. For this purpose, the project proponent must be able to trace the feed supplement fed to livestock from the producer to on-farm consumption.

6. Evidence must be provided that there will be no increase in the manure emissions due to feed supplementation (e.g., evidence-based literature, peer-reviewed publications, study reports).

7. Baseline emissions included in this methodology are CH_4 production from enteric fermentation and are determined as the average activity over at least three continuous years prior to project implementation. Therefore, the project activities are required to meet the following conditions:

    a. Where project areas involve livestock farms that were operating prior to the start of project activities, reliable data (e.g., gross energy intake and dry matter intake) per animal group must be available for a minimum of two years where using baseline emissions Option 1 and three years where using baseline emissions Option 2. See Section 8.1 below for further details on options for quantifying baseline emissions.

    b. Where project areas involve livestock farms for which no farm records or farming data are available, the project proponent must be able to provide evidence to substantiate the animal group to which each new project area is allocated according to the average group as described in national or regional statistical accounts (i.e., the baseline emissions will be considered as the average activity of where the project is located).

5 PROJECT BOUNDARY

The spatial extent of the project boundary encompasses all geographic locations of supplement production, supplement transport, and project activity locations where natural feed supplement is part of the livestock production operation.

Table 3 below indicates the emission sources and GHGs included in the project boundary and the GHGs to be monitored.

Table 3: GHG Sources Included In or Excluded From the Project Boundary

Source		Gas	Included?	Justification/Explanation
Baseline	Enteric Fermentation	CO_2	No	No changes in biogenic CO_2 emissions are expected due to the project activity.
		CH_4	Yes	CH_4 emissions from enteric fermentation, prior to the project technology implementation, represent the major source of emissions in the baseline scenario.
		N_2O	No	No changes in biogenic N_2O emissions are expected due to the project activity.
Project	Enteric Fermentation	CO_2	No	No changes in biogenic CO_2 emissions are expected due to the project activity.
		CH_4	Yes	CH_4 emissions from enteric fermentation are the major source of emissions in the project scenario.
		N_2O	No	No changes in biogenic N_2O emissions are expected due to the project activity.
	Supplement Production and Transport	CO_2	Yes	CO_2 emitted from supplement transportation and production.
		CH_4	Yes	CH_4 may be emitted from combustion of fossil fuels during the processing.
		N_2O	No	N_2O emissions are not expected during the production process.

As indicated in the table above, the project boundary includes CH_4 emissions from enteric fermentation. The dominant pathway for CH_4 emissions from enteric fermentation is exhalation, and therefore CH_4 emissions need only be monitored via exhalation. The project boundary does not include CH_4 emissions from flatulence, because changes in methanogenesis will not impact the fixed ratio of methane released between exhalation and flatulence due to physiology of the rumen (i.e., a decrease in exhaled methane corresponds to a decrease in methane flatulence). Further, due to rumen physiology, changes in methanogenesis does not impact manure decomposition. For this reason, the project boundary also does not include CH_4 or N_2O emissions from decomposing manure.

Ruminants release methane by exhaling the gas mainly through their mouth and nostrils. Enteric CH_4 is produced mainly in the rumen (90%) and, to a smaller extent (10%), in the large intestine (Muray et al., 1999; Dini et al., 2012). Feed supplements that inhibit rumen methanogenesis cannot influence the ratio of enteric methane emissions in exhaled air compared to methane emissions in extracted feces due to the ruminants' physiology. The specific and direct inhibition of the methanogenesis in the rumen is not demonstrated to cause a major change in the overall rumen fermentation as this process is downstream of these metabolic processes.

Consequently, feed supplements will not impact digestion in a way that would lead to an increase in the CH_4 or N_2O emissions in the manure decomposition. Keuzer et al. (2006) concluded, in fact, that feed additives designed to limit methane emissions reduced methane emissions from both the digestive track and manure decomposition. Another study by Nampoothiri et al. (2015) reports that, in general, dietary manipulations have very little effect on manure N_2O production. Further studies (Aguerre et al, 2011; Aguerre et al, 2012; Hristov et al, 2012) verified that methane reduction achieved by manipulating the rumen fermentation had no change in manure emissions. The emissions from this element are expected to be equal or lower in the project as compared to the baseline scenario. Avoidance of increase in the manure emissions due to feed supplementation is dealt with by the applicability condition 6 of this methodology.

6 BASELINE SCENARIO

At the project start date, the most plausible baseline scenario must be identified as the continuation of livestock operations following business as usual practices (i.e., typical feeding regime without using a natural feed supplement to reduce CH_4 enteric fermentation). There are no plausible alternatives to this baseline scenario.

7 ADDITIONALITY

This methodology uses an activity method for the demonstration of additionality. Project proponents applying this methodology must determine additionality using the procedure below:

Step 1: Regulatory surplus

The project proponent must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the *VCS Standard*.

Step 2: Positive list

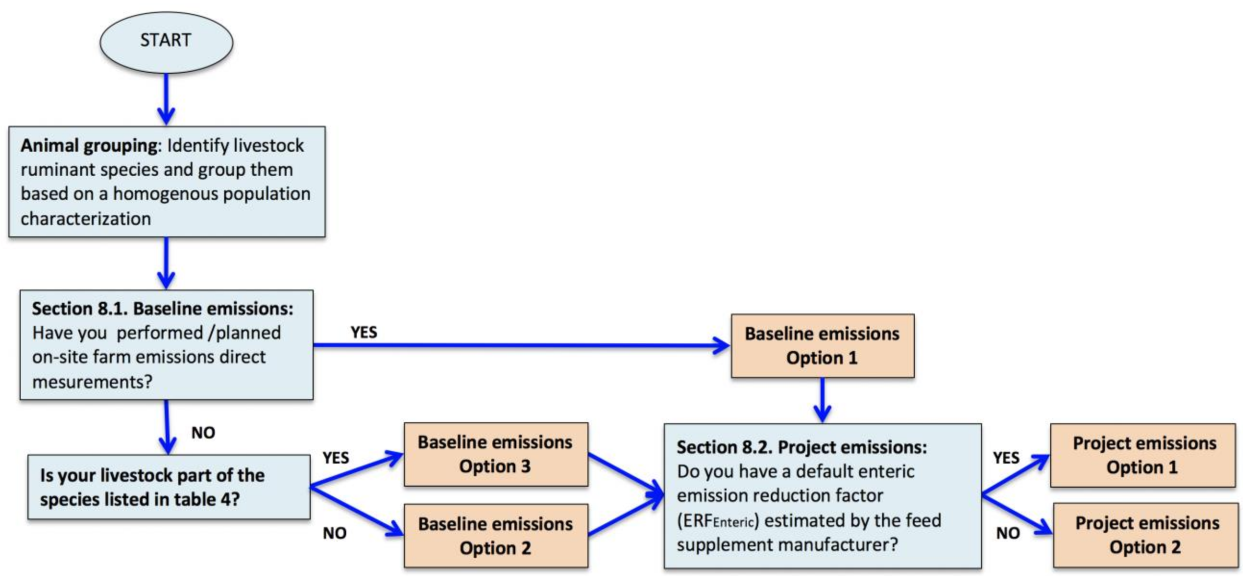
The applicability conditions of this methodology represent the positive list. The project must demonstrate that it meets all of the applicability conditions, and in so doing, it is deemed as complying with the positive list. The positive list was established using the activity penetration option (Option A in the *VCS Methodology Requirements*).

Justification for the activity method is provided in Appendix I.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

This methodology proposes three approaches for the quantification of baseline emissions and two approaches for the quantification of project emissions, the applicability of each being dependent on data availability. Figure 1 outlines the steps involved in determining baseline and project emissions. The steps are listed below and explained in more detail in the following sections.

Figure 1: Decision Tree for CH_4 Emissions from Enteric Fermentation



8.1 Baseline Emissions

Emissions in the baseline scenario are estimated as the sum of annual emissions from enteric fermentation according to the following equation:

$$BE_{Enteric_{\mathbf{i}}} = \sum_{j=1}^{N} [EF_{Enteric_{i,j}}] \bullet \frac{GWP}{1000} \quad (1)$$

Where:

$BE_{Enteric_i}$ Total baseline CH_4 emissions from livestock enteric fermentation for farm *i* (tCO_2e).

Where the project activity includes multiple farms, emissions in the baseline scenario are estimated as the sum of annual emissions from each farm *i*: $\sum_{i=1}^{N}[BE_{Enteric_{\mathbf{i}}}]$

$EF_{Enteric_{i,j}}$ Enteric CH_4 emissions factor for each animal group *j* during the monitoring period (kg CH_4 $group^{-1}$)

GWP Global Warming Potential of methane (tCO_2/tCH_4)

1000 kg per one metric tonne

i Identification of livestock farm (1,2,..,N)

j Animal grouping (1,2,..,N).

