CAPCOA GHG Rx Protocol:

Weatherization of Single Family and Multi-Family Buildings

(Based on the Verified Carbon Standard Methodology Version 1.1, Sectoral Scope 3)

(Approved by the CAPCOA Board on November 3, 2016)

The following conditions apply for use in the CAPCOA GHG Rx:

1. **Projects must be located in California**
2. **Projects must commence on or after 1/1/2007**
3. **Crediting period for emission reductions must be set to the calendar year.**
4. **Energy improvements that are required by a locality do not meet the regulatory surplus test, and therefore cannot be granted credit under this protocol.**

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.

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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.

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[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 90^{th} percentile value within the numerically ordered sample. To calculate the 90^{th} percentile the sample data point values ($v_1, v_{2...}v_N$) must be ordered from least to greatest. The 90^{th} 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*

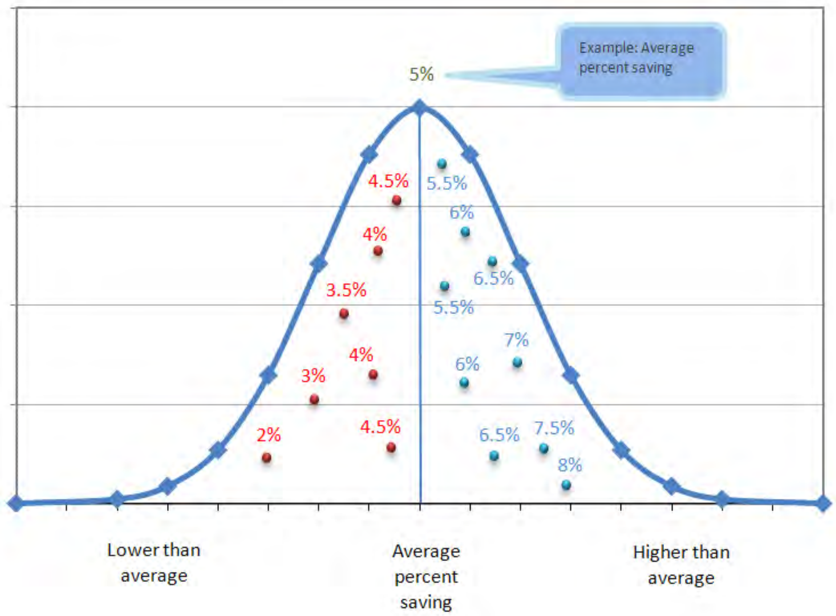

Figure 1. This graph shows the percent savings in energy consumption of buildings and Dwellings within the Same Building Stock. The percent savings is calculated from the change in weather normalized energy consumption in Dwellings from the Same Building Stock over at least the three most recent years 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.

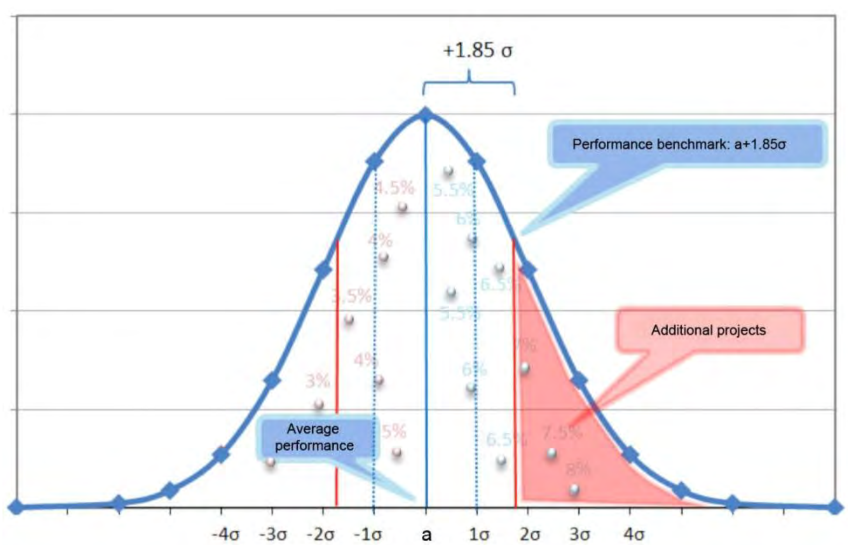

Figure 2. This graph shows how the performance benchmark (vertical red line to the right) is calculated by determining the average performance (vertical solid blue line), defined as the annual average of the percent savings in weather normalized energy consumption in the Same Building Stock over the 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 ($v_1, v_2 \ldots v_N$) 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

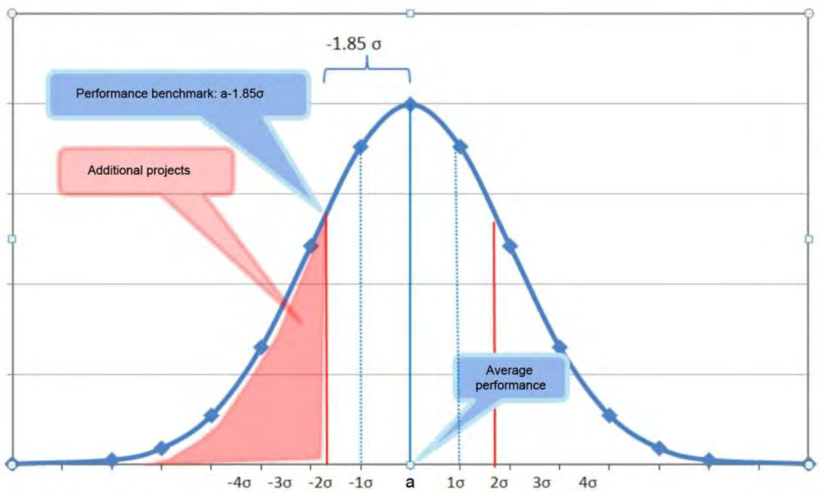

Figure 3. This graph shows how the performance benchmark (vertical red line to the left) is calculated by determining the average performance (vertical solid blue line), defined as the annual average energy consumption by existing Appliances of the same Appliance type and subtracting 1.85σ. The standard 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 90th 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

$$L_{CO2,y,} = \sum_{k=1}^{K} (a_{np,k,y} * h_k * E_{dem,pre,k}) * Elec_{CO2} + \sum_{t=1}^{T-1} L_{(y-t),CO2}$$

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).

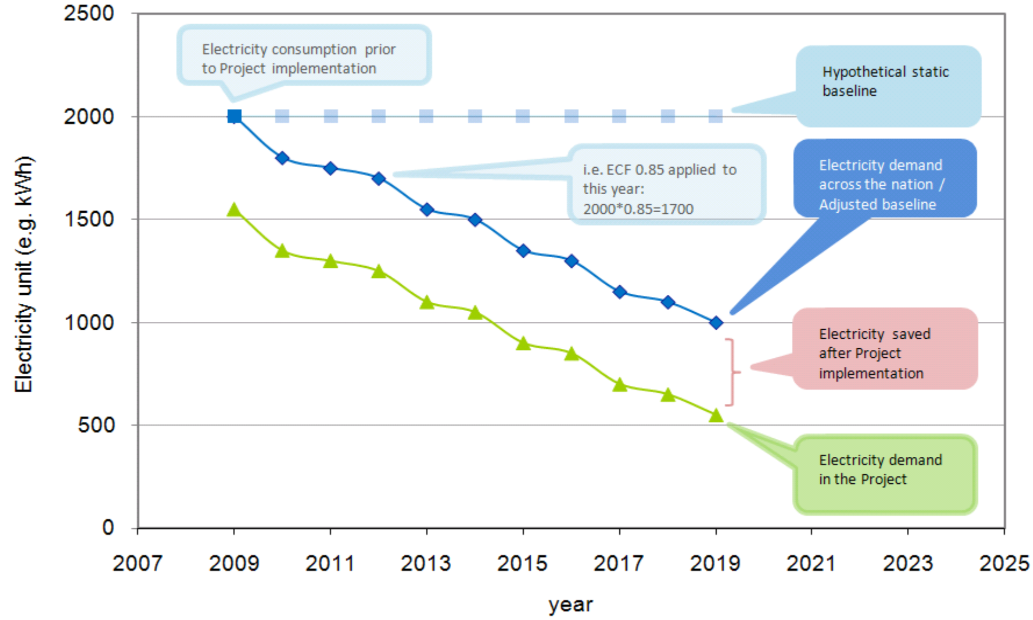

Figure 4 : This graph shows how the adjusted consumption approach takes into account a reduction in electricity consumption over time. Failure to adjust for decreasing consumption over time would result in an over-estimation of emission reductions.

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

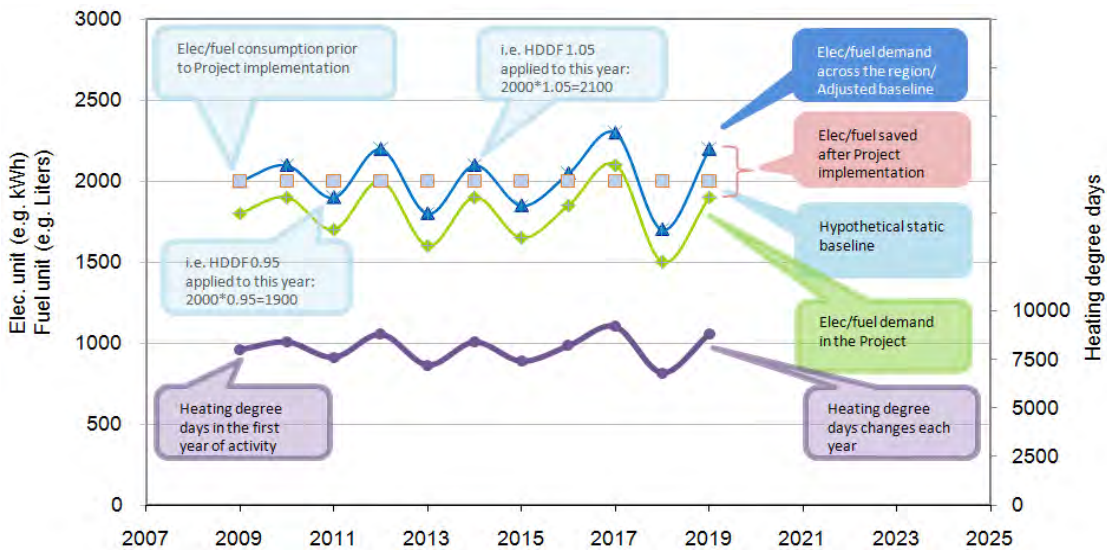

Figure 5: This graph shows how heating degree days affect fuel/electricity consumption over time. Failure to adjust the baseline based on changes in temperature would result in inaccurate calculation of emission reductions.

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*	$H_{load,post,i}$	$kWh/m^2/HDD$ $GJoules/m^2/HDD$	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	*I*	-	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.

CAPCOA GHG Rx Protocol:

Quantifying Greenhouse Gas Reductions from Wetland Implementation and Rice Cultivation in the Sacramento-San Joaquin Delta, San Francisco Estuary and the Coast of California Version 1.0

(Based on the American Carbon Registry's Draft Methodology: Framework Module, Baseline Modules, Project Modules, and Methods Modules)

(Approved by the CAPCOA Board on July 6, 2016)

The following conditions apply for use in the CAPCOA GHG Rx:

1. **Project must occur in California.**
2. **Include a requirement that the project must occur after January 1, 2007.**
3. **Include a requirement for a contract between the project proponent and the lead agency to ensure enforceability.**
4. **Protocol relies on a buffer account to insure against reversal. Recommend approval once buffer account issue is resolved.**

Wetland Implementation and Rice Cultivation in the Sacramento-San Joaquin Delta, San Francisco Estuary and the Coast of California – Methodology for Quantifying Greenhouse Gas Emissions Reductions, Version 1.0 – FRAMEWORK MODULE

Preface

The objective of this methodology is to describe quantification procedures for the reduction of greenhouse gas (GHG) emissions through conversion of land to wetlands and rice cultivation in the Sacramento-San Joaquin Delta, San Francisco Estuary and in coastal areas of California. The methodology has been written in a module format; Project Proponents can choose the applicable modules for their specific project and site. The Framework Module provides background and an over-arching description of the methodology requirements and modules. The remaining modules provide guidance for baseline and project scenario quantification, methods, modeling, calculation of uncertainty, and other quantification tools. Project Proponents should refer first to the Framework Module for applicability requirements and an outline of the specific modules necessary for their project type.

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(WR-MF) Wetland Implementation and Rice Cultivation Methodology – Framework

BACKGROUND

The objective of this methodology is to describe quantification procedures for reducing greenhouse gas (GHG) emissions through conversion of land to wetlands and rice cultivation in the Sacramento-San Joaquin Delta, San Francisco Estuary and in coastal areas of California. The methodology has been written in a module format; Project Proponents can choose the applicable modules for their specific project and site. The Framework Module provides background and an over-arching description of the methodology requirements and modules.

Baseline or business-as-usual scenarios include agriculture, seasonal wetlands and open water areas, where baseline emissions and carbon stock changes result primarily from oxidation of organic matter. Project scenarios include tidal wetlands restoration, and in the Sacramento-San Joaquin Delta permanently flooded managed non-tidal wetlands and rice cultivation. These activities stop or greatly reduce baseline emissions and in the case of wetlands, are net GHG sinks. Table 1 provides a list of relevant land uses and examples of each, which is not necessarily exhaustive.

Table 1. Relevant land use examples and GHG impact.

	Land Use	**Examples**	**Primary GHG Impact**
Baseline	Agricultural	Farmed organic soils on Delta islands	GHG emissions due to oxidation of organic soils
	Agricultural/fallow/seasonal wetlands	Fallow areas or areas that have become impractical to farm due to excessive wetness in the Sacramento-San Joaquin Delta.	GHG emissions due to oxidation of organic soils
	Seasonal Wetlands	Seasonally flooded hunting clubs in Suisun Marsh	GHG emissions due to oxidation of organic soils
	Open water	Subsided salt ponds in the South Bay, Franks Wetland in the Delta	Likely net GHG emissions (but no data exists)
Project	Managed non-tidal wetlands	Twitchell and Sherman islands	Generally net GHG removal (via increasing soil carbon sequestration), despite methane emissions
	Saline/brackish tidal wetlands	Rush Ranch, Suisun Marsh and others cited in Callaway and others[1]	Net GHG removal where there is minimal methane emitted
	Rice	Twitchell Island, Wright Elmwood Tract, Brack Tract, Rindge Tract, Canal Ranch Tract, Delta	Provides net GHG emission reductions on organic soils.

[1] Callaway, John C., Borgnis, Evyan L. Turner, R. Eugene & Milan, Charles S., 2012, Carbon Sequestration and Sediment Accretion in San Francisco Bay Tidal Wetlands, Estuaries and Coasts, (2012) 35:1163–1181.

In the following paragraphs, baseline and project activities are summarized according to currently eligible geographies.

Baseline Conditions
Sacramento-San Joaquin Delta

A key area for implementation of carbon sequestration wetlands and rice is within the 750,000-acre Sacramento-San Joaquin Delta. The Delta is a critical natural resource, an important agricultural region and the hub for California's water supply. Since Delta islands were first diked and drained for agriculture in the late 1800s, more than 3.3 billion cubic yards of organic soils have disappeared. This loss has resulted in land surface elevations as low as 20-25 feet below sea level (Figure 1). The volume below sea level (accommodation space) of approximately 1.7 million acre feet represents a significant opportunity for carbon sequestration.

The primary baseline emission and carbon stock change is due to oxidation of organic matter in farmed and grazed organic and highly-organic mineral soils. This oxidation results in emission of CO_2 and relatively small amounts of CH_4. Also, N_2O is emitted as the result of organic matter oxidation and fertilizer use. These emissions have occurred since the late 1800s due to drainage and cultivation of these soils. Baseline emissions of CO_2, CH_4 and N_2O have been measured and modeled. Specific information and a data summary are provided in Appendix C.