This methodology provides three options for determining the enteric emissions factor ($EF_{Enteric_j}$). Depending on the availability of relevant project data and measurements, each project proponent must choose the most appropriate of the following options for each animal grouping.

$EF_{Enteric_{ij}}$ Option 1

Option 1 calculates the enteric emission factor for each animal group by performing direct enteric methane measurements to estimate the methane production per animal group per day (enteric emissions production factor - $EF_{Production_{i,j}}$). The enteric emissions production factor for each animal group measured by the chosen technology must be available at the validation. Therefore, using Option 1, the enteric emission factor for each animal group is calculated as follows:

$$EF_{Enteric_{\mathbf{i,j}}} = EF_{Production_{i,j}} \bullet N_{i,j} \bullet Days_{i,j} \quad (2)$$

Where:

$EF_{Enteric_{i,j}}$ Enteric CH4 emissions factor for each animal group j during the monitoring period (kg CH4 $group^{-1}$)

$EF_{Production_{i,j}}$ Average enteric emissions production factor for each animal group during the baseline or monitoring period (on-site direct measurement by chosen technology2) (kg CH4 head-1 day-1)

2 See Appendix II

$Days_{i,j}$	Number of days for each animal in the group j during the monitoring period in farm *i*
$N_{i,j}$	Average number of head in each animal grouping *j* in the farm *i* in the monitoring period (head)
i	Identification of livestock farm (1,2,..,N)
j	Animal grouping (1,2,..,N)

Baseline emission production factor ($EF_{Production}$) may be measured prior to project implementation with a sample for each animal group subsequently included in the project. Alternatively, a control group for each animal group can be used during project implementation, thus allowing baseline monitoring and project monitoring to occur simultaneously. The control group is used as a baseline measure and is identical to all other animals with the exception that it does not receive the feed supplement. $EF_{Production}$ remains fixed for the project crediting period once determined. Please see Appendix II for further details regarding the direct methane measurement technologies and procedures.

Two years of farm-specific data (e.g., gross energy intake and dry matter intake) prior to project implementation must be provided during validation. This data will be used to demonstrate that the Option 1 measured baseline does not represent a biased event as compared to the prior conditions at the farm, and therefore the $EF_{Production}$ reflects the average activity of where the project is located.

$EF_{Enteric_{ij}}$ Option 2

Option 2 provides procedures to calculate the enteric emission factor for each animal group by applying an IPCC Tier 2 method, using the following equation. The emission factor for each animal group is calculated as follows:

$$EF_{Enteric_{\mathbf{i,j}}} = \left[GE_{\mathbf{j}} \bullet Y_{\mathbf{m},\mathbf{j}} \bullet N_{i,j} \bullet Days_{i,j}\right] \bullet EC^{-1} \quad (3)$$

Where:

$EF_{Enteric_{i,j}}$	Enteric CH4 emissions factor for each animal group j during the monitoring period (kg CH4 $group^{-1}$)
GE_j	Average gross energy intake per animal grouping *j* in the farm *i* (MJ $head^{-1}$ day^{-1})
Ym_j	Conversion factor (Ym) indicates the proportion of the animal grouping j gross energy intake (GE) converted to enteric CH_4 energy. Energy of CH_4 as a percentage of GE (dimensionless).

Days	Number of days for each animal in the group j during the monitoring period in farm *i*[3]
$N_{i,j}$	Average number of head in each animal grouping *j* in the farm *i* in the monitoring period (dimensionless)
EC	Energy content of methane (=55.65 MJ kg^{-1} of CH_4)
i	Identification of livestock farm (1,2,..,N)
j	Animal grouping (1,2,..,N)

Gross energy intake *GE* is calculated by multiplying dry matter intake by the energy density of the feedstuff, using Equation 4:

$$GE_j = [DMI_j \bullet ED] \tag{4}$$

Where

DMI $_j$ — Average dry mass of feed consumed by animal group j in a given day (Kg $head^{-1}$ day^{-1})

ED — Energy Density. Average energy content of dry matter [MJ kg^{-1}] =

- 18.45 MJ kg^{-1} may be used as a default for diets including edible oils with fat contents in the range of 4 to 6%.
- 19.10 MJ kg^{-1} may be used as a default for diets including edible oils with fat contents below 4%.

$EF_{Entericij}$ Option 3

Option 3 is only suitable for animal species listed in Table 4 below, and where the project proponent does not have the required data for Option 2. The enteric emission factor for each animal group, is calculated as follows:

$$EF_{Enteric_{i,j}} = [EF_{i,j} \bullet N_{i,j} \bullet Days_{i,j} \bullet DF_j] \tag{5}$$

Where:

$EF_{Enteric_{i,j}}$ — Enteric CH_4 emissions factor for each animal group *j* during the monitoring period (kg CH_4 $group^{-1}$)

3 Note that the number of days could be less than 365. For example, in the case of young cattle the number of days represents the length of stay in a specific group.

$EF_{i,j}$	Average enteric CH_4 emissions factor for each animal group *j* during the monitoring period (country or regional specific factors, or those provided in Table 4), (kg CH_4 $head^{-1}$ day^{-1})
Days	Number of days for each animal in the group *j* during the monitoring period in farm *i*
$N_{i,j}$	Average number of head in each animal grouping in the farm *i* in the monitoring period; dimensionless
i	Identification of livestock farm (1,2,..,N)
j	Animal grouping (1,2,..,N)

Table 4: Enteric Fermentation Emission Factors for Tier 1 Method 1 (kg CH_4 $head^{-1}$ day^{-1})

Livestock	Emission Factor
Buffalo	0.15
Sheep	0.02[4]
Goats	0.01
Camels	0.13
Deer	0.05
Alpacas	0.02
Other (e.g., Llamas)	To be determined[5]
Note: All estimates are ±30-50% Sources: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 10, table 10.10. and background paper by Ulyatt, J. et al.	

8.2 Project Emissions

4 For developing countries the emission factor is 5 kg CH4 $head^{-1}$ yr^{-1}. IPCC is an intergovernmental body of the United Nations therefore we assume countries are classified accordingly.

5 One approach for developing the approximate emission factors is to use the Tier 1 emissions factor for an animal with a similar digestive system and to scale the emissions factor using the ratio of the weights of the animals raised to the 0.75 power. Liveweight values have been included for this purpose. Emission factors should be derived on the basis of characteristics of the livestock and feed of interest and should not be restricted solely to within regional characteristics.

Emissions in the project scenario are estimated as the sum of annual emissions from enteric fermentation, and from the production and transport of the supplement, according to the following equation:

$$PE_{Enteric\ i} = \sum_{j=1}^{N}[\mathrm{EF}_{\mathrm{Enteric}_{ij}}] \bullet [1 - \mathrm{ERF}_{\mathrm{Enteric}_j}] \bullet \frac{GWP}{1000} + \mathrm{EFME}_i \quad (6)$$

Where:

$PE_{Enteric_i}$	Total project enteric CH_4 emissions from livestock enteric fermentation for farm *i,* and the production and transport of the supplement used during the monitoring period (tCO_2e) Where the project activity includes multiple farms, emissions in the project scenario are estimated as the sum of annual emissions from each farm *i*: $\sum_{i=1}^{N}[\mathrm{PE}_{\mathrm{Enteric}_i}]$
$EF_{Enteric_{i,j}}$	Enteric CH_4 emissions factor for each animal group during the monitoring period as determined in Equation 2, 3 or 5 above (kg CH_4 $group^{-1}$)
$ERF_{Enteric_j}$	Enteric CH_4 emissions reduction factor (default or determined percentage value). Supplement's percentage reduction of the enteric CH_4 per animal in an animal group *j* during the monitoring period.
$EFME_i$	Total emissions associated with manufacturing and transport of the feed supplement in the farm *i* during the monitoring period (tCO_2e)
GWP	Global Warming Potential of methane (tCO_2/tCH_4)
1000	kg per one metric tonne
i	Identification of livestock farm (1,2,..,N)
j	Animal grouping (1,2,..,N)

8.2.1 Enteric methane emissions reduction factor

There are two options to calculate the enteric methane emission reduction factor:

$ERF_{Enteric}$ Option 1: Apply the default enteric emission reduction factor (%) estimated by the manufacturer of the feed supplement and calculate the emissions using Equation 6.[6] This option may only be used where the enteric methane emission reduction factor provided by the manufacturer of the feed supplement is supported by peer-reviewed literature or farm-specific emissions data that was determined by following the guidelines specified in Appendix II. This

6 The default factor provided by the manufacturer must meet the requirements for default factors set out in Section 2.5.2 of the *VCS Methodology Requirements v4.0*.

information must be provided for review at validation and at each verification. Additionally, there must be no significant differences between project parameters (e.g., feed regime, animal type, weight, production phase, geographic region, and management practices) and the manufacturer's default enteric emission reduction factor study design. Where there are significant differences between the project parameters and the manufacturer's study design, the project must use Option 2.