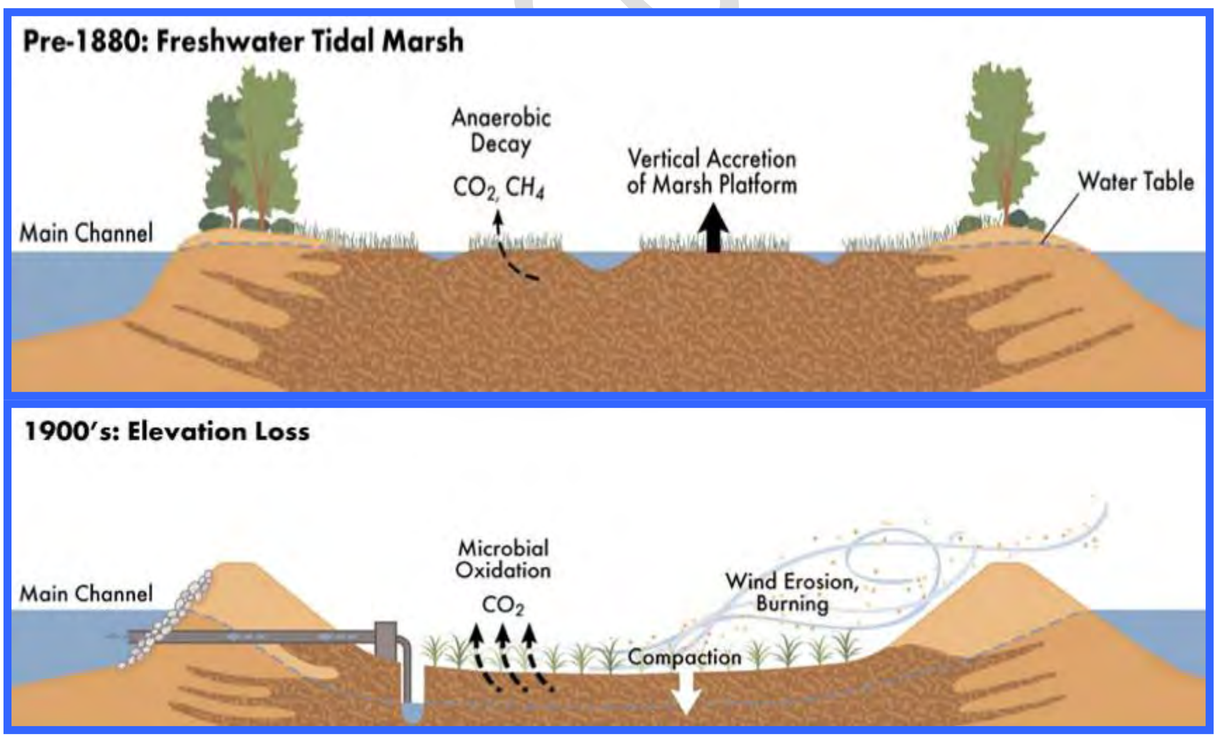

Figure 1. Evolution of Delta subsided islands (modified from Mount and Twiss[2]). During the last 6,800 years, organic soils accreted in a vast tidal marsh as sea level rose. Draining of the land for agriculture resulted in subsidence and loss of soil organic matter.

San Francisco Estuary

In the San Francisco Bay region, the primary baseline emission is due to oxidation of soil organic matter in seasonal wetlands with organic and highly-organic mineral soils. This oxidation results in emissions of CO_2, CH_4 and possibly N_2O. Consistent with the description of the oxidation of drained organic soils above, in an evaluation of different wetland management practices on highly organic mineral soils, USGS researchers determined that seasonal wetlands (flooded during late fall, winter and early spring) resulted in a net GHG emission[3]. Consistently, there are large areas of organic and highly organic mineral soils that have subsided. For example, the Suisun Marsh area is composed of both organic and mineral soils. Reported organic matter content for these soils ranges from 15 to 70 percent[4].

Most of the land within the Suisun Marsh consists of diked wetlands which are flooded part of the year. Approximately 85 percent of these wetlands are drained from mid-July through mid-September when soil temperatures and organic matter oxidation rates are high. In Suisun Marsh, estimated median subsidence rates from the late 1940s to 2006 varied by soil type and ranged up to 2.5 cm/year and were generally proportional to soil organic matter content.[5] The estimated volume below sea level based on the 2006 LIDAR data is 5,800 acre feet[6]. This is the approximate volume of organic soil that has been lost since initial diking and drainage. There have been few baseline measurements or estimates of GHG emissions in the Suisun Marsh or northern San Francisco Bay Area. Recently, the US Geological Survey deployed an eddy covariance tower at the Rush Ranch wetland in Suisun Marsh to measure GHG fluxes.

Open Water

An example area of applicability for this module is San Francisco Bay where diked and managed salt ponds preserved a large area of shoreline in an open state for salt crystallization. Former salt ponds are now open water areas that are undergoing phased conversion to tidal wetlands[7]. Over 15,000 acres

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[2] Mount J, Twiss R. 2005. Subsidence, sea level rise, seismicity in the Sacramento-San Joaquin Delta, San Francisco Estuary and Watershed Science. Vol. 3, Issue 1 (March 2005), Article 5.http://repositories.cdlib.org/jmie/sfews/vol3/iss1/art5

[3] Deverel, S.J., Wang, Bronwen, Rojstaczer, Stuart, 1998, Subsidence in the Sacramento-San Joaquin Delta, *in* (Borchers, J.W., ed.) Proceedings of the Joseph Poland Subsidence Symposium, Association of Engineering Geologists, Special Publication No. 8, Star Publishing, Belmont, California, pp. 489-502.
Robin L. Miller, Lauren Hastings, and Roger Fujii. 2000, Hydrologic Treatments Affect Gaseous Carbon Loss From Organic Soils, Twitchell Island, California, October 1995–December 1997, U.S. Geological Survey Water-Resources Investigations Report 00-4042.

[4] Bates, Leland A., 1977, Soil Survey of Solano County, California, U.S. Dept. of Agriculture, Soil Conservation Service.

[5] HydroFocus, Inc., 2007, Technical Memorandum, Recent And Estimated Future Subsidence Rates and Land Surface Elevation Changes in the Sacramento-San Joaquin Delta And Suisun Marsh, Delta Risk Management Strategy, Department of Water Resources, Sacramento, CA.

[6] HydroFocus, Inc., 2007, Technical Memorandum, Recent And Estimated Future Subsidence Rates and Land Surface Elevation Changes in the Sacramento-San Joaquin Delta And Suisun Marsh, Delta Risk Management Strategy, Department of Water Resources, Sacramento, CA. Assuming an organic soil bulk density of 0.2 g cm^{-3} and 50% organic matter, this volume of 5,800 acre feet translates to about 1.3 million tons of CO_2.

[7] http://www.southbayrestoration.org/.

have been reconnected to the bay or adjacent sloughs. Due to groundwater pumping in this area, many of the areas are substantially below sea level. These subsided lands are potentially influenced by processes that occur outside the project boundaries. For example, allochthonous carbon can enter the subsided areas. Also, there can be large primary productivity and respiration rates in these open water areas thus demonstrating the potential for baseline GHG emissions and removals[8].

Project Conditions

Managed Permanently-Flooded Non-Tidal Wetlands on Subsided Lands

The unique, chemically reducing environment in managed permanently-flooded wetlands on subsided lands facilitates CO_2 sequestration and Methanogenesis (production of CH_4). In permanently flooded wetlands, CO_2 accumulates in plant tissue which becomes litter and eventually accumulates as soil organic matter (SOM). The SOM can be converted to dissolved organic carbon (DOC), bicarbonate (HCO_{3-}), and CH_4. Dissolved organic carbon and CH_4 are byproducts of and leakages from the net accumulation of SOM and CO_2 sequestration. Measurement of net wetland-surface accretion is accomplished through the use of documented techniques such as the use of sedimentation erosion table and collection and chemical analysis of cores of accumulating material.

Wetlands may be considered a GHG sink as CO_2 is removed from the atmosphere and stored in the soil carbon pool. However, a wetland also acts as a GHG source because it emits CH_4, which contributes to atmospheric radiative forcing. In general, the amount of CO_2 sequestered relative to the amount of CH_4 emitted and the relative ability of these gases to absorb infrared radiation ultimately determine whether the wetland is a sink or source for the global warming potential. Carbon fixation in the form of primary production is intimately connected with CH_4 production; the amount of CO_2 fixed on a daily basis has been positively correlated with CH_4 emissions[9]. The correlation of CH_4 emissions with Net Ecosystem Productivity is due to increases in organic substrates associated with root exudates, litter production, and plant turnover[10]. Since the late 1980s, there has been substantial interest in stopping and reversing the effects of subsidence by creating managed wetlands on subsided islands in the Sacramento-San Joaquin Delta. Additional information is provided in Appendix C.

Rice Cultivation on Subsided Lands in the Sacramento-San Joaquin Delta

Within the last 20 years, development of new rice varieties tolerant to low air and water temperatures resulted in Delta rice production with yields comparable to the Sacramento Valley. Available data indicates the combination of in-season and off-season flooding and addition of rice residues stop or greatly reduce oxidative soil loss. Rice has been successfully grown on over 3,000 acres on Delta islands

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[8] Thébault, Julien, Schraga, Tara S., Cloern, James E., Dunlavey, Eric G., 2008, Primary production and carrying capacity of former salt ponds after reconnection to San Francisco Bay, Wetlands, 28, 814-851.

[9] Whiting, G. J. and Chanton, J. P., 1993, Primary production control of methane emissions from wetlands. Nature 364, 794–795.

[10] Whiting, G.J. and Chanton, J.P., 2001, Greenhouse carbon balance of wetlands: methane emission versus carbon sequestration. Tellus, 53B, 521–528. Net Ecosystem Production is defined as the difference between gross primary production and respiration and represents the amount of carbon available for storage.

for over 10 years. Data reported for CO_2 and CH_4 emissions in rice by Hatala et al. and Knox et al.[11] and N_2O data reported by Ye and Horwath[12] demonstrate there is net GHG benefit for conversion to rice where soil organic carbon values range from 5 to 25 %.

Tidal Wetlands in San Francisco Estuary and California Coast

Reported GHG removal rates across or within tidal wetland complexes vary widely and are affected by local plant species composition and productivity, decomposition rates, allochthonous sediment imports, salinity, tidal range, and human activities. There are several large-scale restoration projects underway or planned in the San Francisco Bay Estuary (e.g., Montezuma Wetlands in Suisun Bay, Hamilton Wetlands, the Napa-Sonoma Salt Pond Project, and the South Bay Salt Pond Project) and elsewhere (e.g., Bolsa Chica Wetlands in Huntington Beach and San Deiguito Lagoon in San Diego). In the San Francisco Bay Estuary, tidal wetlands are mostly dominated by perennial pickleweed, *Sarcocornia pacifica*. Using two different dating systems (cesium-137 and lead-210), Calloway et al.[13] reported long-term carbon sequestration rates in the San Francisco Estuary ranging from 0.6 to 2.8 tons CO_2-e/acre-year. The average long-term rate for tidal salt and brackish wetlands was 1.6 tons CO_2-e/acre-year. Drexler[14] estimated millennial rates ranging from 0.6 to 1.1 tons CO_2-e/acre-year in remnant freshwater and brackish tidal marshes in the Delta.

Geographic Applicability

Due to the unique conditions described for the Sacramento-San Joaquin Delta and San Francisco Estuary, the methodology has been specifically developed for these geographic areas and may be used for tidal wetlands in California.

GENERAL GUIDANCE

A. Scope

The modules and tools described here are applicable for quantification of GHG removals and emission reductions for restoration of tidal wetlands (TW); managed, permanently flooded non-tidal wetlands (MW); and rice cultivation (RC) in the eligible geographies. The water quality of eligible activities ranges from fresh to saline and includes lands that are used for agriculture, managed or non-managed seasonal wetlands, and open water.

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[11] Hatala JA, Detto M, Sonnentag O, Deverel SJ, Verfaillie J, Baldocchi DD (2012) Greenhouse gas (CO_2, CH_4, H_2O) fluxes from drained and flooded agricultural peatlands in the Sacramento-San Joaquin Delta. Agriculture, Ecosystems and Environment 150: 1-18.
Knox SH, Sturtevant C, Matthes JH, Koteen L, Verfaillie J, Baldocchi D, 2014, Agricultural peatland restoration: effects of land-use change on greenhouse gas (CO_2 and CH_4) fluxes in the Sacramento-San Joaquin Delta, Global Change Biology, in press.
[12] Ye, R. and Horwath, W.R.,2014. Influence of variable soil C on CH_4 and N_2O emissions from rice fields 2013-2014. Presentation at UC Davis.
[13] Callaway, John C., Borgnis, Evyan L. Turner, R. Eugene & Milan, Charles S., 2012, Carbon Sequestration and Sediment Accretion in San Francisco Bay Tidal Wetlands, Estuaries and Coasts, (2012) 35:1163–1181.
[14] Drexler, J.Z., 2011, Peat Formation Processes Through the Millennia in Tidal Marshes of the Sacramento–San Joaquin Delta, California, USA, Estuaries and Coasts, DOI 10.1007/s12237-011-9393-7.

This methodology does not provide technical guidance for wetland construction, restoration, planting, rice cultivation or any project-related implementation. These activities require the expertise of designated experts such as (but not restricted to) certified wetland scientists, agronomists, hydrologists and civil and environmental engineers. The methodology assumes the Project Proponent has or engages the necessary expertise and requires that the activities implemented under this methodology comply with all applicable local, state, and national laws and regulations.

B. Sources of Information

The methodology structure and text have been adapted from the following methodologies:

- ACR Restoration of Degraded Deltaic Wetlands of the Mississippi Delta[15]
- VCS Methodology for Coastal Wetland Creation[16]
- ACR Emission Reductions Methodology in Rice Management Systems

[15] http://americancarbonregistry.org/carbon-accounting/standards-methodologies/restoration-of-degraded-deltaic-wetlands-of-the-mississippi-delta.
[16] http://www.v-c-s.org/methodologies/methodology-coastal-wetland-creation-v10.

C. Definitions and Acronyms

ACR	American Carbon Registry
A/R	Afforestation and or reforestation
ARR	Afforestation, reforestation, and revegetation
AFOLU	Agriculture forestry and other land use
Baseline	most likely management scenario in the absence of the project
C	Carbon
CDM	Clean development mechanism
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent
CF	Carbon fraction
CH_4	Methane
ERT	Emission Reduction Ton
Ex-ante	'Before the event' or predicted response of project activity
Ex-post	'After the event' or measured response of project activity
GHG	Greenhouse gas
GIS	Geographic information system
GPS	Global positioning system
GWP	Global warming potential
Historical reference period	The historical period prior to the project Start Date that serves as the source of data for defining the baseline
i	Subscript used to represent a stratum
Leakage	Any change in carbon stocks or greenhouse gas emissions that occur outside a project's boundary (but within the same country) that is measurable and attributable to the project activity.
Module	Component of a methodology that can be applied on its own to perform a specific task
N_2O	Nitrous oxide
Open water	Coastal areas where there is no emergent vegetation.
QA	Quality assurance
QC	Quality control
Stratification	A standard statistical procedure to decrease overall variability of carbon stock estimates by grouping data taken from environments with similar characteristics (e.g., vegetation type; age class; hydrology; elevation)
Tool	Guideline or procedure for performing an analysis (e.g., Tool for testing significance of GHG emissions in A/R CDM project activities) or to help use or select a module or methodology
VCS	Verified Carbon Standard

D. Modules and Tools

The following modules and tools are available for use:

Baseline Modules:
BL-Ag - Estimation of agricultural baseline carbon stock changes and GHG emissions for wetland construction and rice cultivation where the project activity includes hydrologic management and infrastructural modification when there are agricultural activities in place immediately prior to the project commencement date

BL-SW - Estimation of baseline carbon stock changes and GHG emissions for managed and non-managed seasonal wetlands when the project case is wetland construction that includes hydrologic management and infrastructural modification

BL-OW – Estimation of open water baseline carbon stock changes and GHG emissions for tidal wetland restoration where the project activity includes hydrologic management and infrastructural modification.

Project Scenario Modules:
PS-MW Estimation of project scenario carbon stock changes and greenhouse gas emissions for construction of managed non-tidal permanently flooded wetlands where the project activity may include hydrologic management, infrastructural modification, and plantings or natural plant regeneration.

PS-TW Estimation of project scenario carbon stock changes and greenhouse gas emissions from tidal wetlands construction and restoration where the project activity may include levee breaching to create tidal influence, plantings, fill and salt flushing

PS-RC Estimation of project scenario carbon stock changes and greenhouse gas emissions from rice cultivation where the project activity may include hydrologic management, infrastructural modification, and rice cultivation

Methods Modules:
MM-W/RC Estimation of carbon stocks in the soil organic carbon pool and in the above- and below ground biomass and estimation of greenhouse gas emissions

E-FFC Estimation of emissions from fossil fuel combustion

MODEL-W/RC Biogeochemical models to be used for estimation of emissions and carbon stock changes under baseline and project conditions.

Uncertainty Modules:
X-UNC Estimation of uncertainty

Tools:

T-SIG	Tool for testing significance of GHG emissions in A/R CDM project activities
T-PERM	The currently approved ACR permanence risk tool
T-PLOTS	Calculation of the number of sample plots for measurements within A/R CDM project activities

Table 2. Determination of mandatory (M), conditional (C), or not required (N/R), module/tool use.

Determination	Module/Tool	Managed Wetland Construction	Tidal Wetland Restoration	Rice Cultivation
Used by all projects	WR-MF T-PERM X-UNC	M M M	M M M	M M M
Baselines	BL-Ag BL- SW BL- OW	C C C	C C C	M C N/R
Carbon Stocks	MM-W/R	M	M	M
Emissions	MM-W/RC E-FFC	M C	M C	M M
Project Scenario	PS-MW PS-TW PS-RC	M N/R N/R	N/R M N/R	N/R N/R M

Modules marked with an M are mandatory: the indicated modules and tools must be used. Modules marked with a C are conditional depending on the baseline scenario and emissions. Modules marked with N/R are not required. The optional pools and sources (Tables 3 and 4) can be included or excluded as determined by the project proponent; if included in the baseline they must also be included in the project scenario and be monitored accordingly.

E. Universal Applicability Conditions

Project Proponents must demonstrate to ACR and the Verifier that they have met the applicability conditions in the Framework Module, in any other modules utilized, and any overarching eligibility criteria set forth in the current version of the *ACR Standard*. The GHG Project Plan shall justify use of modules relevant to the proposed project activities.

Additional specific applicability conditions exist for each module and must be met for the module to be used. The following applicability criteria apply to all projects:

- All project activities must be in regulatory compliance.
- Must be located in the Sacramento-San Joaquin Delta, Suisan Marsh and/or tidal wetlands in California
- The project scenario, and associated baseline for each parcel of land included in the project must be one of the following combinations:
    - Managed permanently shallow flooded wetlands on subsided lands where the baseline includes agricultural areas which result in continued organic soil loss in the Sacramento-San Joaquin Delta;
    - Managed permanently shallow flooded wetlands on subsided lands where the baseline includes seasonal wetlands in the Sacramento-San Joaquin Delta or Suisun Marsh;

  - Tidal wetland restoration in the San Francisco Estuary where the baseline is open water areas in former salt ponds;
  - Tidal wetland restoration in the San Francisco Estuary where the baseline is seasonal wetlands on organic soils which result in continued organic soil loss - these areas include managed seasonally flooded wetlands and areas that have become too wet to farm and have become seasonal wetlands and hunting clubs in the Sacramento-San Joaquin Delta and San Francisco Estuary;
  - Rice cultivation on subsided lands in the Sacramento-San Joaquin Delta where the baseline is farmed organic soils using crops that required a drained root zone
- Eligible management strategies to achieve these project activities include:
  - Alteration of hydrologic conditions, sediment supply, water quality, plant communities, and nutrient management
  - Earth moving
  - Diversion of channel water into wetlands or rice fields
  - Management of surface water levels and wetland outflow
  - Levee breaching with appropriate permits

The project is not eligible if it employs any of the following:

  - Drainage of wetland soils;
  - Activities that cause deleterious impacts or diminish the GHG sequestration function of habitat outside the project area;
  - Activities that will result in a reduction of wetland restoration activities or increase wetland loss outside of the project boundary;
  - Burning of wetland or agricultural vegetation;
  - Activities required under any law or regulation, including Section 404 of the Clean Water Act to mitigate onsite or offsite impacts to wetlands;
  - Activities that involve the use of natural resources within the project boundary that lead to further environmental degradation (fishing, hunting, etc. that do not lead to degradation of the project area are permitted);
  - Harvesting of wood products;
  - Planting of non-native species;
  - Activities that affect fish populations in Delta channels[17].

The Project Proponents shall provide attestations and/or evidence (e.g. permits or permit applications) of environmental compliance to the American Carbon Registry (ACR) at the time of GHG Project Plan submission, and to the validation/verification body at the time of validation, and at each verification. Any changes to the project's regulatory compliance status shall be reported to ACR immediately.

F. Applicable Project and Baseline Modules

Figure 2 shows the relationships between project and Baseline Modules. For the managed wetlands project activity, agricultural and/or seasonal wetlands Baseline Modules can be employed depending on baseline conditions. For the rice cultivation project activity, only the agricultural baseline is applicable. For tidal wetlands project activity, either the seasonal wetland or open water Baseline Modules are

[17] Siphoning of water for wetlands on subsided Delta islands may result in "take" of fish. Fish screens or an alternative mitigation measure may be required to avoid take.

applicable.

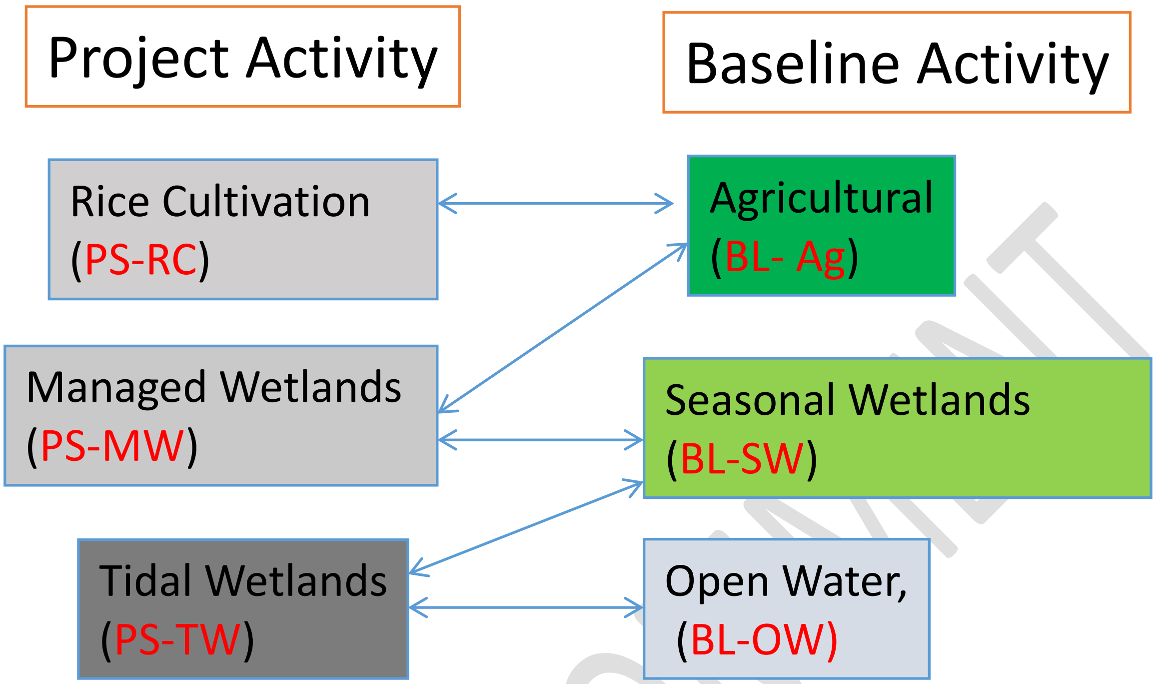

Figure 2. Project and Baseline Modules.

ASSESSMENT OF NET GREENHOUSE GAS BENEFIT

The project proponent shall implement the following steps to assess greenhouse gas reductions.

1. Identification of the baseline activities
2. Definition of project boundaries
3. Demonstration of additionality
4. Development of a monitoring plan
5. Estimation of baseline carbon stock changes and GHG emissions
6. Estimation of project carbon stock changes and GHG emissions
7. Estimation of total net GHG emission reductions (project minus baseline and leakage)
8. Calculation of uncertainty
9. Risk assessment
10. Calculation of Emission Reduction Tons (ERTs)

All steps are required *ex-ante*. For *ex-post*, steps 6 through 10 are applicable. For parameters that will be monitored or modeled subsequent to project initiation, *ex-ante* guidance is given in the relevant modules, MODEL–R/C, MM-R/C, and E-FFC.

Step 1. Identification of the Baseline Activities

Use the flow chart (Figure 2) to identify the appropriate project activity, baseline and relevant modules. A project can include areas with different baselines. In such cases, project and baseline areas shall be delineated in the GHG Project Plan.

Proponents must demonstrate that one of the permissible Baseline Scenarios is credible for their project area by describing what would have occurred in absence of the Project Activities and quantifying GHG emissions and removals. The Baseline Scenarios must be limited to the specified baseline land uses shown in Figure 2 and comply with the applicability conditions described in the framework, Project and Baseline modules.

Step 2. Definition of Project Boundaries

The following categories of boundaries shall be defined:

- The geographic boundaries relevant to the project activity;
- The temporal boundaries;
- The carbon pools that the project will consider and;
- The sources and associated types of GHG emissions

a. Geographic boundaries relevant to the project activity

The Project Proponents must provide a detailed description of the geographic boundary of project activities using a Geographic Information System (GIS). Information to delineate the project boundary may include:

- USGS topographic map or property parcel map where the project boundary is recorded for all areas of land. Provide the name of the project area (e.g., compartment number, allotment number, local name); and a unique ID for each discrete parcel of land
- Aerial map (e.g. orthorectified aerial photography or georeferenced remote sensing images)
- Geographic coordinates for the project boundary, total land area, and land holder and user rights

Project proponents shall provide a GIS shapefile that includes relevant geographic features and the project boundaries

Where multiple baselines exist there shall be no overlap in boundaries between areas appropriate to each of the baselines. Project activities may occur on more than one discrete area of land, but each area must meet the project eligibility requirements. This methodology allows for "Programmatic Aggregated Projects"; new wetland areas may be added to an existing Project after the start of the crediting period as long as all the applicability criteria are met for each new area. The current *ACR Standard* provides guidelines and requirements for projects using a programmatic aggregation design.

b. Temporal Boundaries

The project Start Date is defined as the day Project Proponents began verifiable activities to increase carbon stocks and/or reduce GHG emissions. This methodology employs a 40-year Crediting Period, over which time monitoring and verification must take place at specified intervals to ensure that there are no reversals of carbon stocks. Spatial and temporal patterns of tidal and freshwater wetlands are dynamic, resulting from complex and interactive effects of natural and human-induced processes. These factors shall be accounted for in project monitoring and reporting.

c. Carbon Pools and Sources

Tables 3 and 4 provide guidelines for determining the GHG assessment boundary. Exclusion of carbon pools and emission sources is allowed subject to considerations of conservativeness and significance testing or when inclusion may result in double counting. This can be the case for plant litter, above and below ground biomass and soil organic matter pools. Pools or sources may always be excluded if conservative, i.e. exclusion will tend to underestimate net GHG emission reductions or removal enhancements. Pools, sinks or sources can be excluded (i.e., counted as zero) if application of the tool T-SIG indicates that each source, sink and pool is determined to be insignificant and can be excluded from accounting, i.e. it represents less than 3% of the *ex-ante* calculation of GHG emission reductions/removal enhancements (per ACR *Forest Carbon Project Standard*).

Table 3. Carbon pools to be considered for monitoring or modeling.

Carbon pool	Status	Explanation/Justification	Quantification Methods
Above-ground non-woody biomass	Optional	Major carbon pool affected by Project activity. May be conservatively omitted from field measurements and monitoring to prevent double counting. Included when biogeochemical modeling is used to estimate GHG dynamics in the project and baseline scenario	Biogeochemical models calibrated and validated for project or baseline conditions, Digital photography and leaf area index (LAI), remote sensing, allometric and destructive methods and digital photography, peer-reviewed literature values.
Below ground biomass (associated with non-woody above-ground biomass)	Required when utilizing biogeochemica modeling/ excluded otherwise	Major Project carbon pool affected by project activity. May be conservatively omitted from field monitoring. Included when biogeochemical modeling is used to estimated GHG dynamics in the project and baseline scenarios	Biogeochemical model calibrated and validated for project or baseline conditions, field measurement, and literature values.
Litter	Optional	Result of decaying wetland vegetation and contributes to soil organic carbon. May be conservatively omitted from field monitoring. Included when biogeochemical modeling is used to estimate GHG dynamics in the project and baseline scenario	Biogeochemical model calibrated and validated for project or baseline Conditions, litter bags, literature values.
Crop residue	Optional	Plant biomass (including rice) incorporated into the soil organic matter pool. May be conservatively omitted from field monitoring. Included when biogeochemical modeling is used to estimate GHG dynamics in the project and baseline scenario	Biogeochemical model calibrated and validated for project or baseline conditions, field measurements.
Soil organic matter	Included	Major baseline and project carbon pool. Soil organic carbon stock will likely increase due to the implementation of project activity Included when biogeochemical modeling is used to estimate GHG dynamics in the project and baseline scenario	Monitored using methods described in Methods Module (MM-W/RC). A biogeochemical model calibrated and validated for Project or Baseline conditions can be used (MODEL-W/R)
Harvested biomass	Included for Baseline	Key component of carbon balance for agricultural baseline and rice	Modeling or measurement of harvested product and estimation of carbon content as described in the Methods Module (MM-W/R)

Table 4. Greenhouse gas sources.

	Source	Gas	Status	Justification/Explanation	Quantification Method
Baseline	The production of methane by bacteria	CH_4	Optional	May be conservatively excluded	Field measurement as described in the Methods Module (MM-W/R) module and/or biogeochemical model calibrated and validated for Baseline Conditions (MODEL-W/R).
	Nitrogen transformations due to fertilizer application or organic soil oxidation	N_2O	Optional	May be conservatively excluded	Field measurement as described in the Methods Module (MM-W/R) module and/or biogeochemical model calibrated and validated for Baseline Conditions (MODEL-W/R).
	Oxidation of organic soils	CO_2	Included	Primary baseline emission	Field measurement as described in the Methods Module (MM-W/R) and/or biogeochemical model calibrated and validated for Baseline Conditions (MODEL-W/R).
	Emissions from Fossil Fuel Combustion	CO_2	Included	Primary fossil fuel emission	Calculations described in emissions module (E-FFC)
		N_2O	Excluded	Minor emissions source	
		CH_4	Excluded	Minor emissions source	
Project	The production of methane by bacteria	CH_4	Included/Optional	Primary project emission for all project scenarios. May be excluded in saline tidal marshes under conditions specified in the tidal wetland module (PS-TW).	Field measurement as described in the Methods Module (MM-W/R) module and/or biogeochemical model calibrated and validated for Project Conditions (MODEL-W/R).
	Nitrogen transformations due to fertilizer application or organic soil oxidation	N_2O	Included/Optional	Must be included for rice cultivation. Optional for all other project activities[18].	Field measurement as described in the Methods Module (MM-W/R) module and/or biogeochemical model calibrated and validated for Project Conditions ((MODEL-W/R).
	Oxidation of organic soils	CO_2	Included/Optional	Must be included for rice cultivation. Optional for all other project activities.	Field measurement as described in the Methods Module (MM-W/R) module and/or biogeochemical model calibrated and validated for Project Conditions ((MODEL-W/R).).
	Emissions from fossil fuel combustion	CO_2	Included	May be excluded if justified by demonstrating that fossil fuel emissions for project conditions or equal to or less than baseline conditions.	Calculations described in emissions module (E - FFC).
		N_2O	Excluded	Minor emissions source	
		CH_4	Excluded	Minor emissions source	

d. Leakage for Agricultural Baseline

[18] N_2O emissions can be ignored in permanently flooded wetland conditions. Under permanently flooded soil conditions, N_2O is consumed during denitrification and converted to N_2. See for example:
Butterbach-Bahl K, Baggs EM, Dannenmann M, Kiese R, Zechmeister-Boltenstern S (2013) Nitrous oxide emissions from soils: how well do we understand the processes and their controls? *Philosophical Transactions of the Royal Society B: Biological Sciences,* **368**, 20130122.

Leakage is an increase in GHG emissions outside the project boundaries that occurs as a result of the project action. ACR requires Project Proponents to assess, account for, and mitigate for leakage above de-minimis levels. Project Proponents must deduct leakage that reduces the GWP benefit of a project in excess the applicable threshold specified in the methodology (3%). Activity-shifting leakage occurs when the land uses resulting in baseline emissions that operated in the project area before the project start date are relocated to another area outside of the project boundary. Market-effects leakage is transmitted through market forces; a supply reduction can result in an upward pressure on price that may incentivize increased production and shifts in cropping patterns elsewhere. The change in the GWP as the result of these market-effects leakage shall be accounted for in the net project GHG removals. For the activities included in this methodology, only market-effects leakage would result from replacement of crops currently grown in the Delta by wetlands and rice. All other project scenarios need no further leakage analysis and may use a leakage value of zero.

As part of this methodology development, a leakage analysis was conducted for replacement of traditional crops in the Delta with wetlands and rice. First an economic analysis was conducted to determine how crop acreages statewide would be affected by Delta land conversion. Next, the estimated the change in GWP was estimated as the result of this crop-area change. The report describing the results is included as a supplementary document.