$ERF_{Enteric}$ Option 2: Determine the enteric methane emissions reduction factor for each animal group by performing direct enteric methane measurements to estimate the methane production per animal group per day while consuming the feed supplement during the monitoring period. The feed supplement's enteric emission reduction factor will be quantified by comparing actual project performance to enteric emission factors determined when quantifying baseline emissions, using Equation 7.

Enteric emissions reduction factor calculation:

$$\text{ERFEnteric}_{i,j} = \frac{EF_{Enteric\ \boldsymbol{i,j}} - (\,PE_{\ \boldsymbol{j}} \bullet N_j * Days)}{EF_{Enteric\ \boldsymbol{i,j}}} \bullet 100 \qquad (7)$$

Where:

$ERF_{Enteric_{i,j}}$	Enteric CH_4 emissions reduction factor for each animal group *j* in farm *i* (default percentage value)
$EF_{Enteric_{i,j}}$	Enteric CH_4 emissions factor for each animal group *j*, determined using Option 1, 2 or 3 in Section 8.1 above (kg CH_4 $group^{-1}$)
$PE_{i,j}$	Average enteric emissions production factor for each animal group *j* during the monitoring period in farm *i* (on-site direct measurement by chosen technology[7]) (kg CH_4 $head^{-1}$ day^{-1})
$N_{i,j}$	Average number of head in each animal grouping *j* in the farm *i* in the monitoring period; dimensionless
$Days_{i,j}$	Number of days for each animal in the group *j* during the monitoring period in farm *i*
i	Identification of cattle farm (1,2,..,N)
j	Animal grouping (1,2,..,N)

7 See Appendix II, Table 7: Measurement technologies of enteric methane emissions

8.2.2 GHG emissions from feed supplement manufacturing and transport

Emissions from the feed supplement are estimated by including all GHG sources from manufacturing and transport. Accounting for these GHG sources is not required for a project where such emissions are shown to be *de minimis*[8]. Otherwise, these emissions must be estimated as follows:

$$EFME_i = \frac{FM_i \bullet EF_P}{1000} + EF_{T\,i} \qquad (8)$$

Where:

$EFME_i$	Total emissions associated with manufacturing and transport of the feed supplement in the farm *i* during the monitoring period (tCO_2e)
FM_i	Amount of feed supplement purchased by the farm *i* during the monitoring period (kg)
EFP	Emission factor for production of feed supplement (kg CO_2e kg^{-1})
EFT	Emissions for transport of feed supplement consumed during monitoring period to the farm *i* (tCO_2e)

Project emissions from the production of the feed supplement at the manufacturer's production facility are calculated as:

$$EF_P = (Q_{elec} \bullet EF_{elec}) + (Q_{ff\,a} \bullet FC_a \bullet EF_a) \qquad (9)$$

Where:

Q_{elec}	Quantity of electricity from the grid used per kilogram of feed supplement production MWh kg^{-1}) during the monitoring period. To be determined by the feed supplement manufacturer.
EF_{elec}	Emissions factor for electricity (kg CO_2 MWh^{-1})[9]
Qff_a	Quantity of fossil fuel type *a* used per kilogram of feed supplement production during the monitoring period (volume or kg fuel/kg feed supplement). To be determined by the feed supplement manufacturer.

8 The pool or source may be excluded only if it is determined to be insignificant using appropriate approved tools for significance testing (e.g., the CDM "Tool for Testing Significance of GHG Emissions in A/R CDM Project Activities", available at http://cdm.unfccc.int/EB/031/eb31_repan16.pdf).

9 The latest approved version of CDM tool "Tool to calculate the emission factor for an electricity system" may be used to determine EF_{elec} if country or state/province values are not available.

FC_a Energy content per unit of fuel type *a* combusted (terajoule or TJ/ volume or kg fuel).

EFfuel Emission factor of fuel type *a* (kg CO_2e/ TJ).

a Fossil fuel type

Project emissions from the transport of the feed supplement to the project site are calculated as:

$$EF_T = TEF_i \bullet D_i \bullet FM_i \quad (10)$$

Where:

TEF_i Tonnes per km or miles of CO_2 emitted by transport mode *m* per kg of feed delivering feed supplement consumed during the monitoring period to farm *i* (t CO_2 $kg^{-1}km^{-1}$)

D_i Distance travelled by transport mode *m* delivering feed supplement consumed during the monitoring period to farm *i* (km or miles)

FM_i Amount of feed supplement purchased by the farm *i* during the monitoring period (kg)

8.3 Leakage

In the context of this methodology, leakage could potentially consist of a change in the number of animals in the livestock operation due to livestock performance impacts of introducing the supplement, thereby necessitating changes in livestock populations in non-project operations to fulfill market demand. However, supplements are expected to have an insignificant impact on livestock performance. Additionally, due to the economics of livestock production, it is unlikely that the costs and risks associated with increasing or decreasing the number of animals in the operation is justified from the minimal expected changes in animal performance alone. Therefore, leakage is considered to be zero.

8.4 Net GHG Emission Reductions and Removals

Net GHG emission reductions are calculated as follows:

$$ER_{Enteric\ i} = \sum_{i=1}^{N}[BE_{Enteric\ i} - PE_{Enteric\ i}] \quad (11)$$

Where:

$BE_{Enteric_i}$ Total GHG emission reductions due to project activities during the monitoring period (tCO2e)

$BE_{Enteric_i}$	Total baseline enteric CH_4 emissions from livestock enteric fermentation in the farm *i* during the monitoring period (tCO_2e)
$PE_{Enteric_i}$	Total project enteric CH_4 emissions from livestock enteric fermentation in the farm *i,* and the production and transport of the supplement used during the monitoring period (tCO_2e)
i	Identification of farm (1,2,..,N)

9 MONITORING

9.1 Data and Parameters Available at Validation

Data / Parameter	GE_j
Data unit	MJ head^{-1} day^{-1} of dry matter
Description	Average gross energy intake for a specific animal group
Equations	3
Source of data	Records and data from livestock operator or associated partners for three continuous years of historical data prior to the initiation of the project or from national/regional statistical accounts. Records and data during the project implementation also required.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Gross energy intake can be calculated by dividing dry matter intake by the energy density of the feedstuff using equation 4 The gross energy (GE) content of the diets is calculated based on the fat level of the diets, therefore the livestock operator or associated partners need to demonstrate the fat content of the diet. Parameter to be updated with any change in the animal's feeding regime.
Purpose of Data	Calculation of baseline emissions
Comments	Calculated based on measured Daily Dry Matter Intake (DMI)

Data / Parameter	DMI_j
Data unit	Kg head^{-1} day^{-1}
Description	Average dry mass of feed consumed by an animal in a given day
Equations	4

Source of data	Records and data from livestock operator or associated partners for three continuous years of historical data prior to the initiation of the project or from national/regional statistical accounts. Records and data during the project implementation also required.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Data must be provided by the livestock operator or associated partners for each animal group. The farm records must document the average daily dry matter intake by animal grouping in the project. Parameter to be updated with any changes in the animal's feeding regime.
Purpose of Data	Calculation of baseline emissions
Comments	Required to calculate gross energy intake for equation 3

Data / Parameter	Ym_j
Data unit	Dimensionless
Description	Percentage of feed energy converted to methane for each animal group
Equations	3
Source of data	Country or regional and population specific Ym values should be used when available to better reflect the ruminants' population characteristics. Default values provided in Table 7 or 8 (Appendix III) may be used as an alternative where regional values are not available.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	National environmental agencies or similar government and research institutions have accurate peer-reviewed studies that provide Ym values. Therefore, these values must be preferred and used where direct applicability can be demonstrated. The IPCC default values for the Ym (Table 7 in Appendix III) are provided for the different animal categories which can be used when no respective values are available from country-specific research. The associated uncertainty estimation of ± 1% of the IPCC Ym values reflects the fact that diets can alter the proportion of feed energy emitted as enteric methane. Table 8 in Appendix III provides Ym values derived from cattle with diets containing various levels of neutral detergent fibers (NDF). The NDF values of the feed used in the project must be available in order to use Table 8. Detailed information can be found in Appendix III.