A peer-reviewed, statewide agricultural economic model that simulates market-driven changes for over 6 million acres of California agriculture, was used to estimate crop acreage changes for the following alternatives in which land-use changes were simulated to occur by 2030; conversion of traditional field crops and pasture to wetlands or rice. Where a policy removed land from production and allocated it to wetlands, this acreage was not modeled specifically as a crop in the model but modeled as fallow land. Field crops and pasture predominate in areas where there are oxidizing organic soils that contribute to baseline carbon dioxide emissions.

1. No Action Alternative (NAA)
2. Remove 35,000 acres of field crops from the Delta and leave the land fallow
3. Remove 35,000 acres of field crops from the Delta and convert those acres to rice
4. Remove 10,000 acres of irrigated pasture from the Delta and leave the land fallow
5. Remove 10,000 acres of irrigated pasture from the Delta and convert those acres to rice

To estimate GWP changes, the results of statewide GHG modeling and field experiments for over 40 crops were used. The GWP changes were aggregated into the 7 groups used in the economic model analysis and the GWP was estimated on a per acre basis. We used the estimated GWP in tons of CO_2 equivalents per acre per year multiplied by the non-Delta acreage changes for the crop groups to estimate the potential GWP leakage for each scenario. In all alternatives except for alternative 4, the range of GWP changes by incorporating uncertainty was 3% or less relative to baseline emissions. For alternative 4, the range of GWP was 4% or less relative to baseline emissions. Therefore, for managed wetlands and rice projects implemented on agricultural lands that include less than 35,000 acres of crop land or 10,000 acres of pasture, no leakage deduction is required. Additional leakage analysis is required if the cumulative acreage of wetlands and rice acreage in the Sacramento-San Joaquin Delta exceeds these acreages.

e. Stratification

Stratification is a standard procedure to decrease overall variability of carbon stock estimates by grouping data taken from environments with similar characteristics. When estimating baseline emissions, several strata can be assessed. If the area is not homogeneous, stratification shall be implemented to improve the accuracy and precision of carbon stock estimates. Different stratifications may be required for the baseline and project scenarios, especially if there will be a change in hydrology, in order to achieve optimal accuracy and precision of the estimates of net GHG benefit. Within each module, specific guidelines are provided for stratification.

The stratification for *ex-ante* estimations shall be based on the content of the project monitoring plan. The stratification for *ex-post* estimations shall be based on the actual implementation of the project monitoring plan. If natural or anthropogenic impacts (e.g., levee breaks and flooding) or other factors (e.g., altered hydrology or water management) add variability in the vegetation of the project area, then the stratification shall be revised accordingly. Project Proponents may use remotely sensed data acquired close to the time of project commencement and/or the occurrence of natural or anthropogenic impacts for *ex-ante* and *ex-post* stratification.

Step 3. Demonstration of Additionality

Eligible offsets must be generated by projects that yield surplus GHG reductions that exceed any GHG reductions otherwise required by law or regulation or any GHG reduction that would otherwise occur in a conservative business-as-usual scenario. These requirements are assessed through the Legal Requirement Test and the Performance Standard Evaluation.

a. Legal Requirement Test

Emission reductions achieved by a Rice Cultivation or Wetland project must exceed those required by any law, regulation, or legally binding mandate as required in the jurisdiction where they are located. The following legal requirements apply to all Rice Cultivation and Wetland projects:

I. The activities that result in GHG reductions and GHG removal enhancements are not required by law, regulation, or any legally binding mandate applicable in the offset project's jurisdiction, and would not otherwise occur in a conservative common practice business-as-usual scenario.

II. If any law, regulation, or legally binding mandate requiring the implementation of project activities at the field(s) in which the project is located exists, only GHG emission reductions resulting from the project activities that are in excess of what is required to comply with those laws, regulations, and/or legally binding mandates are eligible for crediting under this protocol.

b. Performance Standard Evaluation

Emission reductions achieved by a Rice Cultivation or Wetland project must exceed those likely to occur in a conservative business-as-usual scenario and are subject to the following practice-based performance standard for wetlands and rice cultivation.

c. Practice-based Performance Standards

I. Managed Non-Tidal Permanently Flooded Wetlands on Subsiding Lands Where Organic and Highly Organic Mineral Soils are Present in the Sacramento-San Joaquin Delta

Managed, permanently flooded, non-tidal wetlands on lands which were formally in agriculture currently represent less than 2 percent of the approximately 200,000 acres where organic and highly organic mineral soils are present and subsiding to various degrees in the Sacramento-San Joaquin Delta[19]. Costs for conversion of agricultural land to managed non-tidal wetlands range from $600[20] to over $6,000[21] per acre. Because wetland restoration is not a common practice among Delta landowners, Managed Non-Tidal Wetland projects using this methodology are deemed "beyond business as usual" and therefore additional. Thus, a Managed Non-Tidal Wetland Project that occurs on agricultural land where there are organic or highly organic mineral soils satisfies the Practice-Based Performance Standard. There will likely be an increase in wetland acreage over time, which will change the results of the analyses used to establish and validate the performance standard. ACR reserves the right to review and require revisions to this performance standard as necessary at an interval no less frequent than once every 10 years following the approval of this Methodology.

II. Rice Cultivation on Subsiding Organic Soils and Highly Organic Mineral Soils in the Sacramento-San Joaquin Delta

Rice currently represents less than 3 percent of the approximately 200,000 acres where organic and highly organic mineral soils are present and subsiding to various degrees in the Sacramento-San Joaquin Delta. Costs for conversion of agricultural land farmed to traditional crops such as corn to rice range from $116[22] to over $1,000[23] per acre. Because Conversion to Rice Cultivation is not common practice by Delta landowners, projects using this methodology are deemed "beyond business as usual" and therefore additional. Therefore, a Rice Cultivation Project that occurs on agricultural land where there are organic or highly organic mineral soils satisfies the Practice-Based Performance Standard. There will likely be additional rice acreage during next decade. ACR reserves the right to review and require revisions to this performance standard as necessary at an interval no less frequent than once every 10 years following the approval of this Methodology.

III. Tidal wetlands in San Francisco Estuary

San Francisco Bay has lost an estimated 90 percent of its historic wetlands to fill or alteration[24]. Tidal wetlands currently represent about 16% of the approximately 208,000 acre area of historic wetlands in

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[19]Steven J. Deverel, Christina E. Lucero, Sandra Bachand, 2014, Evolution of reduced arability on organic and highly organic mineral soils, Sacramento-San Joaquin Delta, California, in review, San Francisco Estuary and Watershed Science.

[20]A. Merrill, S. Siegel, B. Morris, A. Ferguson, G. Young, C. Ingram, P. Bachand, Holly Shepley, Maia Singer, Noah Hume. 2010. Greenhouse Gas Reduction and Environmental Benefits in the Sacramento-San Joaquin Delta: Advancing Carbon Capture Wetland Farms and Exploring Potential for Low Carbon Agriculture. Prepared for The Nature Conservancy, Sacramento, California. Available at: (http://www.stillwatersci.com/).

[21]Brock, Bryan, Engineer, California Department of Water Resources, Personal Communication, June, 2011.

[22] Canivari, M., Klonski, K. M. And DeMoura, R.L., 2007, Sample costs to produce rice in 2007 for the Delta Region for continuous rice culture.

[23] Brock, Bryan, Engineer, California Department of Water Resources, Personal Communication, June, 2011.

[24] Rubissow Okamoto, Ariel and Wong, Kathleen M., 2011, *Natural History of the San Francisco Bay*, University of California Press, Berkeley, CA.

the San Francisco Estuary.[25] Because tidal wetlands restoration is not common practice, projects using this methodology are deemed "beyond business as usual" and therefore additional. Therefore, a Tidal Wetlands Project that occurs in the San Francisco Estuary in areas of former historic wetlands satisfies the Practice-Based Performance Standard. ACR reserves the right to review and require revisions to this performance standard as necessary at an interval no less frequent than once every 10 years following the approval of this Methodology.

Step 4. Development of a Monitoring Plan

Project Proponents shall include a single monitoring plan in the GHG Project Plan. For monitoring changes in wetland cover and carbon stock changes, the monitoring plan shall use the methods given in the model and Methods Modules (MM-W/R, MODEL-W/RC) and relevant Project Modules (PS-MW, PS-RC, or PS-TW). All relevant parameters from the modules shall be included in the monitoring plan. Monitoring shall occur for the life of the project.

The monitoring plan shall include the following:

1. Definition and revision of the baseline[26] (as needed);
2. Monitoring of actual carbon stock changes and GHG emissions;
3. Estimation of *ex-post* net carbon stock changes and greenhouse gas emissions.

For each of these tasks, the monitoring plan shall include the following sections:

a. Technical description of the monitoring task
b. Data to be collected. The list of data and parameters to be collected shall be given in the GHG Project Plan
c. Description of data collection and/or sampling procedures
d. Use of biogeochemical models for estimating emissions and carbon stock changes if used
e. Quality control and quality assurance procedures
f. Data archiving plan
g. Organization and responsibilities of the parties involved in all the above

Step 5. Estimation of Baseline Carbon Stock Changes and Greenhouse Gas Emissions

Per the most recent version of ACR Standards, the GHG project baseline is a forecast of the likely stream of emissions or removals to occur if the Project Proponent does not implement the project, i.e., the "business as usual" case. There are various potential approaches to baseline determination, including existing actual or historical emissions or emissions of activities undertaken in a recent period in similar social, economic, environmental and technological circumstances. For example, the agricultural baseline emissions could be measured at the project site using methods described in the Methods Module (MM-W/R) or estimated using eligible biogeochemical models. Alternatively, emissions could be measured for a reference site with sufficiently similar agricultural practices, hydrologic conditions and soils. Forecasted emissions can be determined using biogeochemical models calibrated for the Delta.[27]

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[25] Bayland Goals Technical Update, Chapter 7 – Carbon Accounting and GHG Flux.
[26] Baselines are only revised at the end of the crediting period.
[27] Deverel S.J. and Leighton D.A., 2010, Historic, Recent, and Future Subsidence, Sacramento-San Joaquin Delta, California, USA. San Francisco Estuary and Watershed Science 8(2). http://www.escholarship.org/uc/item/7xd4x0xw.

The following modules contain methods for estimating baseline carbon stock changes and greenhouse gas emissions (see Figure 2):

- Agriculture (BL-Ag)
- Seasonal wetlands (BL-SW)
- Open water or seasonally inundated (BL-OW)

A description of and justification for the identified baseline scenario and the results of the estimations shall be given in the GHG Project Plan.

Step 6. Estimation of Project Carbon Stock Changes and Greenhouse Gas Emissions

The following modules contain guidance for estimating project carbon stock changes and greenhouse gas emissions for projects where wetlands and rice cultivation are planned (Figure 2):

- Managed wetlands (PS-MW)
- Tidal wetlands (PS-TW)
- Rice cultivation (PS- RC)

Methods for estimation of project carbon stock changes and greenhouse gas emissions are described in the Methods Module (MM-W/R).

Step 7. Estimation of Total Net Greenhouse Gas Emissions Reductions (project minus baseline and leakage)

The total net greenhouse gas project reductions are calculated as follows:

$$\Delta C_{ACR,t} = (\Delta C_{actual} - \Delta C_{BSL}) * (1\text{-}LK) \quad (1)$$

where:

$\Delta C_{ACR,t}$ is the cumulative total net greenhouse gas emission reductions at time *t* (t CO_2-e);

ΔC_{actual} is the cumulative total of carbon stock changes and greenhouse gas emissions under the project scenario since the last reporting period (t CO_2-e) (from the selected Project Module);

ΔC_{BSL} is the cumulative total of carbon stock changes and greenhouse gas emissions under the baseline scenario up to time t (t CO_2-e) (from the selected individual baseline, or the sum of selected baselines if the project includes more than one baseline); and

LK is the cumulative total of the carbon stock changes and greenhouse gas emissions due to leakage up to time t expressed as a fraction of ΔC_{BSL}

a. Use of Models

Models can be useful tools for estimating GHG dynamics in the baseline and project scenarios. Process-based biogeochemical models may be used to estimate changes in various carbon pools and GHG sources in this methodology. Project proponents must validate and calibrate models for the soils, hydrologic and biogeochemical conditions in the proposed project area. Models must:

- Be documented in the peer-reviewed literature;
- Be validated in the Project Area or similar sites using peer-reviewed or other quality controlled data (i.e. collected as part of a Government soils inventory or experiment) for baseline and project conditions;
- Be parameterized using peer-reviewed or other quality-controlled data appropriate to each identified strata;
- Be able to effectively simulate GHG emissions and removals and carbon stock changes for baseline and project conditions;
- Models that include litter, above and below ground biomass and soil organic matter pools must demonstrate that there is no double counting of carbon pools and include consideration of conservativeness and significance testing;
- Use of models shall be conservative in estimating GHG emission reductions.

Step 8. Calculation of Uncertainty

Project proponents shall use X-UNC to calculate overall project uncertainty and estimate the uncertainty adjustment for total net GHG emissions reductions for every reporting period. If calculated total project uncertainty (UNC) exceeds 10% at the 90% confidence level, then $C_{ACR,t}$ (Equation 1) shall be adjusted as follows:

$$Adjusted\ \Delta C_{ACR,t} = \Delta C_{ACR,t} * (100\% - UNC + 10\%) \qquad (2)$$

where:

Adjusted $\Delta C_{ACR,t}$ is the cumulative total net GHG emission reductions at time *t* adjusted to account for uncertainty (t CO_2-e);

$\Delta C_{ACR,t}$ is the cumulative total net greenhouse gas emission reductions at time *t* (t CO_2-e); and

UNC is the total uncertainty (project and baseline) as derived in X-UNC (%).

If the calculated total project uncertainty (UNC) in module X-UNC is less than or equal to 10%, then no adjustment shall be made for uncertainty.

Step 9. Risk Assessment

Project activities have the potential for GHG reductions and removals to be unintentionally reversed, such as when a project is subject to flooding, damage from wildlife, erosion; or intentional reversals or termination, such as landowners choosing to discontinue project activities before the project minimum term has ended. Wetland offsets are inherently at some risk of reversal or termination. Project Proponents shall mitigate reversal and termination risk per the requirements of the current ACR

Standard and any applicable sector Standard.

To assess the risk of reversal or termination, the Project Proponents shall conduct a risk assessment addressing internal, external and natural risks using the most recently approved ACR risk assessment tool. Internal risk factors include project management, financial viability, opportunity costs and project longevity. External risk factors include factors related to land tenure, community engagement and political forces. The primary natural termination risk to wetlands and rice projects in the in the San Joaquin Delta and San Francisco Estuary is flooding due to sea level rise and/or levee failure. Levee failure and flooding in managed non-tidal wetlands and rice on subsided islands in the Sacramento-San Joaquin Delta will result in termination and reversal of cumulated GHG removals if the island is not reclaimed. The Delta Risk Management Strategy Project calculated the risk of levee failure throughout Delta and Suisun Marsh[28] for baseline conditions. However, risk of levee failure will be reduced by implementation of constructed non-tidal wetlands on subsided Delta islands.[29]

The output of ACR's most-recently approved version of the risk assessment tool is a total risk rating for the project which equals the percentage of offsets that must be deposited in the ACR buffer pool to mitigate the risk of reversal or termination (unless another ACR approved risk mitigation mechanism is used in lieu of buffer contribution). The risk assessment, overall risk rating, and proposed mitigation or buffer contribution shall be included in the GHG Project Plan.

a. Mitigation of Risk via the ACR Buffer Pool

For Project Proponents choosing the ACR buffer pool, the Project Proponents shall contribute either a portion of the project offsets, or an equal number of ERTs of another type and vintage, to a buffer account held by ACR in order to replace unforeseen losses of carbon stocks. The number of ERTs contributed to the buffer pool shall be determined through the Risk Assessment. Buffer contributions are made with each new issuance of ERTs to a project.

In lieu of making a buffer contribution of ERTs from either the project or purchased from another acceptable source, Project Proponents may use an alternate ACR-approved risk mitigation mechanism, or propose an insurance product or other risk mitigation mechanism to ACR for approval.

Step 10. Calculation of Emission Reduction Tons (ERTs)

$$ERTt = (\Delta C_{ACR,t}) * (1 - BUF) \qquad (3)$$

where:

ERTt	is the number of Emission Reduction Tons during the reporting period (t CO_2-e);
$\Delta C_{ACR,t}$	is the cumulative total net greenhouse gas emission reductions at time *t* (t CO2-e); and

[28] http://www.water.ca.gov/floodsafe/fessro/levees/drms/docs/drms_execsum_ph1_final_low.pdf.
[29] Deverel, Steven J.; Ingrum, Timothy; Lucero, Christina; & Drexler, Judith Z. (2014). Impounded Marshes on Subsided Islands: Simulated Vertical Accretion, Processes, and Effects, Sacramento-San Joaquin Delta, CA USA. San Francisco Estuary and Watershed Science, 12(2). jmie_sfews_12893. http://escholarship.org/uc/item/0qm0w92c.