	The *IPCC Guidelines for National Greenhouse Gas Inventories* is internationally recognized and the data provided in the guidelines is peer reviewed. Parameters from any source (e.g., IPCC or national agencies) must apply the most conservative value of any uncertainty component. Parameters to be updated each crediting period where new data exists.
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	NDF_j
Data unit	Dimensionless
Description	Forage quality indices (% Neutral detergent fibers)
Equations	None
Source of data	Records and data from livestock operator or associated partners for three continuous years of historical data prior to the initiation of the project or from national/regional statistical accounts. Records and data during the project implementation also required.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Data must be provided by the livestock operator or associated partners for each animal group. The assessment of the quality of forages is typically provided by the farmer's nutritionist formulating the rations for the animals. NDF values are used to determine the Ym. Detailed information can be found in appendix III.
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	ED
Data unit	MJ per kg of dry matter
Description	Energy content of dry matter
Equations	4
Source of data	Default value or farm specific data
Value applied	N/A

Justification of choice of data or description of measurement methods and procedures applied	Farm specific values should be used, when available, otherwise use the typical values provided below: The typical energy density of feedstuff is: - 18.45 MJ kg'$^{-1}$ may be used as a default for diets including edible oils with fat contents in the range of 4 to 6% - 19.10 MJ kg'$^{-1}$ may be used as a default for diets including edible oils with fat contents below 4% Parameters to be updated each crediting period where new data exists.
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	EC
Data unit	MJ per kg of methane
Description	Energy content of methane
Equations	3
Source of data	Default value taken from IPCC 2006 guidance (Section 10.3.2)
Value applied	55.65
Justification of choice of data or description of measurement methods and procedures applied	This is a standard property of methane. In addition, the *IPCC Guidelines for National Greenhouse Gas Inventories* is internationally recognized and the data provided in the guidelines is peer reviewed. Parameters to be updated each crediting period where new data exists.
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter	$EF_{Enteric\,i,j}$
Data unit	kg CH_4 per animal group
Description	Enteric methane emission factor for each animal group
Equations	1
Source of data	Calculated using equation 2 or 3 or 5
Value applied	N/A
Justification of choice of data or description of	To allow for flexibility for potential projects, this methodology provides different options to calculate baseline emissions.

measurement methods and procedures applied	For option 2 and option 3 the first step in collecting data should be to investigate existing national statistics, national industry sources, research studies and International Environmental Agencies or FAO statistics. National environmental agencies or similar government and research institutions have accurate peer-reviewed data on emission factors or Ym for each animal group. Where no data are available on-site farm measurements can be performed (baseline option 1). The direct enteric methane measurements for ruminants can be conducted using state of the art technologies, well documented in the scientific literature and peer reviewed publications, see examples in table 6 in Appendix II. Parameters from any source (e.g., IPCC, national agencies, or direct measurement) must apply the most conservative value of the uncertainty component. Parameters to be updated each crediting period where new data exists.
Purpose of Data	Calculation of baseline emissions
Comment	Where direct measurements of methane emissions are performed, the project proponent or associated partner must demonstrate experience in methane measurement technologies (i.e., a professional in the area of animal science, livestock health and nutrition who has an M.Sc. or Ph.D. in the relevant discipline).

Data / Parameter	GWP of CH_4
Data unit	tCO_2/tCH_4
Description	Global warming potential of methane
Equations	1,6
Source of data	IPCC defaults
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	The IPCC Guidelines for National Greenhouse Gas Inventories is internationally recognized, and the data provided in the guidelines is peer reviewed. To be updated each crediting period where new data exist or accepted by Verra.
Purpose of Data	Calculation of baseline emissions
Comments	N/A

Data / Parameter:	PE_j
Data unit:	kg CH_4 head^{-1} day^{-1}
Description:	Average project enteric CH_4 emissions calculated by direct measurements using the chosen technology in farm *i* during the monitoring period (kg CH_4 head^{-1} day^{-1})
Equations	7
Source of data:	Measured for each animal group. Data records and study report of farm operations.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	To quantify the project enteric CH_4 an animal sample for each group is selected to perform the direct measurement. The project proponent needs to describe the required sampling protocols against objectives conditions. Sampling protocols should include sufficient numbers and sampling times to account for diurnal and postprandial variation in CH_4. All CH_4 measurement techniques are subject to experimental variation and random errors therefore it should be taken into account when reporting the final enteric CH_4 emission value. Detailed information can be found in appendix II. Parameter to be updated each crediting period or where the PE value is no longer representative (e.g., due to changes in feed regime, animal type, weight, production phase, geographic region, and management practices) new data must be collected.
Purpose of Data	Determination and calculation of project emissions
Comments	Because this requires direct measurements of methane emissions project proponent or associated partner must demonstrate experience in methane measurement technologies (i.e., a professional in the area of animal science, livestock health and nutrition who has an M.Sc. or Ph.D. in the relevant discipline).

Data / Parameter:	$ERF_{Enteric\ j}$
Data unit:	Percentage (dimensionless)
Description:	Enteric emission reduction factor
Equations	6 or 7
Source of data:	Provided by the feed manufacturer for each animal group or calculated using equation 6. Data records and study report of farm operations.
Value applied	N/A

Justification of choice of data or description of measurement methods and procedures applied	For equation 6 the default percentage value is determined from data provided by the feed supplement manufacturer (Option 1). For equation 7 (option 2) the project proponent must provide evidence to demonstrate the percentage enteric CH_4 reduction for each animal group. The project proponent will need to provide during verification the scientific protocol and the results of the measurements. Parameters from the feed manufacturer must apply the most conservative value of the uncertainty component.
Purpose of Data	Determination and calculation of project emissions
Comments	N/A

Data / Parameter:	$EFProduction_{i,j}$
Data unit:	kg CH_4 head^{-1} day^{-1}
Description:	Average project enteric CH_4 emissions calculated by direct measurements using the chosen technology A in farm *i* during the monitoring period (kg CH_4 head^{-1} day^{-1})
Equations	2
Source of data:	Measured for each animal group. Data records and study report of farm operations
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	To quantify the project enteric CH_4 production per animal samples for each group are selected to perform the direct measurement (option 1). The project proponent needs to describe the required sampling protocols for the relevant project conditions. Sampling protocols should include sufficient numbers and sampling times to account for diurnal and postprandial variation in CH_4. In animal studies the most favoured and most scientific method is the calculation of sample size by power analysis (Charan and Kantharia, 2013). All CH_4 measurement techniques are subject to experimental variation and random errors, therefore it should be taken into account when reporting the final enteric CH_4 emission value. Detailed information on reporting such error can be found in Appendix II. Parameter to be updated each crediting period or where the value is no longer representative (e.g., feed regime, animal type, weight, production phase, geographic region, and management practices).
Purpose of Data	Determination and calculation of baseline emissions
Comments	Because this requires direct measurements of methane emissions project proponent or associated partner must demonstrate experience in methane measurement technologies (i.e, at least one team member

	should be a professional in the area of animal science, livestock health and nutrition who has an M.Sc. or Ph.D. and working/research experience in the relevant discipline)

Data / Parameter:	$EF_{i,j}$
Data unit:	kg CH_4 $head^{-1}$
Description:	Average enteric CH_4 emissions factor for each animal in the group *j* during the monitoring period (country or regional specific factors or table 4), (kg CH_4 $head^{-1}$ day^{-1})
Equations	5
Source of data:	Country or regional and population specific factors should be used when available, to better reflect the ruminants' population characteristics. Default values provided in Table 4 may be used as an alternative where regional values are not available.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Country or regional specific EF values should be used, when available, to reflect the ruminant's characteristics. When not available, use the default values provided in Table 4. Parameters from any source (e.g., IPCC or national agencies) must apply the most conservative value of the uncertainty component, (i.e., a 50% reduction must be applied to values taken from Table 4) Parameter to be updated each crediting period where new data exists.
Purpose of Data	Determination and calculation of baseline emissions
Comments	N/A

9.2 Data and Parameters Monitored

Data / Parameter:	N_{ij}
Data unit:	Number of animals (head)
Description:	Average number of head in each animal grouping *j* in the farm *i* consuming a supplement during the monitoring period.
Equations	2, 3, 5 and 7
Source of data:	Data records of livestock operations using the feed supplement. Farm records.
Description of measurement methods and procedures to be applied:	Farm inventory data must be calculated as the average number of animals in each grouping, taking into account animal entry and exit movements from the grouping; this is a weighted average approach using the animal head*days factor; an example is demonstrated in the table below.

	<table><tr><td>Days on feed</td><td>Number of head</td></tr><tr><td>1</td><td>100</td></tr><tr><td>2</td><td>100</td></tr><tr><td>3</td><td>103</td></tr><tr><td>Total=3</td><td>Avg=101</td></tr></table>
Frequency of monitoring/recording:	Single value depending on the number of heads in each animal grouping using the natural feed supplement. Measured by daily or weekly average records.
QA/QC procedures to be applied:	Each farm record must list the number of animals in each group. Management and monitoring system to be established by the project proponent at the start of project. It could include data recording and verification procedures.
Purpose of data:	• Calculation of baseline emissions • Calculation of project emissions • Calculation of emission reduction
Calculation method:	No calculations are needed.
Comments:	Monitoring is established at the feed purchaser level. An appropriate and unique identification system for the purchasers, e.g. Project participant name, tax identification number, number of animals in each group, unique invoice number and date, would avoid double counting of emissions reduction claimed. At the time of reporting, baseline and project emissions shall be calculated based on livestock population, climatic conditions and other factors specific to the project and time period.

Data / Parameter:	Days
Data unit:	Days
Description:	Number of days project activity implemented in the specific animal grouping.
Equations	2, 3, 5, and 7
Source of data:	Data records of livestock operations using project feed supplement
Description of measurement methods and procedures to be applied:	None

Frequency of monitoring/recording:	Once for start date of supplement feeding and once for end date of supplement feeding, for each animal grouping
QA/QC procedures to be applied:	Management and quality control system to be established by the project proponent at the start of project. It could include data recording and verification procedures. The number of days could be less than 365. For example, in the case of young cattle the number of days represents the length of stay in a specific animal group.
Purpose of data:	• Calculation of baseline emissions • Calculation of emission reduction
Calculation method:	No calculations are needed
Comments:	N/A

Data / Parameter:	j
Data unit:	Animal grouping
Description:	Animals at each farm *i* should be grouped based on a homogenous ruminant population characterization
Equations	1,2, 3, 5, 6 and 7
Source of data:	Data records of livestock operations using project feed supplement.
Description of measurement methods and procedures to be applied:	Ruminant Population Characterization: Methane emissions from ruminants vary by animal type, weight, production phase (e.g., pregnant or lactating cow), feed type and seasonal conditions. Accounting for these variations in a ruminant population throughout the year is important to accurately characterize annual emissions. Project proponents must provide evidence at each validation and verification that emissions estimates are based on a homogenous population and the herd size and individual animal characteristics remain constant for a given period. Table 10.1 Representative Livestock Categories, in the IPCC 2006 report is an example of detailed characterization required for each livestock species.
Frequency of monitoring/recording:	Once for validation and at least once per monitoring period
QA/QC procedures to be applied:	Management and quality control system to be established by the project proponent at the start of project. It could include data recording and verification procedures.
Purpose of data:	• Calculation of baseline emissions • Calculation of emission reduction
Calculation method:	No calculations are needed

Comments:	N/A

Data / Parameter:	FM
Data unit:	Kg per month
Description:	Amount of feed supplement purchased by the farm *i* during the monitoring period
Equations	8,10
Source of data:	Data records of livestock operations purchasing project feed supplement
Description of measurement methods and procedures to be applied:	Monitoring is established at the feed purchaser level. An appropriate and unique identification system for the purchasers, e.g. Client name, unique invoice number and date, feed purchase receipts, weights, etc. and/or; feed delivery records. Delivery notes and invoices need to be reconciled between buyer and seller to verify records integrity. Sales records should be cross-checked with both buyer and seller of the feed supplemental to make sure records are consistent.
Frequency of monitoring/recording:	Monthly
QA/QC procedures to be applied:	Management and quality control system to be established by the project proponent at the start of project. It could include data recording and verification procedures. Farm records or third-party managed data showing both monthly-purchased complete feed and manufactured complete feed delivered to each grouping
Purpose of data:	Calculation of project emissions
Calculation method:	No calculations are needed
Comments:	Necessary to measure in order to determine monthly volumes of the feed supplement purchased.

Data / Parameter:	EF_P
Data unit:	tCO2e kg^{-1}
Description:	Emission factor for production of feed supplement. GHG emitted per kg of feed. All activities involved at the manufacturer's production facility of the feed supplement.
Equations	9

Source of data:	Records and documentation provided by the feed manufacturer.
Frequency of monitoring/recording:	Monthly
QA/QC procedures to be applied:	These values must be based on well-documented, reliable sources (e.g., national energy balances, government publications, industry associations, WRI/WBCSD GHG Protocol)
Purpose of Data	Determination and calculation of project emissions
Calculation method:	No calculations are needed
Comments	N/A

Data / Parameter:	EF_{T_i}
Data unit:	tCO2
Description:	Emission factor for transportation of feed supplement to the feed mill or directly to the farm *i* during the monitoring period. GHG emitted per kg of feed.
Equations	10
Source of data:	Records and documentation provided by the feed manufacturer.
Frequency of monitoring/recording:	Monthly
QA/QC procedures to be applied:	The project proponent must provide evidence to demonstrate the level of emission the monitoring period. These values must be based on well-documented, reliable sources (e.g., national energy balances, government publications, industry associations, WRI/WBCSD GHG Protocol)
Purpose of Data	Determination and calculation of project emissions
Calculation method:	No calculations are needed
Comments	N/A

Data / Parameter:	Qelec
Data unit:	MWh kg^{-1}
Description:	Quantity of electricity used by production facility supplied by the grid per kg of feed supplement produced
Equations	9

Source of data:	Documentation and date provided by the feed manufacturer
Description of measurement methods and procedures to be applied:	Electric utility bills provided by the manufacturer. For the production of the feed supplement, the monitoring would be for the manufacturer to provide the electricity consumption at the specific production line used for the manufacturing of the monthly quantity. Alternatively, where product line level data is not available the manufacturer can use a ratio based on the percentage the feed supplement represents in the total volume produced by the facility.
Frequency of monitoring/recording:	Monthly
QA/QC procedures to be applied:	To confirm the production of feed supplement monthly production output data need to be available by the manufacturer.
Purpose of data:	Calculation of project emissions
Calculation method:	No calculations are needed
Comments:	N/A

Data / Parameter:	Qff
Data unit:	Volume or kg fuel/kg feed supplement
Description:	Quantity of fossil fuel used (L, m^3 or other of each type of fuel used) at the production facility per kg feed supplement produced.
Equations	9
Source of data:	Report provided by the feed manufacturer
Description of measurement methods and procedures to be applied:	Fossil fuel invoices provided by the manufacturer. For the production of feed supplement, the monitoring would be for the manufacturer to provide the quantity of fossil fuel used at the specific production line for the manufacturing of the monthly quantity. Alternatively, where product line level data is not available the manufacturer can use a ratio based on the percentage the feed supplement represents in the total volume produced by the facility.
Frequency of monitoring/recording:	Monthly
QA/QC procedures to be applied:	To confirm the production of feed supplement monthly production output data need to be available by the manufacturer.
Purpose of data:	Calculation of project emissions
Calculation method:	No calculations are needed
Comments:	N/A

Data / Parameter:	EF_{elec}
Data unit:	kg CO2 MWh^{-1}
Description:	Emission factor for electricity
Equations	9
Source of data:	Country-specific emission factors for grid electricity from a reputable regional or national source. Otherwise from an International organization like the International Energy Agency (IEA).
Description of measurement methods and procedures to be applied:	Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. Estimation, reference values must be obtained from the relevant national GHG inventory. The value used should be consistent with the source of generation. In the absence of local or regional data, reference values may be obtained from the most recent version of the IPCC guidelines for National Greenhouse Gas Inventories.
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	N/A
Purpose of data:	Calculation of project emissions
Calculation method:	No calculations are needed
Comments	The latest approved versions of CDM tools “Tool to calculate the emission factor for an electricity system” may be used to determine EFelec where country or state/province data are not available. https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v7.0.pdf

Data / Parameter:	FCa
Data unit:	TJ //volume or kg of fuel
Description:	Energy content per unit of fuel type *a*
Equations	9
Source of data:	Regional or national default values from recognized sources or IPCC reports
Description of measurement methods and procedures to be applied:	Where more than one recognized source is available, the most appropriate source must be selected, based on data quality indicators including technological appropriateness, regional specificity, and vintage of the data.

	These values must be based on well-documented, reliable sources (e.g., national energy balances, government publications, industry associations, WRI/WBCSD GHG Protocol) In the absence of local or regional data, reference values must be obtained from the most recent version of the IPCC guidelines for National Greenhouse Gas Inventories.
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	N/A
Purpose of data:	Calculation of project emissions
Calculation method:	No calculations are needed
Comments	N/A

Data / Parameter:	EF_{fuel}
Data unit:	kg GHG (CO_2, CH_4, N_2O) per L, m^3 or other of each type of fuel used
Description:	Emission factor for fuel combustion type
Equations	9
Source of data:	Regional or national default values from recognized sources or IPCC reports
Description of measurement methods and procedures to be applied:	Where more than one recognized source is available, the most appropriate source must be selected, based on data quality indicators including technological appropriateness, regional specificity, and vintage of the data.
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. These values must be based on well-documented, reliable sources (e.g., national energy balances, government publications, industry associations, WRI/WBCSD GHG Protocol) In the absence of local or regional data, reference values must be obtained from the most recent version of the IPCC guidelines for National Greenhouse Gas Inventories.
Calculation method:	Calculation of project emissions
Comments	This parameter may be updated over the course of the crediting period (as a project description deviation) due to the availability of more recent information.