BUF is the fraction of project ERTs contributed to a buffer pool, if applicable.

Per the *Forest Carbon Project Standard, BUF* is determined using an ACR-approved risk assessment tool. If the Project Proponent elects to make the buffer contribution in non-project ERTs, or elects to mitigate the assessed reversal risk using an alternate risk mitigation mechanism approved by ACR, *BUF* shall be set to zero.

PARAMETERS ORIGINATING IN OTHER MODULES

Data /parameter:	ΔC_{BSL}
Data unit:	t CO_2-e
Used in Equations:	1
Description:	Cumulative total of carbon stock changes and greenhouse gas emissions for the baseline scenarios where there are agricultural activities in place immediately prior to the project commencement date.
Module parameter originates in:	BL-AG, BL-SW, or BL-OW

Data /parameter:	ΔC_{actual}
Data unit:	t CO_2-e
Used in Equations:	1
Description:	Cumulative total of carbon stock changes and greenhouse gas emissions for the project scenario where the project activity can include hydrologic management, infrastructure modification, and plantings or natural plant recruitment.
Module parameter originates in:	PS-MW, PS-TW, or PS-RC

Data /parameter:	LK
Data unit:	Fraction (dimensionless)
Used in Equations:	1
Description:	Cumulative total of the carbon stock changes and greenhouse gas emissions due to leakage up to time t expressed as a fraction of ΔC_{BSL}
Module parameter originates in:	Leakage analysis

Data /parameter:	BUF
Data unit:	t CO_2-e
Used in Equations:	1
Description:	Cumulative total of carbon stock changes and greenhouse gas emissions for the project scenario where the project activity can include hydrologic management, infrastructure modification, and plantings or natural plant recruitment.
Module parameter originates in:	PS-MW, PS-TW, or PS-RC

Data /parameter:	UNC
Data unit:	Percentage
Used in Equations:	2
Description:	Total uncertainty (project and baseline)

Module parameter originates in:	X-UNC

Wetland Implementation and Rice Cultivation in the Sacramento-San Joaquin Delta, San Francisco Estuary and the Coast of California – Methodology for Quantifying Greenhouse Gas Emissions Reductions, Version 1.0 – BASELINE MODULES

Preface

The objective of this methodology is to describe quantification procedures for the reduction of greenhouse gas (GHG) emissions through conversion of land to wetlands and rice cultivation in the Sacramento-San Joaquin Delta, San Francisco Estuary and in in coastal areas of California. The methodology has been written in a module format; Project Proponents can choose the applicable modules for their specific project and site. The Framework Module provides background and an over-arching description of the methodology requirements and modules. The remaining modules provide guidance for baseline and project scenario quantification, methods, modeling, calculation of uncertainty, and other quantification tools. Project Proponents should refer first to the Framework Module for applicability requirements and an outline of the specific modules necessary for their project type.

Contents

Tables

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(BL-Ag) Wetland Restoration and Rice Methodological Module - Estimation of agricultural baseline greenhouse gas emissions and carbon stock changes

I. SCOPE, BACKGROUND, APPLICABILITY AND PARAMETERS

Scope

This module provides guidance for estimating carbon stock changes and GHG emissions for agricultural lands in the Sacramento-San Joaquin Delta in the baseline case where the project activity will be managed wetland construction or rice cultivation. The module provides specific guidance for identifying the baseline scenario, defining the project GHG boundary, stratification and estimating carbon stock changes and GHG emissions.

Applicability

The module is applicable for estimating baseline GHG emissions and carbon-stock changes for project areas planned for wetland construction and/or rice cultivation. Project activities will occur due to some combination of hydrologic management changes and infrastructural modification with assisted natural regeneration, and seeding. Infrastructural modification includes drainage modification and earth moving. Project activities shall meet the applicability conditions in the methodology framework listed under wetland construction and rice cultivation. The following conditions must be met to apply this module.

- The project area must be on agricultural lands where crops are grown and/or animals are grazed in the Sacramento-San Joaquin Delta. Agricultural land that is temporally fallow for a maximum of 2 years is also included.
- The project area must have been used as agricultural land at least 6 out of the 10 years prior to the project start date, with no more than two consecutive fallow years.

Parameters

This module provides procedures to determine the following parameter:

Parameter	SI Units	Description
$\Delta C_{BSL\ Ag\ W/RC}$	Metric tons CO_2-e (t CO_2-e)	Cumulative total of carbon stock changes and greenhouse gas emissions for the baseline agricultural scenario when the project activity will include managed wetlands or rice
Comment	The notation for this parameter in the Framework Module is expressed in its generic form as ΔC_{BSL} in Equation 1	

II. PROCEDURE

Step 1. Identification of the Baseline Scenario and Performance Standard Evaluation

Project Proponents must identify the most plausible and credible baseline scenario describing what would have occurred in absence of the Project Activities. Under this module, the baseline scenario must be limited to agricultural land uses. The geographical coordinates of the boundaries of each project area must be unambiguously defined and provided to the Validation/Verification Body (VVB) in shapefile format.

Evaluation Against Established Performance Standard

Emission reductions and carbon stock changes achieved by a rice cultivation or wetland project must exceed those likely to occur in a conservative business-as-usual scenario and are subject to a practice-based performance standard. Practice based performance standard requirements are detailed in the Wetland-Rice Methodology Framework Module (WR-MF).

Step 2. Establishment and Documentation of the GHG Boundary

The project GHG boundary describes the carbon pools and emissions sources that will be included or excluded from GHG accounting, as defined in the WR-MF. It shall be demonstrated that each discrete parcel of land to be included in the project boundary is eligible as an ACR project activity. For the baseline case, the primary carbon pools include the soil organic carbon pool and emissions due to oxidation of soil organic matter and fertilizer use. Further, the project proponent must account for GHG emissions and removals that affect the determination of net baseline GHG emissions.

Table 1. Baseline emissions sources included in the project boundary. Nitrous oxide and methane are considered optional (see Framework Module, WR-MF)

Source	**Gas**
Soil emissions due to fertilizer application	N_2O
Soil emissions due to oxidation of organic soils	N_2O, CO_2, CH_4
Emissions resulting from Fossil Fuel Combustion	CO_2

Step 3. Baseline Stratification

For estimation of baseline net GHG removals or emissions, or estimation of project net GHG benefit, strata shall be defined based on parameters that affect GHG removals or emissions and/or are factors the influence measurement of changes in biomass stocks. These may include but are not limited to factors and practices shown in Table 6. Baseline sampling may be used to delineate strata.

Table 2. Factors and practices that can be used for stratification and their effects on GHG emissions and removals.

Stratification Factor or Practice	**Description**	**Potential GHG Effect**
Wetland management practices	Depth of water	Depth of water affects GHG removal and emissions and vegetation
Wetland management practices	Flow through or limited or zero outflow	May affect CH_4 emissions
Wetland vegetation	Variation in species	May affect GHG removals
Wetland vegetation	Planted seedlings, seeded, colonization or natural recruitment	Affects time required for vegetative cover, CH_4 emissions and GHG removal.
Wetland vegetation	Open water areas	Minimal GHG removal, CH_4 emissions
Wetland spatial variability	Location relative water circulation	May affect GHG removals and GHG emissions
Wetland age		May affect GHG removal rates
Soil chemical composition – soil organic matter content	For baseline conditions	Soil organic matter is key determinant of baseline GHG emissions on organic soils
Soil hydrology	Depth to groundwater, oxidation-reduction conditions	Depth to groundwater is an important determinant of baseline GHG emissions on organic soils
Agricultural land use	Crop type	Affects baseline GHG emissions and removals

It will generally be sufficient to stratify according to soil organic matter content, agricultural land use (i.e., field crops, hay and grain crops, pasture, etc.), fertilizer use, soil chemical and physical properties (e.g., redox conditions, temperature) and average depth to groundwater as these are the primary factors that affect GHG emissions for baseline conditions.

Step 4. Baseline Carbon Stock Changes and Emissions

The baseline scenario consists of the most likely projected emissions and removals in the absence of project implementation for the life of the project. The baseline scenario is fixed for the life of the project. The baseline net GHG emissions shall be estimated using the methodology described in this section and the Methods Module (MM-W/R) and/or using biogeochemical models as specified in the Models Module (MODEL-WR/C). For *ex-ante* calculation of baseline net GHG emissions, the Project Proponents shall provide estimates of the site-specific values for the appropriate parameters used in the calculations and/or model estimates. Project Proponents shall retain a conservative approach in making these *ex-ante* estimates.

The cumulative total carbon stock change for the baseline agricultural scenario when the project activity will include managed wetlands or rice;

$$\Delta C_{BSL\ Ag\ W/RC} = \Delta GHG_{BSL\ Ag\ W/RC} + T_p * E_{FFC} \quad (4)$$

where:

$\Delta GHG_{BSL\ Ag\ W/RC}$ is the cumulative total of GHG emissions due to oxidation of organic soils as shown in the Methods Module (MM-W/R) and determined using eddy covariance, subsidence measurements or biogeochemical models (t CO_2-e);

T_p is the period of time which corresponds to the project reporting period (yr); and

E_{FFC} is the emissions of fossil fuels per time period (t CO_2-e per T_p).

It is assumed that the soil carbon pool is decreasing via oxidation, and emissions and carbon stock changes are accounted for by $\Delta GHG_{BSL\ Ag\ W/RC}$ in the above equation. The decrease in the soil carbon pool is estimated using methods described in the Methods Module (MM-W/R). For calculation of fossil fuel combustion see the module "estimation of emissions from fossil fuel combustion" (E-FFC).

Step 5. Monitoring Requirements for Baseline Renewal

A Crediting Period for all projects using this methodology is 40 years, during which the baseline scenario is fixed. In order to renew the crediting period the Project Proponents must:

- Re-submit the GHG Project Plan in compliance with then-current GHG Program standards and criteria;
- Re-evaluate the project baseline;
- Demonstrate additionality against then-current regulations and performance standards;
- Use GHG program-approved baseline methods, emission factors, tools, models and methodologies in effect at the time of Crediting Period renewal;
- Undergo validation by an approved validation/verification body.

PARAMETERS ORIGINATING IN OTHER MODULES

Data /parameter:	$\Delta GHG_{BSL\ Ag\ W/RC}$
Data unit:	t CO_2-e
Used in Equations:	4
Description:	Cumulative total of GHG emissions due to oxidation of organic soils for the baseline scenario
Module parameter originates in:	M-M-W/RC
Any comment:	Baseline GHG emissions due to organic soil oxidation from the project area shall be estimated from direct measurement of gaseous fluxes using the eddy covariance technique, subsidence measurements, by modeling or equivalent method or determined based on an acceptable proxy, data from peer-reviewed literature or approved parameters or a combination of gaseous flux and subsidence measurements.

Data /parameter:	E_{FFC}
Data unit:	t CO_2-e

Used in Equations:	4
Description:	Annual emission of fossil fuels in the baseline scenario
Module parameter originates in:	E-FFC
Any comment:	Only included if significant

(BL-SW) Wetland Restoration and Rice Methodological Module - Estimation of baseline greenhouse gas emissions and carbon stock changes for seasonal wetlands

I. SCOPE, BACKGROUND, APPLICABILITY AND PARAMETERS

Scope

This module provides guidance for estimating carbon stock changes and GHG emissions for seasonal wetlands in the Sacramento-San Joaquin Delta and San Francisco Estuary in the baseline case where the project activity will be managed wetland construction or rice cultivation. The module provides specific guidance for identifying the baseline scenario, defining the project GHG boundary, stratification and estimating carbon stock changes and GHG emissions.

Applicability

The module is applicable for estimating baseline GHG emissions and carbon stock changes for project areas planned for wetland construction or rice cultivation in the Sacramento-San Joaquin Delta or San Francisco Estuary. These land use changes will occur due to some combination of hydrologic management changes and infrastructural modification with assisted natural regeneration, and seeding. Infrastructural modification includes drainage modification and earth moving. The following conditions must be met to apply this module.

- The project area must be on lands where there are seasonal wetlands in the Sacramento-San Joaquin Delta or San Francisco Estuary.
- This module is always mandatory when the project activity will include hydrologic management and infrastructural modification for wetland construction and restoration and rice cultivation on lands where there are seasonal wetlands and organic soils or highly organic mineral soils.
- Seasonal wetlands include areas in the Delta and San Francisco Estuary that may be used for attracting and breeding waterfowl for hunting such as duck clubs (Table 7).

Table 3. Examples of eligible seasonal wetlands.

Seasonal Wetland Type	**Examples**	**Comments**
Managed seasonal wetlands or organic soils	Suisun Marsh seasonal wetlands used for attracting and breeding waterfowl for hunting. There are also seasonal wetlands used for hunting in the Delta.	Most of the land within Suisun Marsh (85%) consists of diked wetlands which are flooded part of the year and are drained from mid-July through mid-September[1].
Unmanaged seasonal wetlands on organic soils in the Delta	Many areas of the central Delta where elevations are less than -2 m have become too wet to farm and are now seasonal wetlands.[2]	These areas likely continue to subside and emit carbon dioxide although there are no measurements.

Parameters

This module provides procedures to determine the following parameter:

Parameter	**SI Unit**	**Description**
$\Delta C_{BSL\_SW W/RC}$	t CO_2-e	Cumulative total of carbon stock changes and greenhouse gas emissions for the seasonal wetlands baseline scenario.
Comment	The notation for this parameter in the Framework Module is expressed in its generic form as ΔC_{BSL} in Equation 1	

II. PROCEDURE

Step 1. Identification of the Baseline Scenario and Performance Standard Evaluation.

Project Proponents must identify the most plausible and credible baseline scenario that would have occurred in absence of the Project Activities. Therefore, the project developer needs to demonstrate that seasonal wetlands are the most likely scenario. The geographical coordinates of the boundaries of each project area must be unambiguously defined and provided to the Validation/Verification Body (VVB) in shapefile format.

Step 2. Establishment and Documentation of the GHG Boundary

The project GHG boundary describes the carbon pools that will be included or excluded from GHG accounting. It shall be demonstrated that each discrete parcel of land to be included in the boundary is eligible for wetland or rice project activity. For the baseline case, the GHG boundary includes primarily emissions due to oxidation and loss of soil organic carbon. Hydrologic management and infrastructural modification practices in seasonal wetlands may result in GHG emissions that shall be accounted for. These include emissions associated with earth moving and vegetation control if determined to be significant. Exclusion of carbon pools and emission sources is allowed subject to considerations of

[1] Steven Chappell, November 2006, Suisun Marsh Resource Conservation District, personal communication Rubissow Okamoto, Ariel, Wong, Kathleen, 2011, Natural History of San Francisco Bay, University of California Press. Map on p. 189 shows the large area of managed habitat in Suisun Marsh.

[2] Deverel, Steven J., Lucero, Christina, Bachand, Sandra, 2015, Evolution of arability and land use, Sacramento-San Joaquin Delta, California, San Francisco and Estuary Science

conservativeness and significance testing. Pools or sources can be neglected (i.e., counted as zero) if application of the tool T-SIG indicates that the source is insignificant, i.e. the source represents less than 3% of the *ex-ante* calculation of GHG emission reductions/removal enhancements. If monitoring of baseline and project emissions determines that an emission source(s) initially included in the GHG assessment boundary is insignificant using the tool T-SIG, monitoring may cease. The baseline scenario consists of the most likely emissions and removals in the absence of project implementation as shown in Table 8.

Table 4. Baseline emissions sources included in the project boundary. Nitrous oxide and methane are considered optional (see Framework Module).

Source	**Gas**
Soil emissions due to fertilizer application	N_2O
Soil emissions due oxidation of organic soils	N_2O, CO_2, CH_4
Emissions resulting from Fossil Fuel Combustion	CO_2,

Step 3. Baseline Stratification

For estimation of baseline net GHG removals or emissions, or estimation of project net GHG benefit, strata shall be defined based on parameters that affect GHG removals or emissions and/or are factors that influence measurement of changes in biomass stocks. Potential stratification factors for seasonal wetlands as a baseline scenario are listed in Table 9.

Table 5. Factors and practices that can be used for stratification and their effects on GHG emissions and removals.