Data / Parameter:	TEF
Data unit:	Tonnes per km or miles per kg of feed ($tCO2\ kg^{-1}km^{-1}$)
Description:	Emission factor values for each mode of transport m
Equations	10
Source of data:	Regional or national default values from recognized sources
Description of measurement methods and procedures to be applied:	Default values must be sourced from recognized, credible sources and be geographically and temporally relevant to project specifics. These values must be based on well-documented, reliable sources. The range of appropriate data must be documented and the chosen data must be justified, using criteria that include data source (recognized and authoritative sources); geographic, temporal and technology specificity; conservativeness (i.e., does not overestimate emission reduction); and where the data is peer reviewed (preferred)
Frequency of monitoring/recording:	Monthly
QA/QC procedures to be applied:	Where more than one recognized source is available, the most appropriate source must be selected, based on data quality indicators including technological appropriateness, regional specificity, and vintage of the data.
Purpose of data:	Calculation of project emissions
Calculation method:	No calculations are needed
Comments:	N/A

Data / Parameter:	D_i
Data unit:	Distance unit (e.g. kilometers, miles)
Description:	Total distance travelled by transport mode m for farm i (km or miles)
Equations	10
Source of data:	Data provided by the project proponent or manufacturer
Description of measurement methods and procedures to be applied:	Distance travelled by transport mode m delivering feed supplement consumed during the monitoring period to the project location, farm. Where the feed supplement goes through a feedmill then the distance to the feedmill should be measured and not to the farm.
Frequency of monitoring/recording:	Monthly
QA/QC procedures to be applied:	N/A

Purpose of data:	Calculation of project emissions
Calculation method:	No calculations are needed
Comments:	N/A

9.3 Description of the Monitoring Plan

The project proponent must establish, maintain and apply a monitoring plan and GHG information system that includes criteria and procedures for obtaining, recording, compiling and analyzing data, parameters and other information important for quantifying and reporting GHG emissions. Where measurement and monitoring equipment is used, the project proponent must ensure the equipment is calibrated according to current good practice (e.g., relevant industry standards).

The project proponent must be able to demonstrate the ruminants for which it is claiming emission reductions have been fed with the appropriate quantity of feed supplement. In order to do so, project proponents must provide detailed feeding records as per manufacturer instructions (applicability condition 3c) for each farm as well as proof of purchase of an appropriate quantity of the feed supplement. Proof of purchase may be provided through delivery receipts and invoices, which must contain batch information, or other identification information, that can trace the feed supplement back to the manufacturer.

All necessary documents must be collected and centrally stored by the project proponent, and be available for verification at any time. The data subject to monitoring and required for the determination and further verification must be archived and stored in electronic format by the project proponent for at least two years after initial verification.

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APPENDIX I: JUSTIFICATION FOR ACTIVITY METHOD

This initial assessment of activity penetration indicates that there is not enough activity in any country that would put such penetration above the 5% threshold called for in the VCS Program requirements. It is known that no country has an activity penetration rate higher than 5% at this time due to the unique technology availability.

Per the VCS rules, Verra will reassess whether the activity penetration levels remain within the permitted threshold within three years of the initial approval of the methodology. At that time, Verra will base its assessment on national boundaries, focusing on countries where feed supplements that reduce methanogensis have been used. Also, and in the spirit of conservativeness, where sub-national regulations or policies may impact the likelihood of the project activity being implemented, Verra may use such boundaries as the basis of the reassessment of the activity penetration rate.

Positive List

This project activity in particular, and CH_4 enteric fermentation reduction in general, is a relatively recent field with few, if any, fully commercial technologies. Thus, the methodology uses an activity method for demonstrating additionality, with this technology (the natural feed supplement) as the basis for a positive list. This approach stipulates that the total number of ruminants fed with a supplement inhibiting methanogenesis does not amount to five percent of the total number of ruminants in agricultural settings worldwide. Five percent is the activity penetration threshold set by the *VCS Methodology Requirements v4.0*, and is determined by taking the Observed Activity (OA) divided by the Maximum Adoption Potential (MAP). Where the result of this equation is less than five percent, the project activity may be considered additional.

Activity penetration is given as:

$APy = OAy / MAPy$

Where:

APy = Activity penetration of the project activity in year y (percentage)

OAy = Observed adoption of the project activity in year y

$MAPy$ = Maximum adoption potential of the project activity in year y

Maximum adoption potential (MAP) of the project activity in year y

The *VCS Methodology Requirements v4.0* defines MAP as "the total adoption of a project activity that could currently be achieved given current resource availability, technological capability, level of service, implementation potential, total demand, market access and other relevant factors within the methodology's applicable geographically defined market." In this case, given the early stage of feed supplements for reducing enteric methane emissions, it is difficult to say that there are any resource (or other) constraints that would limit the adoption of this technology.

However, for the purposes of this methodology, the maximum adoption potential of this activity may be limited to ruminants that have been reared for the production of meat and dairy products worldwide. The reason for this selection is due to market access and implementation constraints (e.g., necessary infrastructure for getting the feed supplement to the farm, and appropriate facilities to administer the feed supplement to the animal on a regular basis).

The global ruminant livestock population is roughly 3.6 billion[10], of which approximately 2 billion represents the total number of livestock animals used for meat and dairy products. Figure 2 below illustrates the amount of livestock ruminants worldwide11. Table 5 below illustrates the number of livestock animals used for meat and dairy products:

Table 5 Total number of livestock animals used for meat and dairy products

Type of animal	Number of livestock animals
Dairy cattle[12]	278,000,000
Dairy sheep and goat[13]	463,444,034
Cattle for meat production[14]	300,074,797
Sheep, and goat for meat production[15]	989,247,558
TOTAL	2,030,766,389

10 For the purpose of this analysis the ruminant sector comprises cattle, sheep and goat, and buffalo. The global ruminant population in 2010 was estimated to be 3 612 million (FAOSTAT, 2012), with cattle making up nearly 40 percent, sheep and goat 55 percent, and buffalo the remaining 5 percent. (FAO (2017) and https://ourworldindata.org/meat-production#livestock-counts)

11 Data from 1961 onwards is sources from the UN Food and Agricultural Organization (FAO) statistics. Available at: http://www.fao.org/faostat/en/#data/QA

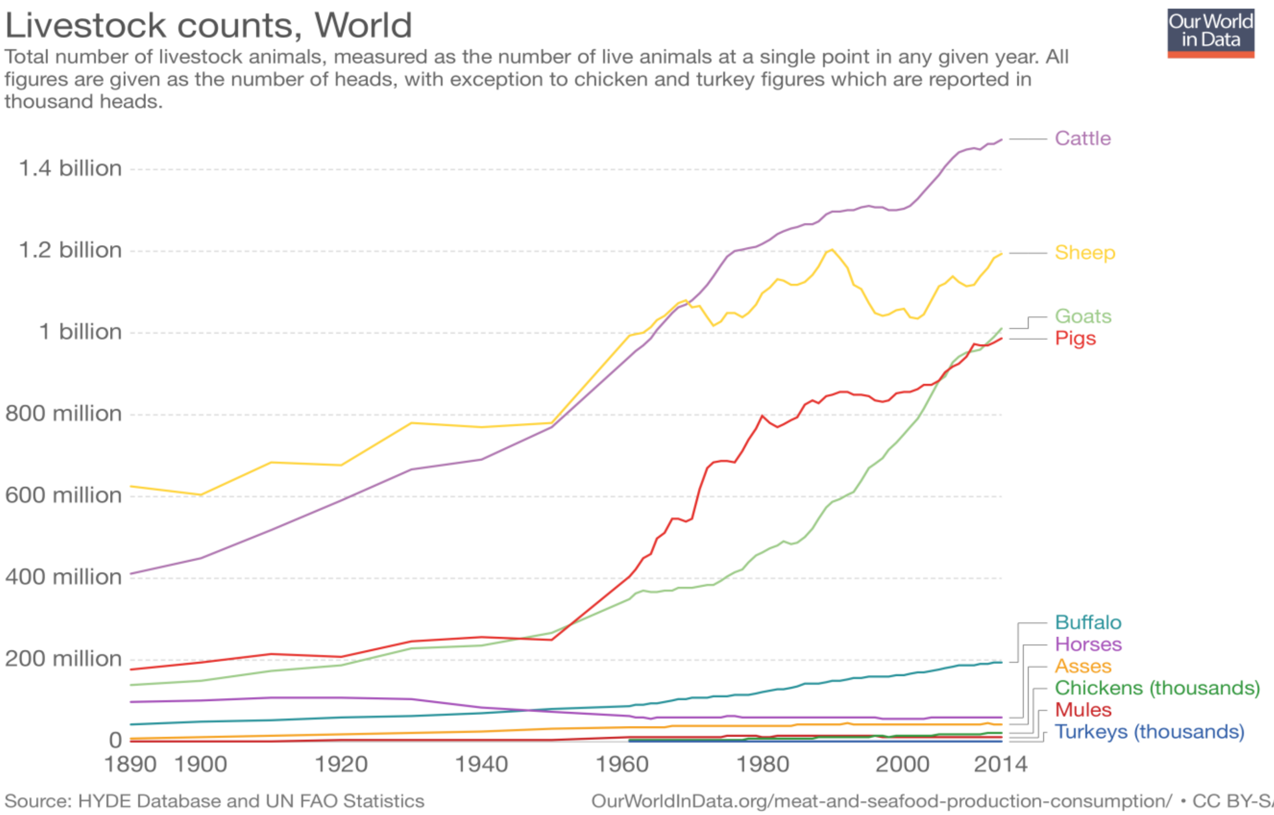
12 https://dairy.ahdb.org.uk/market-information/farming-data/cow-numbers/world-cow-numbers/#.XZxhmS-B2L4

13 Dairy small ruminants account for approximately 21% of all sheep and goats in the world (2'206'876'356 animals, https://ourworldindata.org/meat-production#livestock-counts);

14 Total number of livestock animals slaughtered for meat; FAO (2017) and https://ourworldindata.org/meat-production#number-of-animals-slaughtered-for-meat

15 https://www.sciencedirect.com/science/article/pii/S0022030218305290#targetText=There%20are%20approximately%202%2C200%20million,in%202016%20(799%20Mt)

Figure 2: Total Number of Livestock Animals in The World



According to FAO[16] grazing animals supply about 9 percent of the world's production of beef and about 30 percent of the world's production of sheep and goat meat. In grazing conditions, logistical limitations might occur due to accessibility. Considering that this project activity requires administration of the feed supplement to the animal on a regular basis, grazing animals should be excluded as feeding control cannot be exercised. Dairy animals are not excluded as they can have daily access to the feed in the milking parlour.

Therefore, for the purposes of this methodology, the maximum adoption potential of this activity is limited to MAPy= 1.707 billion.

Observed adoption of the project activity in year y

Few dietary strategies have been proposed to lower methane production in ruminants (Knapp et al, 2014; Boadi et al 2004). However, most of these are not commercially available and/or have no impact

16 http://www.fao.org/3/x5303e/x5303e00.htm#Contents

on enteric fermentation. Currently only a few products have been observed in the market.

Namely, linseed and alfalfa products containing high levels of omega-3 fatty acids can reduce the level of saturated fatty acids, and the elevation of dietary fat levels in ruminant diets may be a suitable way of lowering methane production. From a 2010 report,17 linseed and alfalfa were fed to approximately 50,000 cows. From an article published in 2018,18 a different product consisting of a blend of essential oils that claim to reduce methane production by cattle has reached approximately one million cattle. Neither of these publications report on the reduction of enteric emissions via a reduction of methanogenesis. However, for the purposes of this demonstration of additionality, it is assumed that the project activities are the same. To be conservative it is assumed that the published reports were only capturing half of all enteric emission reduction activities, which results in an estimated activity of 2.1 million ruminants.

Therefore:

APy = *OAy / MAPy*
APy = *2.1 million / 1'707 billion*
APy = *0.123%*
APy < *5%*

Given the current ruminants population and the commercially available feed supplements, and in particular those which have a significant effect on reducing enteric methane emissions by direct inhibition of methanogens in the rumen, it is demonstrated that the activity penetration level of the project activity covered by this methodology is below the five percent threshold, and the project activity may be deemed additional.

Where the project activity has been commercially available in any area of the applicable geographic scope for less than three years (i.e., it uses a new technology or measure), it shall be demonstrated that the project activity faces barriers to its uptake, per the VCS rules. This proposed project activity faces technological barriers that prevent its implementation:

1. The project activity requires extra effort from the farmers to administer the feed supplement as per feeding instructions provided by the manufacturer. In some cases, this might require properly trained farmers to secure the default level of reduction of the enteric methane emissions, such as the feeding routine and dose, to maintain the technology in a way that does not lead to an unacceptably high risk of equipment disrepair and malfunctioning or other underperformance.

17 http://www.pinallet.com/data/FEEEDINFO%20Interviews%20VALOREX%20CEO.pdf

18 https://www.greenoptimistic.com/swiss-company-develops-new-cow-feed-fewer-farts-20181006/#.XF

2. This project activity implementation will require the purchase of feed supplement, which is an addition to the existing farmers' variable costs. Farmers make multiple decisions in the agricultural cycle about the adoption of products and practices. According to Loevinsohn et al. (2013), farmers' decisions about whether and how to adopt new technology are often the result of a comparison of the uncertain benefits of the new invention with the uncertain costs of adopting it. For adoption to occur, farmers need to know that a technology exists, believe that it will improve productivity, and understand how to use it effectively. Given the early stage of feed supplements for reducing enteric methane emissions, farmers willingness to adopt and carry on the activity increase the risk of technological failure due to the process.

3. Natural products occur during a certain time of year (seasonal crops). Therefore, working capital can fluctuate drastically which can lead to an unacceptably high risk of technology availability. Since this methodology is based on natural plant-based technology, the project activity implementation will require management of the seasonal effects on working capital. During the seasonal peak, the company will require higher net investment in short-term (current) assets.

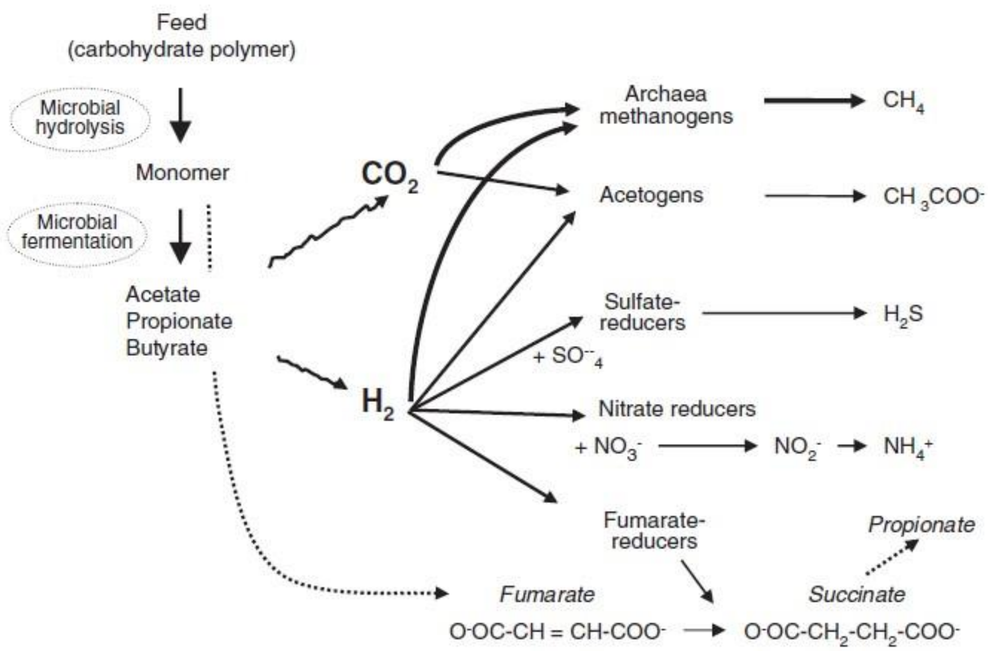
APPENDIX II: BACKGROUND INFORMATION ON PROJECT ACTIVITY

Enteric fermentation is the second largest source of global emissions from livestock supply chains, contributing about 40 percent of total emissions. Cattle emit 77 percent of all enteric methane (Gerber et al., 2013). Ruminants, in particular, release methane as a result of their digestion process of feed material in the rumen. These are enteric emissions from ruminants and are significant contributors to greenhouse gas emissions.