Stratification Factor or Practice	Description	Potential GHG Effect
Wetland management practices	Depth of water	Depth of water affects GHG removal and emissions and vegetation
Wetland management practices	Flow through or limited or zero outflow	May affect CH_4 emissions
Wetland vegetation	Variation in species	May affect GHG removals
Wetland vegetation	Planted seedlings, seeded, colonize or natural recruitment	Affects time required for vegetative cover, CH_4 emissions and GHG removal.
Wetland vegetation	Open water areas	Minimal GHG removal, GHG emissions
Wetland spatial variability	Location relative water circulation	May affect GHG removals and GHG emissions
Wetland age		May affect GHG removal rates
Soil chemical composition – soil organic matter content	For baseline conditions	Soil organic matter is key determinant of baseline GHG emissions on organic soils
Soil hydrology	Depth to groundwater, oxidation-reduction conditions	Depth to groundwater is an important determinant of baseline GHG emissions on organic soils

For baseline net GHG emissions, it will usually be sufficient to stratify according to soil organic matter content, vegetation, soil chemical and physical properties (e.g., redox conditions, temperature) and surface-water depth as these are the primary factors that affect GHG emissions.

For actual baseline emissions, the stratification for *ex-ante* estimations shall be based on the project monitoring plan. The stratification for *ex post* estimations shall be based on the actual implementation of the project monitoring plan. If natural or anthropogenic impacts (e.g., levee breaks and flooding) or other factors (e.g. altered hydrology or water management) add variability in the vegetation of the project area, then the stratification shall be revised accordingly. The Project Proponents may use remotely sensed data acquired close to the time of project commencement and/or the occurrence of natural or anthropogenic impacts for *ex-ante* and *ex-post* stratification.

Step 4. Baseline Emissions and Carbon Stock Changes

The baseline net GHG emissions shall be estimated using methodology described in this section and the Methods Module (MM – W/R) and/or using biogeochemical models as specified in the Models Module (MODEL-WR/C) and the Framework Module (W/R – FM). For *ex-ante* calculation of baseline net GHG emissions, the Project Proponents shall provide estimates of the site-specific values for the appropriate parameters used in the calculations and/or model estimates. Project Proponents shall retain a conservative approach in making these *ex-ante* estimates.

The cumulative total of carbon stock change for the baseline seasonal wetlands scenario when the project activity will include managed wetlands or rice:

$$\Delta C_{BSL\ SW\ W/RC} = \Delta GHG_{BSL\ SW\ W/RC} + T_p * E_{FFC} \qquad (5)$$

where:

$\Delta GHG_{BSL\ SW\ W/RC}$	is the cumulative net emissions due to oxidation of organic soils as shown in Equations 13 and 18 in the Methods Module (MM-W/R) and determined using eddy covariance, subsidence measurements or biogeochemical models (t CO_2-e);
T_p	is the period of time which corresponds to the project reporting period (yr); and
E_{FFC}	is the emissions of fossil fuels per time period (t CO_2-e per T_p).

It is assumed that the soil carbon pool is decreasing via oxidation and emissions are accounted for by $\Delta GHG_{BSL\ SW\ W/RC}$ in the above equation. For calculation of fossil fuel combustion see the module "estimation of emissions from fossil fuel combustion" E-FFC.

Step 5. Monitoring Requirements for Baseline Renewal

A Crediting Period for a project is a predetermined length of time for which the baseline scenario is applicable. This period of time is used for carbon quantification of offsets generated relative to its baseline. In order to renew the Crediting Periods the Project Proponents must:

- Re-submit the GHG Project Plan in compliance with then-current GHG Program standards and criteria
- Re-evaluate the project baseline
- Demonstrate additionality against then-current regulations and performance standard data
- Use GHG program-approved baseline methods, emission factors, tools, and methodologies in effect at the time of Crediting Period renewal
- Undergo validation by an approved validation/verification body

PARAMETERS ORIGINATING IN OTHER MODULES

Data /parameter:	$\Delta GHG_{BSL\ SW\ W/RC}$
Data unit:	t CO_2-e
Used in Equations:	5
Description:	Cumulative net emissions due to oxidation of organic soils for the baseline scenario
Module parameter originates in:	MM-W/RC
Any comment:	The net baseline GHG emissions due to organic soil oxidation from the project area shall be estimated from direct measurement of gaseous fluxes using the eddy covariance technique, subsidence measurements, by modeling or equivalent method or determined based on an acceptable proxy, data from peer-reviewed literature or approved parameters or a combination of gaseous flux and subsidence measurements.
Data /parameter:	E_{FFC}
Data unit:	t CO_2-e
Used in Equations:	5
Description:	Annual emission of fossil fuels in the baseline scenario
Module parameter originates in:	E-FFC
Any comment:	

(BL OW W) Wetland Restoration and Rice Methodological Module - Estimation of baseline greenhouse gas emissions and carbon stock changes for open water

I. SCOPE, BACKGROUND, APPLICABILITY AND PARAMETERS

Scope

This module provides guidance for estimating carbon stock changes and GHG emissions for open water areas in the San Francisco Estuary in the baseline case where the project activity will be tidal wetland restoration. The module provides specific guidance for identifying the baseline scenario, defining the project GHG boundary, stratification and estimating carbon stock changes and GHG emissions.

Applicability

The module is applicable for estimating baseline carbon stock changes and GHG emissions for project areas planned for tidal wetland construction and restoration. This module is always mandatory when the project activity includes hydrologic management and infrastructural modification for tidal wetlands including tidal marshes and eelgrass meadows. These land use changes will occur due to some combination of hydrologic management changes and infrastructural modification with assisted natural regeneration, and seeding. Infrastructural modification includes earth moving, berm and levee construction, drainage modification and application of dredge materials.

The following condition must be met to apply this module.

- Under this module, the baseline scenario must be limited to open water in the San Francisco Estuary and the Sacramento-San Joaquin Delta.

Parameters

This module provides procedures to determine the following parameter:

Parameter	SI Unit	Description
$\Delta C_{BSL\_OW\ W/RC}$	t CO_2-e	Cumulative total of carbon stock changes and greenhouse gas emissions for the open water baseline scenario.
Comment	The notation for this parameter in the Framework Module is expressed in its generic form as ΔC_{BSL} in Equation 1	

II. PROCEDURE

Step 1. Identification of the Baseline Scenario and Performance Standard Evaluation

Project Proponents must identify the most plausible and credible baseline scenario describing what would have occurred in absence of the Project Activities. Under this module, the baseline scenario must be limited to open water and tidal wetlands. The geographical coordinates of the boundaries of each project area must be unambiguously defined and provided to the Validation/Verification Body (VVB) in shapefile format.

Step 2. Establishment and Documentation of the GHG Boundary

The project GHG boundary describes the carbon pools that will be included or excluded from GHG accounting as defined in the WR-MF. It shall be demonstrated that each discrete parcel of land to be included in the boundary is eligible for project activity. For the open-water/tidal wetland baseline case, emissions will occur due to fossil fuel combustion during dredging operations, infrastructural modification, earth moving and construction. These emissions must be accounted for if they are determined to be significant. Methane ebullition may also occur. Emissions shall be estimated based on site/project specific data, an acceptable proxy, reference sample plots or field monitoring of similar sites, peer-reviewed literature, approved local parameters and model estimates. Baseline emissions include GHG emissions within the project boundary within the year prior to site preparation, or the most likely emissions in the absence of the project activity (Table 10).

Table 6. Baseline emissions sources included in the project boundary. Nitrous oxide and methane are considered optional (see Framework Module, WR-MF).

Source	**Gas**
Emissions due oxidation of organic matter	N_2O, CO_2, CH_4
Emissions resulting from Fossil Fuel Combustion	CO_2,

Allochthonous carbon may enter the open water area from outside source which may contribute to carbon accumulation at the site. However, for purposes of this methodology, carbon from outside sources is not counted in determination of baseline GHG emissions or removals as per guidance in the Methods Module. Only autochthonous processes are to be considered in the determination of the GHG baseline removals or emissions.

The Project Proponents using emission values from the literature or non-site data must make conservative estimates to determine the baseline GHG emissions. Exclusion of carbon pools and emission sources is allowed subject to considerations of conservativeness and significance testing. This may be accomplished by using peer-reviewed literature, reference sample plots or field monitoring of similar sites, approved local or national parameters, the most recent default emission factors provided by IPCC, government reports and models. Pools or sources may be excluded if exclusion will tend to underestimate net project GHG emission reductions or removal enhancements relative to the baseline. Additional guidance is provided in the Methods Module (MM-W/RC).

Pools or sources can be neglected (i.e., counted as zero) if application of the tool T-SIG (http://unfccc.int/home/items/2783.php) indicates that the source is insignificant, i.e. the source represents less than 3% of the *ex-ante* calculation of GHG emission reductions/removal enhancements. If monitoring of baseline and project emissions indicate that an emission source(s) initially included in the GHG assessment boundary is insignificant using the tool T-SIG, monitoring may cease.

Step 3. Baseline Stratification

For estimation of baseline net GHG emissions, strata shall be defined based on parameters that affect GHG emissions. These may include:

- Elevation and depth of open water
- Water quality (e.g. salinity, nutrient inputs, distance from source, etc.)

For baseline conditions, it will usually be sufficient to stratify according to soil organic matter content, vegetation, soil chemical and physical properties (e.g. redox conditions, temperature) and surface-water depth as these are the primary factors that affect GHG emissions. If natural or anthropogenic impacts (e.g., levee breaks and flooding) or other factors (e.g. altered hydrology or water management) add variability in the vegetation of the project area, then the stratification shall be revised accordingly.

Step 4. Baseline Carbon Stock Changes and Emissions

The baseline scenario consists of the emissions immediately prior to tidal wetland construction. The baseline net GHG emissions may be estimated using methodology described in this section and the Methods Module (MM-W/R). When applying these methods for the *ex-ante* calculation of baseline net GHG removals or emissions, the Project Proponents shall provide estimates of the site-specific values for the appropriate parameters. The Project Proponents shall retain a conservative approach in making these *ex-ante* estimates.

Net baseline emissions and cumulative carbon stock changes are estimated using the following equations.

The net carbon stock changes in the baseline are equal to the soil organic carbon stock minus the baseline greenhouse gas emissions including the combustion of fossil fuels if determined to be significant. Project Proponents may elect to assume carbon stock changes in the baseline are de minimis and proceed to step 5.

Baseline stock changes, $\Delta C_{BSL,}$ must be estimated using the following equations:

$$\Delta C_{BSL\_OW\ W/RC} = (\Delta C_{SOC} - NBE) * T_{pp} \quad (6)$$

$$NBE = GHG_{BSL\_OW\ W/RC} + E_{BSL,FFC} \quad (7)$$

where:

NBE is the net baseline annual greenhouse gas emissions (t CO_2-e yr^{-1});

$GHG_{BSL\_OW\ W/RC}$ is the annual net emissions of N_2O, CO_2, and CH_4 due to the oxidation of organic matter (t CO_2-e yr^{-1});

$E_{BSL\ FFC}$ is the annual net emissions as a result of fossil fuel combustion within the project boundary for the baseline scenario (t CO_2-e yr^{-1});

ΔC_{SOC} is the annual carbon stock change of soils for the baseline scenario (t CO_2-e yr^{-1}); and

T_{pp} is the period of time which corresponds to the pre-project reporting period (yr).

If deemed significant based on *ex-ante* estimates, the baseline GHG emissions due to organic matter oxidation from the project area may be estimated from direct measurement of gaseous fluxes prior to project activity using eddy covariance technique or by modeling or equivalent method or determined based on an acceptable proxy, data from peer-reviewed literature or approved parameters.

Estimation of emissions from fossil fuel combustion shall be estimated as described in the emissions module (E-FFC). The total baseline emission is the sum of the product of NBE and the area of each stratum for all strata in the project area (t CO_2-e yr^{-1}).

Step 5. Monitoring Requirements for Baseline Renewal

A Crediting Period for a project is a predetermined length of time for which the baseline scenario is applicable. This period of time is used for carbon quantification of offsets generated relative to its baseline. In order to renew the Crediting Periods the Project Proponents must:

- Re-submit the GHG Project Plan in compliance with then-current GHG Program standards and criteria
- Re-evaluate the project baseline

- Demonstrate additionality against then-current regulations and performance standard data
- Use GHG program-approved baseline methods, emission factors, tools, and methodologies in effect at the time of Crediting Period renewal
- Undergo validation by an approved validation/verification body

PARAMETERS ORIGINATING IN OTHER MODULES

Data /parameter:	$\Delta GHG_{BSL\_OW\ W/RC}$
Data unit:	t CO_2-e
Used in Equations:	7
Description:	Cumulative total of GHG emissions due to the oxidation of organic matter for the baseline scenario
Module parameter originates in:	MM – WR/C
Any comment:	

Data /parameter:	ΔC_{SOC}
Data unit:	t CO_2-e yr^{-1}
Used in Equations:	6
Description:	Annual carbon stock change of soils for the baseline scenario
Module parameter originates in:	MM – WR/C
Any comment:	

Data /parameter:	$E_{BSL\ FFC}$
Data unit:	t CO_2-e
Used in Equations:	7
Description:	Cumulative total of GHG emissions as a result of fossil fuel combustion for the baseline scenario
Module parameter originates in:	E-FFC
Any comment:	

Wetland Implementation and Rice Cultivation in the Sacramento-San Joaquin Delta, San Francisco Estuary and the Coast of California – Methodology for Quantifying Greenhouse Gas Emissions Reductions, Version 1.0 – PROJECT MODULES

Preface

The objective of this methodology is to describe quantification procedures for the reduction of greenhouse gas (GHG) emissions through conversion of land to wetlands and rice cultivation in the Sacramento-San Joaquin Delta, San Francisco Estuary and in coastal areas of California. The methodology has been written in a module format; Project Proponents can choose the applicable modules for their specific project and site. The Framework Module provides background and an over-arching description of the methodology requirements and modules. The remaining modules provide guidance for baseline and project scenario quantification, methods, modeling, calculation of uncertainty, and other quantification tools. Project Proponents should refer first to the Framework Module for applicability requirements and an outline of the specific modules necessary for their project type.

Contents

Tables

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(PS-MW) Wetland Restoration and Rice Methodological Module - Estimation of project carbon stock changes and greenhouse gas emissions for managed wetlands

I. SCOPE, BACKGROUND, APPLICABILITY AND PARAMETERS

Scope

This module provides guidance for estimating *ex-ante* and *ex-post* carbon stock enhancements and greenhouse gas (GHG) emissions related to managed non-tidal wetlands when the project activity includes hydrologic management, infrastructural modification, and plantings or natural plant regeneration. The module provides specific guidance for determining applicability, monitoring project implementation, stratification and estimating carbon stock changes and GHG emissions.

Applicability

This module is always mandatory when the project activity includes hydrologic management, infrastructural modification and plantings or natural plant regeneration for construction of managed non-tidal wetlands that occur in the Sacramento-San Joaquin Delta and San Francisco Estuary. Infrastructural modification includes drainage modification and earth moving. The baseline scenario for this project activity is limited to agriculture and seasonal wetlands on organic soils.

The following conditions must be met to apply this module.

- The project area must be on agricultural lands where crops are grown and/or animals are grazed in the Sacramento-San Joaquin Delta or seasonal wetlands in the Sacramento-San Joaquin Delta or San Francisco Estuary.
- The baseline is as defined for agricultural lands or seasonal wetlands.
- Baseline emissions are due to the oxidation of organic soils.
- The project activity is implementation of managed non-tidal wetlands.

Parameters

This module produces the following parameter.

Parameter	**SI Unit**	**Description**
$\Delta C_{actual\text{-}MW}$	Metric tons carbon dioxide equivalents (t CO_2-e)	Cumulative total of carbon stock changes and greenhouse gas emissions under the managed wetlands project scenario.
Comment	The notation for this parameter in the Framework Module is expressed in its generic form as ΔC_{actual} in Equation 1	

II. PROCEDURE

Step 1. Project Boundaries

Information to delineate the project boundary may include:

- USGS topographic map or property parcel map where the project boundary is recorded for all areas of land. Provide the name of the project area (e.g., compartment number, allotment number
- Local name and a unique ID for each discrete parcel of land
- Aerial map (e.g. orthorectified aerial photography or georeferenced remote sensing images)
- Geographic coordinates for the project boundary, total land area, and land holder and user rights

A Geographic Information System shapefile which specifies project boundary locations and related information is required.

Step 2. Stratification

In the GHG Project Plan, Project Proponents shall present an *ex-ante* stratification of the project area or justify the absence of stratification. Stratification for *ex-ante* estimations shall be based on the Project Management Plan. Table 11 provides typical factors and practices that can be used for stratification.

Table 1. Factors and practices that can be used for stratification and their effects on GHG emissions and removals.