Research on various feed management activities has already been conducted to assess their ability to reduce methane production (Eger et al., 2018). Enteric methane is produced from microbial fermentation of feed (HOBSON et al., 1981; Whitford et al., 2001). Primary anaerobic microbiomes degrade organic matter into volatile fatty acids. In this process, hydrogen gas and carbon dioxide are produced as by-products. Methanogens metabolize hydrogen and carbon dioxide into methane (HEGARTY, 1999; Moss et al., 2000). Figure 1 provides an illustration of the microbial fermentation of feed polysaccharides and H_2 reduction pathways to CH_4 in the rumen.

The production of methane in the rumen can represent a loss of energy up to 12% (Johnson and Johnson, 1995). Therefore, production increases and energy efficiencies by the natural feed supplement could be seen as complementary outcomes when enteric methanogenesis is reduced (Graz et al., 2017). An additional goal of reducing enteric fermentation is to enable livestock producers to improve the environmental profile of meat and dairy products and provide consumers with sustainable climate-friendly products with a quantified carbon footprint reduction.

Figure 3: Schematic microbial fermentation of feed polysaccharides and H_2 reduction pathways to CH_4 in the rumen (Morgavi et al., 2010).



Direct enteric methane measurements

The direct enteric methane measurements for ruminants may be conducted using state of the art methods, well documented in the scientific literature. This includes respiration chambers as an established and widely used technique since 1958. However, some operations require measurements of CH_4 emissions of a larger number of animals, and therefore, short-term measurement techniques such as automated head chambers (e.g., the GreenFeed system) and (handheld) laser CH_4 detection (Hammond et al., 2016) are used to meet this objective with the spot measurement of gas concentrations in samples of exhaled air at certain time points. Repeated spot measurements can be taken whilst the animals are feeding or standing, and during the milking parlour for dairy operations. There are diverse technologies being used worldwide for quantifying enteric methane emission, however, there is no joined-up protocol covering all aspects, including, data collection, data extraction, data handling, and estimating methane volume from the measured concentration. Experience in animal studies is required to develop a protocol to generate accurate results.

In case the manufacturer of the natural feed supplement cannot provide sufficient documentation to support a default emission reduction factor, the project proponent must perform direct enteric methane measurements. The baseline emissions factors may still be set using option 2 or 3 as described in Section 8.1 above. Overall the chosen measurement technology and the measuring procedures must meet the following conditions:

1. The technology must be well documented in the scientific literature in peer-reviewed publications.

2. The technology enables measurements for animals in their 'normal' environment, which can be applied under conditions relevant to project livestock production.

3. The measurement error of the technology and sample error needs to be reported under the project conditions.

4. The project proponent or associated partner need to demonstrate technical skills and experience in operating direct enteric methane measurements to generate accurate results

5. The recommended measurement protocol needs to determine optimal sample size and recording duration.

6. The project proponent shall estimate the measurement uncertainty and apply confidence deductions to reduce bias and uncertainties as far as is practical. Methods used for estimating uncertainty shall be based on recognized statistical approaches such as those described in the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. Confidence deductions shall be applied using conservative factors such as those specified in the *CDM Meth Panel guidance on addressing uncertainty in its Thirty Second Meeting Report, Annex* 14

Table 6 provides a description of three different technologies for direct measurement of enteric methane emissions and, therefore, calculate the emission reductions following a specific scientific protocol. These three technologies are used for demonstration purposes and are not restrictive, as improving technologies could allow more accurate measurements in the future.

Table 6: Measurement technologies of enteric methane emissions

Type of measurement method/technology	Description of the method/technology
Respiration Chambers	Respiration chambers are used to measure CH_4 at an individual animal level under research conditions. The principle of the respiration chamber is to collect exhaled CH_4 emissions from all sources of enteric fermentation (mouth, nostrils and rectum) from the animal and measure the concentration. The cow needs to be in the chamber up to 4 days. All open-circuit chambers are characterized by an air inlet and exhaust fans. Each chamber is fitted with internal ventilation fans for efficient mixing of expired gases and incoming gases. The chamber is equipped with sensors for measuring relative humidity, temperature, barometric pressure and gas (CH_4, H_2, O_2, H_2S).
Automated head chambers – Infra-red method for methane measurements (e.g., GreenFeed – Large Animals)	Short-term CH_4 emissions can be measured by automated head chambers. One such device is the GreenFeed (GF) system (C-Lock Inc., Rapid City, South Dakota, USA). The GreenFeed (GF) system is a static short-term measurement device that measures CH_4 (and other gases including CO_2) emissions from individual ruminant by integrating measurements of airflow, gas concentration, and detection of head position during each animal's visit to the unit (Zimmerman and Zimmerman, 2012).

Laser system for methane detection (LMD)	A handheld methane detector (LMD) is a tool for estimating the methane emissions from individual ruminants by measuring the profiles of the exhaled air. The method uses laser absorption spectroscopy to measure the methane concentration (ppm-m) in a distance of one meter, between the hand-portable instrument and the solid target (cow's nostrils). The analysis is based on real-time breath analysis. The measurement time depends on the natural fluctuation, which arises around once in three minutes (Chagunda et al., 2013).

APPENDIX III: Y_M PERCENTAGE OF GROSS ENERGY IN FEED CONVERTED TO METHANE FOR A SPECIFIC ANIMAL GROUP

The Ym value is defined as the percentage of gross energy intake by the ruminant that is converted to methane in the rumen. As mentioned in section 9 for Ym, national environmental agencies or similar government and research institutions have accurate peer-reviewed studies that provide Ym values.

In the IPCC guidelines (1996) default values for the CH_4 conversion rates are provided for the different animal categories when no respective values are available from country-specific research (table 7). These estimates are based on the general feed characteristics and production practices found in either developed or developing countries. The associated uncertainty estimation of ± 1% of the Ym values reflects the fact that diets can alter the proportion of feed energy emitted as enteric methane. When the quality of the feed is good the lower bounds should be used (i.e., high digestibly and energy value). Higher bounds are more appropriate when poorer quality of feed is available. Neutral detergent fiber (NDF) is often considered a good determinant of quality. NDF measures total cell wall content of plant and indicates maturity; the higher the value, the more mature and lower quality the forage.

Table 7:Livestock CH_4 Conversion Factors[19,20]

Livestock category	Ym 21
Feedlot fed Cattle 22	3.0% ± 1.0%
Dairy Cows (Cattle and Buffalo) and their young	6.5% ±1.0%

19 When the quality of the feed is high the lower bounds should be used (i.e., high digestibly and energy value). Higher bounds are more appropriate when poorer quality of feed is available. The neutral detergent fiber (NDF) provides information to the quality of the feed. NDF within a given feed regime is a good measure of feed quality and plant maturity. For legume forages, NDF content below 40% would be considered high quality, while above 50% would be considered poor. For grass forages, NDF < 50% would be considered high quality and > 60% as low quality.

20 Note that in some cases, CH_4 conversion factors may not exist for specific livestock types. In these instances, CH_4 conversion factors from the reported livestock that most closely resembles those livestock types can be reported. For example, CH_4 conversion factors for other cattle or buffalo could be applied to estimate an emission factor for camels.

21 The methane conversion factor ± values represent the range.

22 When fed diets contain 90 percent or more concentrates

Other Cattle and Buffaloes that are primarily fed low quality crop residues and by- products	6.5% ±1.0%
Other Cattle or Buffalo – grazing	6.5% ± 1.0%
Lambs (<1 year old)	4.5% ± 1.0%
Mature Sheep	6.5% ± 1.0%
Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 10, table 10.12 and table 10.13.	

The following Table 8 may be used (as an alternative to Table 7) to estimate Ym. The values of the table are derived from cattle with diets containing various levels of NDF. The NDF values of the feed used in the project must be available in order to use Table 8.

Table 8: Estimates of the Percentage of Gross Energy in Feed Converted to Methane (Ym) for Various Diets (Grainger and Beauchemin, 2011 and Moate et al. 2011)

Various Diets	Ym (% of GEI)
Default (unknown diet composition)	6.50%
Diet with < 25% NDF	5.50%
Diet with 25-30% NDF	6.25%
Diet with 30-50% NDF	6.50%
Diet with >50% NDF	7%
Situations in which adjustments apply to YM values above*	
Feeding fats*	
Calcium salts of palm oil (or similar bypass fats)	No reduction
Other Fat Sources*, not to exceed 80 g fat/kg DM . Reduction of Ym for each 10g increase in fat content per kg of animal feed on a dry matter basis (10g fat/kg DMdiet)	-3.40%
*Corn DDGS cannot exceed 20% of dry matter of ration, and the higher protein content of the DDGS must be addressed in the ration formulation to prevent excess nitrogen excretion. The procedures to implement proper use of lipids and corn DDGS must be documented by the nutritionist Source: Alberta Offset System: Quantification protocol for reducing greenhouse gas emissions from fed cattle	