Stratification Factor or Practice	Description	Potential GHG Effect
Wetland management practices	Depth of water and land surface elevation	Depth of water affects GHG removal and emissions and vegetation
Wetland management practices	Flow through or limited or zero outflow	May affect CH_4 emissions
Wetland vegetation	Variation in species	May affect GHG removals
Wetland vegetation	Planted seedlings, seeded, colonize or natural recruitment	Affects time required for vegetative cover, CH_4 emissions and GHG removal.
Wetland vegetation	Open water areas	Minimal GHG removal, GHG emissions
Wetland spatial variability	Location relative water circulation	May affect GHG removals and GHG emissions
Wetland age		May affect GHG removal rates
Soil chemical composition – soil organic matter content	For baseline conditions	Soil organic matter is key determinant of baseline GHG emissions on organic soils
Soil hydrology	Depth to groundwater, oxidation-reduction conditions	Depth to groundwater is an important determinant of baseline GHG emissions on organic soils
Agricultural land use	Crops or seasonal wetlands	Affects baseline GHG emissions and removals

Step 3. Monitoring Project Implementation

As described in Methodology Framework (MF-W/R), Project Proponents shall include a single monitoring plan in the Project Plan that includes description of baseline and project monitoring and estimation of carbon stock changes. Information shall be provided in the monitoring plan (as part of the GHG Project Plan), to document that:

a. The geographic position of the project boundary is recorded for all areas of land;
b. The geographic coordinates of the project boundary (and any stratification inside the boundary) are established, recorded, and archived;
c. Commonly accepted principles of wetland management are implemented;
d. Standard operating procedures (SOPs) and quality control / quality assurance (QA/QC) procedures for field data collection and data management are applied;
e. Use or adaptation of relevant practices already applied in managed wetland monitoring, or available from published relevant materials are implemented;
f. The monitoring plan, together with a record of implemented practices and monitoring during the project, shall be available for validation and verification.

Step 4. Project GHG Emissions

Greenhouse-gas emissions shall be estimated using methodology described in the Methods Module (MM-W/R). The Methods Module (MM-W/RC) provides the appropriate methods for measuring and estimating emissions for project and baseline activities. The methods listed in the MM-W/R module may be used alone or in tandem with the other methods listed for estimating project GHG emissions. Emissions can be estimated using appropriate peer-reviewed proxy measurements or estimates for similar situations in which case the environmental setting for the estimates shall be detailed. Also, there shall be an in-depth demonstration of conservatism and applicability. Biogeochemical models documented in the peer-reviewed literature that are calibrated and validated for the project area and demonstrably similar project conditions can be used for estimating GHG emissions.

Parameter estimates shall be based on measured data or existing published data where appropriate and can be demonstrated as applicable. If different values for a parameter used in models or calculations are equally plausible, a value that does not lead to over-estimation of net GHG emission reductions must be selected and its use documented. If project activities include moving sediments, fossil fuel combustion emissions must be quantified during project activities using methods described in module E-FFC if determined to be significant using module T-SIG. An *Ex-Ante* estimate shall be made of fuel consumption based on projected fuel usage.

Step 5. Project Carbon Stock Changes

Methods are described in the Methods Module (MM-W/R) for calculating above- and below-ground biomass and soil organic carbon stock changes. Acceptable methods include eddy covariance and soil coring. For use of the mean in estimating carbon stock changes, the 90% statistical confidence interval (CI) for estimated values of carbon stock changes can be no more than +/-10% of the mean estimated amount of the combined carbon stock change across all strata[1].

A 5-year monitoring and reporting frequency is considered adequate for the determination of changes in soil carbon stocks. Specifically, coring for measurements of carbon stock changes can be conducted every five years after project inception and placement of feldspar markers. If eddy covariance measurements are used to estimate carbon stock changes, continual monitoring shall occur from project inception unless another method is selected (such as a calibrated biogeochemical modeling). Project Proponents shall demonstrate that the spatial and temporal monitoring frequency adequately reflects reported and credited changes. Peer-reviewed biogeochemical models developed and calibrated for project conditions shall be used to simulate project carbon stock changes and GHG emissions at 5-year intervals.

Pertinent concepts and assumptions

1. Above- and below-ground biomass of wetland vegetation and litter contribute to the soil organic carbon (SOC) pool in wetlands.
2. Net increases in the SOC pool as the result of biomass contributions shall be estimated using methods described in the Methods Module (MM-W/R).
3. Project Proponents shall not double count carbon stock changes in above- and below-ground biomass and the SOC pool.

Step 5. Estimation of Project Emission Reductions or Enhancement Removals

The actual net GHG removals by sinks shall be estimated using the equations in this section. When applying these equations for the *ex-ante* calculation of actual net GHG removals by sinks, Project Proponents shall provide estimates of the values of those parameters that are not available before the start of the crediting period and commencement of monitoring activities. Project Proponents should retain a conservative approach in making these estimates.

$$\Delta C_{ACTUAL\_MW} = \Delta C_p - \Delta GHG_p - \mathrm{E}_{\mathrm{FFC,i,t}} \qquad (8)$$

where:

ΔC_{ACTUAL_MW} is the cumulative total of carbon stock changes and greenhouse gas emissions under the project scenario (t CO_2-e);

ΔC_p is the cumulative total of carbon stock changes under the project scenario (t CO_2-e);

ΔGHG_p is the cumulative total of GHG emissions as a result of implementation of the project activity (t CO_2-e); and

$\mathrm{E}_{\mathrm{FFC,i,t}}$ is the cumulative total emission from fossil fuel combustion in stratum *i* (t CO_2-e).[2]

[1]For calculating pooled confidence interval of carbon pools across strata, see equations in Barry D. Shiver, *Sampling Techniques for Forest Resource Inventory* (John Wiley & Sons, Inc., 1996).

[2] Include in equation if project activities include moving sediment and fossil fuel combustion emissions have been determined to be significant using module T-SIG.

Note: In this module, Equation 8 is used to estimate actual cumulative net GHG removals for the period of time elapsed since the last verification period.

PARAMETERS ORIGINATING IN OTHER MODULES

Parameter	ΔC_p
Units	Metric tons carbon dioxide equivalents (t CO_2-e)
Used in Equation	8
Description	Cumulative total of carbon stock changes under the project scenario up to time *t*
Module	Methods Module (MM-W/R)
Comment	Relevant information shall be included in the GHG Project Plan

Parameter	ΔGHG_p
Units	t CO_2-e
Used in Equation	8
Description	Cumulative total of GHG emissions as a result of implementation of the project activity up to time *t*
Module	Methods Module (MM-W/R)
Comment	Relevant information shall be included in the GHG Project Plan

Parameter	$E_{FFC,i,t}$
Units	t CO_2-e
Used in Equation	8
Description	Cumulative total emission from fossil fuel combustion in stratum *i*
Module	E-FCC
Comment	Relevant information shall be included in the GHG Project Plan

(PS -TW) Wetland Restoration and Rice Methodological Module - Estimation of Project Carbon Stock Changes and Greenhouse Gas Emissions for Tidal Wetlands with in the San Francisco Bay Estuary

I. SCOPE, APPLICABILITY AND PARAMETERS

Scope

This module provides guidance for estimating *ex-ante* and *ex-post* carbon stock enhancement and greenhouse gas (GHG) emissions related to tidal wetlands construction and restoration in the San Francisco Estuary. The module provides specific guidance for determining applicability, monitoring project implementation, stratification and estimating carbon stock changes and GHG emissions.

Applicability

This module is always mandatory for use with tidal wetlands when the project activity includes hydrologic management and infrastructural modification with plantings, natural plant recruitment, or seeding. Tidal wetland restoration includes tidal marshes and Eelgrass meadows in the San Francisco Estuary. Hydrologic management and infrastructural modification activities include levee breaching and construction, earth moving, levee construction and other activities related to re-introducing tidal action and application of dredged material. The following conditions must be met to apply this module.

- The project activity is restoration of tidal wetlands where the baseline scenario is seasonal wetlands or open water in the San Francisco Estuary;
- This module is not applicable where application of nitrogen fertilizer(s) such as chemical fertilizer or manure, occurs in the project area during the project period.

Parameters

This module produces the following parameter.

Parameter	SI Unit	Description
ΔC_{actual_TW}	Metric tons carbon dioxide equivalents (t CO_2-e)	Cumulative total of carbon stock changes and greenhouse gas emissions under the project scenario.
Comment	The notation for this parameter in the Framework Module is expressed in its generic form as ΔC_{actual} in Equation 1	

II. PROCEDURE

Step 1. Project Boundaries

Guidance for definition of geographic and temporal boundaries is provided in the Framework Module (WR-MF). The Project Proponent must provide a detailed description of the geographic boundaries for project activities. Note that the project activities may occur on more than one discrete area of land, but each area must meet the project eligibility requirements.

Step 2. Stratification

Strata shall be delineated using spatial data (e.g. maps, GIS, classified imagery). Strata must be spatially discrete and stratum areas must be known. Areas of individual strata must sum to the total project area. For estimation of *ex-ante* carbon stocks, strata should be defined based on parameters that affect GHG sequestration or emissions and/or that are key variables for the methods used to measure changes in carbon stocks. Potential strata criteria are as follows.

a. Wetland elevation
b. Vegetation type and species, such as eelgrass meadows
c. Age class
d. Water quality (e.g. salinity, nutrient inputs, distance from source, etc.). See discussion below for relevance to methane (CH_4) emissions
e. Hydrology (e.g. wetland water depth, depth of eelgrass meadow)
f. Soil type (e.g. organic or mineral soils)

Tidal wetlands may also be stratified according to salinity with relevance for CH_4 emissions. It is generally understood that wetlands exposed to high concentrations of sulfate (an anion present in seawater) emit CH_4 at relatively low rates due to low rates of CH_4 production. The presence of sulfate in tidal marsh soils allows sulfate-reducing bacteria to outcompete methanogens for energy sources, consequently inhibiting CH_4 production[3]. However, sulfate can be reduced to sulfide in marsh soils and thus the inhibitory effect of marine-derived saline water can be affected by site-specific conditions that allow CH_4 production to persist if sulfate availability is limited by diffusion or oxidation-reduction conditions[4]. Moreover, temporal and spatial variation in sources and sinks for sulfate and CH_4 can create conditions where both processes can coexist[5]. Therefore, estimates of CH_4 emissions and corresponding stratification may require direct measurements or conservative estimates as described in Step 4 below.

Established strata may be merged if reasons for their establishment have disappeared or have proven

[3] Poffenbarger, Hanna J. Needelman, Brian A. & Megonigal, J. Patrick, 2011, Salinity Influence on Methane Emissions from Tidal Marshes, Wetlands, 31:831-842.
[4] E.g. Megonigal JP, Hines ME, Visscher PT (2004) Anaerobic metabolism: linkages to trace gases and aerobic processes. In: Schlesinger WH (ed.) Biogeochemistry. Elsevier-Pergamon, Oxford, pp 317–424.
Weston NB, Vile MA, Neubauer SC, Velinsky DJ (2011) Accelerated microbial organic matter mineralization following salt-water intrusion into tidal freshwater marsh soils. Biogeochemistry 102:135–151.
[5] Callaway, John C., Borgnis, Evyan L. Turner, R. Eugene & Milan, Charles S., 2012, Carbon Sequestration and Sediment Accretion in San Francisco Bay Tidal Wetlands, Estuaries and Coasts, (2012) 35:1163–1181.

irrelevant to key variables for estimating net GHG emission reductions or removals. In the GHG Project Plan, Project Proponents shall present an *ex-ante* stratification of the project area or justify the absence of stratification. Stratification for *ex-ante* estimations shall be based on the Project Management Plan. Aerial or satellite imagery used to delineate strata shall be verified in the field. The *ex-ante* defined number and boundaries of the strata may change during the crediting period (*ex-post*). The *ex-post* stratification shall be updated if natural or anthropogenic impacts or other factors add variability to the carbon stock changes or emissions of the project area.

Eelgrass Meadows

Seagrasses which include Eelgrass (*Zostera marinas)* are among the planet's most effective natural ecosystems for sequestering (capturing and storing) carbon However, there is limited data and quantifying and modelling the GHG removal capacity is critical for successfully managing Eelgrass ecosystems to maintain their substantial abatement potential[6]. Given the tendency of eelgrasses to respond differently under different light and depth regimes, projects may differentiate between eelgrass meadow sections that occur at different depths given discrete - or relatively abrupt - bathymetric and substrate changes. For Eelgrass meadow restoration projects in areas with existing Eelgrass meadows, Project Proponents must quantify the percentage of natural meadow expansion that can be attributed to the restoration effort. Existing meadows are not eligible for inclusion in calculations of project emissions, even in cases where the restored meadow influences carbon emission rates in existing meadows.

New beds that result from natural expansion must be contiguous with restored meadow plots to be included in project accounting unless Project Proponents can demonstrate that non-contiguous meadow patches originated from restored meadow seeds. This may be done through genetic testing or estimated as a percentage of new meadow in non-contiguous plots observed no less than four years after the project start date[7]. This percentage must not exceed the proportion of restored meadow area relative to the total Eelgrass meadow areal extent and Project Proponents 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), Project Proponents must delineate the line at which the two meadows joined. Project proponents may use either aerial observations showing meadow extent or direct field observations.

Step 3. Monitoring Project Implementation

As described in Methodology Framework (WR-MF), Project Proponents shall include a single monitoring plan in the Project Plan that includes description of baseline and project monitoring and estimation of carbon stock changes and emissions. Information shall be provided in the monitoring plan (as part of the GHG Project Plan), to document that:

a. The geographic position of the project boundary is recorded for all areas of land;

[6] P.I. Macreadie, M.E. Baird, S.M. Trevathan-Tackett, A.W.D. Larkum, P.J. Ralph, 2014, Quantifying and modelling the carbon sequestration capacity of seagrass meadows – A critical assessment, Marine Pollution Bulletin, 82, 430 - 439.

[7] McGlathery, KL, LK Reynolds, LW Cole, RJ Orth, SR Marion, A. Schwarzchild. 2012. Recovery trajectories during state change from bare sediment to eelgrass dominance. *Marine Ecology Progress Series* 448: 209-221.

b. The geographic coordinates of the project boundary (and any stratification inside the boundary) are established, recorded, and archived;
c. Commonly accepted principles of wetland management are implemented;
d. Standard operating procedures (SOPs) and quality control / quality assurance (QA/QC) procedures for field data collection and data management are applied;
e. Use or adaptation of relevant practices already applied in managed wetland monitoring, or available from published relevant materials are implemented;
f. The monitoring plan, together with a record of implemented practices and monitoring during the project, shall be available for validation and verification.

Step 4. Project GHG Emissions

Greenhouse-gas emissions shall be estimated using methodology described in the Methods Module (MM-W/R) which provides the appropriate methods for measuring and estimating emissions for project and baseline activities (use Baseline Modules BL OW W or BL SW W). The methods listed the Methods Module may be used alone or in tandem with the other methods listed. For emissions measurements for tidal wetland project activities, chamber and eddy covariance methods are appropriate. The Methods Module provides guidance, and quality assurance and control precautions and recommendations for chamber and eddy covariance techniques. Emissions can be estimated using appropriate proxy measurements or estimates for similar situations documented in the peer-reviewed literature. In this case, the environmental setting for the estimates shall be detailed. Also, there shall be a comprehensive demonstration of conservatism and applicability.

As discussed above, CH_4 fluxes are generally influenced by salinity that can affect stratification. Methane emissions can be measured using methods described in the Methods Module. These methods can be used to directly determine and characterize the spatial and temporal variability resultant from topography, temperature, vegetation and water levels. Alternatively, a conservative estimate of CH_4 emissions requires measurement in the stratum where emissions are likely to be the largest. That is, chamber or eddy covariance measurements shall be conducted at times and places in which CH_4 emissions are expected to be the highest based on expert judgment, datasets or literature. These are likely to be wettest strata that support emergent vegetation, but may include stagnant pools of water. If eddy flux towers are used for the conservative approach, they will be placed so that the footprint lies in the stratum with the highest CH_4 emissions for 50% of the time.

Where a default factor approach is used based on salinity, the salinity average or low value shall be measured in shallow pore water or soil salinity within 30 cm of land surface using acceptable technology or analytical determination of total dissolved solids. Sulfate concentrations shall also be determined when salinity is measured using standard analytical methods at a certified laboratory. The salinity average shall be calculated from measurements during periods of peak CH_4 emissions. When the number of measurements is fewer than monthly for one year, the minimum salinity value shall be used. The salinity of the floodwater source may be used as a proxy for salinity in pore water provided there is regular hydrologic exchange between the source and the wetland (i.e. the source floods the wetland at least on 20% of the time during high tides).

The default factor[8] may be used with caution (see exceptions below) where the salinity average or salinity minimum is greater than 18 parts per thousand. Thus the estimated default CH_4 flux:

$$fGHG_{TW,i} = 0.0045 \text{ t } CH_4 \text{ acre}^{-1} \text{ yr}^{-1} \quad (9)$$

Where

$fGHG_{TW,i}$ is the annual rate of CH_4 emissions (t CO_2-e) from the project area in stratum i.

The default factor shall not be used where oxidation-reduction conditions or sulfate concentrations are such that CH_4 production may not be inhibited. For example, Winfrey and Ward[9] demonstrated greatly increased CH_4 pore-water concentrations with decreasing sulfate to chloride ratios in intertidal sediments below 0.01. Morris and Riley[10] reported a sulfate chloride ratio of 0.14 +/- 0.00023 for the world's oceans.

Specific applicability conditions follow for the use of the default factor:

1. The default factor shall not be used when sulfate/chloride ratios are less 0.01;
2. In intertidal areas where there are likely sulfate to chloride ratios near or below 0.01, CH_4 fluxes shall be measured using methods described in the Methods Module (MM-R/C);
3. Methane flux measurements shall be used to characterize the spatial and temporal variability caused by topography, temperature, vegetation and water levels or conservatively estimated based on direct measurements taken at times and places in which CH_4 emissions are expected to be the highest based on expert judgment, datasets or literature

Project proponents may also estimate GHG emissions using locally calibrated and peer-reviewed biogeochemical models as per guidance in the biogeochemical modeling Methods Module and the Framework Module (WR-MF). Proponents shall provide transparent calculations for the parameters or data used for modeling during the crediting period. Parameter estimates shall be based on measured data or existing published data where appropriate and can be demonstrated as applicable. In addition, Project Proponents must be conservative in estimating parameters. If different values for a parameter used in models or calculations are equally plausible, a value that does not lead to over-estimation of net GHG emission reductions must be selected and its use documented. Emissions of N_2O may be conservatively set to zero for Eelgrass meadows.

If project activities include moving sediments, fossil fuel combustion emissions must be quantified during project activities using methods described in module E-FFC if determined to be significant using module T-SIG. An *Ex-Ante* estimate shall be made of fuel consumption based on projected fuel usage.

[8] Poffenbarger, Hanna J. Needelman, Brian A. & Megonigal, J. Patrick, 2011, Salinity Influence on Methane Emissions from Tidal Marshes, Wetlands, 31:831-842.
[9] Winfrey, M.R. and Ward, D.M., 1983, Substrates for Sulfate Reduction and Methane Production in Intertidal Sediments, Applied and Environmental Microbiology, January, 193-199.
[10] Morris, A.W. and Riley, J.P., 1966, The bromide/chorinity and sulphate/chlorinity ratio in sea water, Deep Sea Research and Oceanographic Abstracts, August, 699 – 705.

Step 5. Project Carbon Stock Changes

Methods are described in the Methods Module (MM-R/C) for calculating above- and belowground biomass and soil organic carbon stock changes. Acceptable methods for estimating soil carbon stock changes include eddy covariance and soil coring as described in the Methods Module (MM-R/C). For use of the mean value or replicate measurements in time and space in estimating carbon stock changes, guidance in the uncertainty (X-UNC) and framework (WR-MF) modules .

A 5-year monitoring and reporting interval is considered adequate for the determination of changes in soil carbon stocks. Specifically, coring for measurements of carbon stock changes shall be conducted every five years after project inception and placement of feldspar markers or sediment pins where opening of the project area would wash feldspar markers away due to tidal influence. Sediment pins are pounded into the ground to refusal and sediment accretion is measured against the pin's height[11].

If eddy covariance measurements are used to estimate carbon stock changes, continual monitoring shall occur from project inception until such time as biogeochemical models can effectively predict carbon stock changes. As per guidance in the Methods Module aqueous carbon fluxes shall be accounted for when eddy covariance methods are used for estimating soil carbon stock changes. Project Proponents shall demonstrate that the spatial and temporal monitoring frequency adequately reflects reported and credited changes. Biogeochemical models developed and calibrated for project conditions shall be used to simulate cumulative project carbon stock changes and GHG emissions at 5-year intervals.

Pertinent concepts and assumptions

1. Above- and belowground biomass of wetland vegetation and litter contribute to the soil organic carbon (SOC) pool in wetlands. Measurement of these biomass contributions to the wetland can only be used as inputs for biogeochemical models and will not be double counted with changes in the SOC pool for estimating carbon sequestration.
2. Net increases in the SOC pool as the result of biomass contributions shall be estimated using methods described in the Methods Module (MM-W/R).
3. Project Proponents using non-project specific values must demonstrate use of conservative estimates.

Step 6. Estimation of Project Emission Reductions and GHG Removals

Equations and methods for project emissions and carbon stock changes are provided in the Methods Module (MM-R/C. The Framework Module provides equations for calculating net carbon stock change. The project carbon stock change shall be estimated using the equations in this section. In applying these equations *ex-ante*, Project Proponents shall provide estimates before the start of the crediting period and monitoring activities. Project Proponents shall utilize a conservative approach in making these estimates. The net carbon stock change when using soil coring is estimated as follows.

$$\Delta C_{actual\_TW} = \Delta C_p - \Delta GHG_p - E_{FFC} \qquad (10)$$

[11] US Geological Survey. 2012. Sediment pin standard operating procedures. Unpublished protocols. USGS, Western Ecological Research Center, San Francisco Bay Estuary Field Station, Vallejo, CA. http://www.tidalmarshmonitoring.org/pdf/USGS-WERC-Sediment-Pin-SOP.pdf

where:

ΔC_{actual_TW} is the cumulative total of carbon stock changes and greenhouse gas emissions (t CO_2-e);

ΔC_p is the cumulative total of carbon stock changes under the project scenario (t CO_2-e);

ΔGHG_p is the cumulative total of GHG emissions as a result of implementation of the project activity (t CO_2-e); and

E_{FFC} is the cumulative emissions of fossil fuels (t CO_2-e).

Where allochthonous soil organic carbon (soil organic carbon originating outside the project boundary and being deposited in the project area) accumulates on the project site in the project scenario, the following procedure is provided for a compensation factor, D_{cf}.

$$D_{cf} = \Delta C_{p\ i} \times (\%C_{alloch} / 100) \quad (11)$$

where:

D_{cf} is the deduction to account for the percentage of the carbon stock that is derived from allochthonous soil organic carbon (t CO_2-e);

ΔC_p is the cumulative total of carbon stock changes under the project scenario (t CO_2-e);

$\%C_{alloch}$ is the percentage of carbon stock derived from allochthonous soil organic carbon (%); and

i is the stratum within the project boundary (1,2,3,…M).

D_{cf} may be conservatively set to zero for the baseline.

PARAMETERS ORIGINATING IN OTHER MODULES

Parameter	ΔC_p
Units	Metric tons carbon dioxide equivalents (t CO_2-e)
Used in Equation	10
Description	Cumulative total of carbon stock changes under the project scenario up to time *t*
Module	Methods Module (MM-W/R)
Comment	Relevant information shall be included in the GHG Project Plan

Parameter	ΔGHG_p
Units	t CO_2-e
Used in Equation	10
Description	Cumulative total of GHG emissions as a result of implementation of the project activity up to time *t*
Module	Methods Module (MM-W/R)

Comment	Relevant information shall be included in the GHG Project Plan

(PS RC W/RC) Wetland Restoration and Rice Methodological Module - Estimation of project carbon stock changes and greenhouse gas emissions for rice cultivation

I. SCOPE, APPLICABILITY AND PARAMETERS

Scope

This module provides methods for estimating *ex-ante* and *ex-post* carbon stock enhancement greenhouse gas (GHG) emissions related to rice cultivation (RC) when the project activity includes hydrologic management and infrastructural modification on subsided lands in the Sacramento-San Joaquin Delta. The module provides specific guidance for determining applicability, monitoring project implementation, stratification and estimating carbon stock changes and GHG emissions.

Applicability

This module is always mandatory when the project activity includes rice cultivation on organic and highly organic mineral soils in the Sacramento-San Joaquin Delta. The module is applicable for estimating project GHG emissions and carbon-stock changes for project areas planned for rice cultivation where drained agriculture is the baseline activity as discussed in the agricultural Baseline Module (BL-Ag). The rice cultivation project activity includes a combination of hydrologic management changes with planting and infrastructural modification. Infrastructural modification includes drainage modification and earth moving.

The following conditions must be met to apply this module.

- The project area must be on agricultural lands where crops are grown and/or animals are grazed in the Sacramento-San Joaquin Delta or seasonal wetlands in the Sacramento-San Joaquin Delta.
- The baseline is as defined for agricultural lands. Baseline emissions are due to the oxidation of organic soils.
- The project activity is rice cultivation on subsided lands where there are organic soils.
- Rice shall remain flooded during the growing season at depths ranging from not less than 4 inches up to 1 foot.
- Straw burning and removal are not allowed.
- Baseline drained agricultural activities as described in the agricultural Baseline Module (BL-Ag) shall be in place during 5 years prior to beginning rice cultivation.

Parameters

This module produces the following parameters:

Parameter	SI Unit	Description
ΔC_{actual_RC}	Metric tons carbon dioxide equivalents (t CO_2-e)	Cumulative total carbon stock changes and greenhouse gas emissions under the project scenario.
Comment	The notation for this parameter in the Framework Module is expressed in its generic form as ΔC_{actual} in Equation 1	

II. PROCEDURE

Step 1. Project Boundaries

The geographic boundaries of a rice project are fixed *ex-ante*. Guidance for definition of geographic and temporal boundaries is provided in the Framework Module (WR-MF). The Project Proponent must provide a detailed description of the geographic boundaries for project activities. Note that the project activities may occur on more than one discrete area of land, but each area must meet the project eligibility requirements.

Step 2. Stratification

If the project activity area is not homogeneous (and where applicable), proponents shall implement stratification to improve the accuracy and precision of carbon stock estimates. For estimation of *ex-ante* carbon stocks, strata should be defined based on parameters that affect GHG removal or emissions and/or that are key variables for the methods used to measure changes in carbon stocks. The key factors affecting GHG emissions are fertilization and soil organic carbon concentrations. Potential strata criteria are described in Table 12.

Table 2. Factors and practices that can be used for stratification and their effects on GHG emissions and removals.

Stratification Factor or Practice	Description	Potential GHG Effect
Rice water- management practices	Depth of water	Depth of water affects GHG removal and emissions and vegetation
Rice water management practices	Flow through or limited or zero outflow	May affect GHG emissions
Rice cultivar	Time for maturity varies among cultivars	Affects length of growing season which affects GHG removals and emissions
Soil chemical composition – soil organic matter content	For baseline conditions	Soil organic matter is key determinant of baseline GHG emissions on organic soils
Soil hydrology	Depth to groundwater, oxidation-reduction conditions	Depth to groundwater is an important determinant of baseline GHG emissions on organic soils
Agricultural land use	Baseline crops or seasonal wetlands	Affects baseline GHG emissions and removals
Fertilization rates and timing	Optimum fertilization rates vary for different organic matter[12].	Nitrous oxide emissions affected by rates and timing[13].

In the GHG Project Plan, the Project Proponents shall present an *ex-ante* stratification of the project area or justify the absence of stratification. Stratification for *ex-ante* estimations shall be based on the Project Management Plan. Aerial photography or satellite imagery used to delineate strata shall be verified in the field. The *ex-ante* defined number and boundaries of the strata may change during the crediting period (*ex-post*). The *ex-post* stratification shall be updated if natural or anthropogenic impacts or other factors add variability to the growth pattern or emissions of the project area.

Step 3. Monitoring Plan

As described in the Methodology Framework, Project Proponents shall include a single monitoring plan in the Project Plan that includes a description of baseline and project monitoring and estimation of carbon stock changes. Information shall be provided in the monitoring plan (as part of the Project Plan), to establish that:

a. The geographic position of the project boundary is recorded for all areas of land;
b. The geographic coordinates of the project boundary (and any stratification inside the boundary) are established, recorded, and archived;
c. Commonly accepted principles of rice cultivation for minimizing GHG emissions in the Delta are

[12] Matthew B. Espe, Emilie Kirk, Chris van Kessel, William H. Horwath, and Bruce A. Linquist, 2015, Indigenous nitrogen supply of rice is predicted by soil organic carbon, Soil Sci. Soc. Am. J, doi:10.2136/sssaj2014.08.0328.
[13] Ye, R. and Horwath, W.R., 2014 Influence of variable soil C on CH_4 and N_2O emissions from rice fields 2013-2014. Presentation at UC Davis.

implemented as described in the Appendix;

d. Standard operating procedures (SOPs) and quality control / quality assurance (QA/QC) procedures for field data collection and data management are implemented;
e. The monitoring plan, together with a record of implemented practices and monitoring during the project, shall be available for validation and verification.

Step 4. Project GHG Emissions

GHG emissions shall be estimated using the methodology described in this section and the Methods Module (MM-W/R) which provides the appropriate methods for measuring and estimating emissions for project and baseline activities. The methods listed in the Methods Module may be used alone or in tandem with the other methods listed. For emissions measurements for rice cultivation project activities, chamber and eddy covariance methods are appropriate. Monitoring shall occur during the entire calendar year. Emissions can be estimated using appropriate proxy measurements or estimates for similar situations if proxy measurements are used, the environmental setting relevance and scientific validity shall be detailed. Also, there shall be a demonstration of conservatism. Peer-reviewed biogeochemical models that are calibrated and validated for the project area and demonstrably similar project conditions can be used for estimating GHG emissions.

Project Proponents shall provide transparent calculations or estimates for the parameters that are monitored or used for calculations or modeling during the crediting period. These estimates shall be based on measured data or existing published data where appropriate. In addition, Project Proponents shall apply the principle of conservativeness. If different values for a parameter are equally plausible, a value that does not lead to demonstrable overestimation of net GHG emission reductions must be selected. If project activities include moving sediments, fossil fuel combustion emissions must be quantified during project activities using methods described in module E-FFC if determined to be significant using the T-SIG tool. An *Ex-Ante* estimate shall be made of fuel consumption based on projected fuel usage.

Step 5. Estimation and Monitoring of Project Carbon Stock Changes

Methods can be found in the Methods Module (MM-W/R) for calculating above-and belowground biomass and soil organic carbon stock changes. Acceptable monitoring methods include eddy covariance, remote sensing techniques and biogeochemical models. If eddy covariance techniques are used, the carbon of the harvested biomass must be accounted for as described in the Methods Module. The 90% statistical confidence interval (CI) for estimated values of carbon stock changes can be no more than +/-10% of the mean estimated amount of the combined carbon stock change across all strata[14]. If the Project Proponents cannot meet the targeted +/-10% of the mean at 90% confidence, then the reportable amount for calculation of offsets shall be adjusted as per the Framework Module (W/R-FM) A 5-year monitoring and reporting frequency is considered adequate for the determination of changes in soil carbon stocks. The Project Proponents shall demonstrate that the spatial and temporal monitoring frequency adequately reflects and supports reported and credited changes.

[14] For calculating pooled confidence interval of carbon pools across strata, see equations in Barry D. Shiver, *Sampling Techniques for Forest Resource Inventory* (John Wiley & Sons, Inc., 1996).

Pertinent concepts and assumptions

1. Above-and belowground biomass of rice vegetation and litter contribute to the soil organic carbon (SOC) pool. As discussed in the Methods Modules, monitoring of biomass and soil organic carbon stock changes shall not be used to double count GHG removal or carbon sequestration.
2. The mass of carbon in the harvested grain shall be counted in the carbon stock change estimates. The mass of carbon in the seed may also be counted.
3. Net increases and/or avoided losses in the soil-organic-carbon pool as the result of rice cultivation shall be estimated using methods described in the Methods Module (MM-W/R).
4. Emissions shall be measured in the field under project conditions or may be quantified by an acceptable proxy, reference sample plots, or field monitoring of similar sites, using approved local or national parameters, peer-reviewed biogeochemical models or peer-reviewed literature.
5. Project Proponents using non-project specific values must use conservative estimates and demonstrate applicability.

Step 6. Estimation of Project Emission Reductions

This section describes calculation of $\Delta C_{Actual\text{-}RC}$ (cumulative total of the carbon stock changes and GHG emissions under the project scenario in tons CO_2-e). The actual net GHG removals by sinks shall be estimated using the equations in this section. When applying these equations for the *ex-ante* calculation of actual net GHG removals by sinks, Project Proponents shall provide estimates of the values of those parameters that are not available before the start of the crediting period and commencement of monitoring activities. Project Proponents should retain a conservative approach in making these estimates.

The net carbon stock change is estimated using the following general equation.

$$\Delta C_{actual\_RC} = \Delta C_p - \Delta GHG_p - E_{FFC} \qquad (12)$$

where:

ΔC_{ACTUAL_RC} is the cumulative total of carbon stock changes and greenhouse gas emissions under the project scenario (t CO_2-e);

ΔC_p is the cumulative total of carbon stock changes under the project scenario (t CO_2-e) (MM-W/R);

ΔGHG_p is the cumulative total of GHG emissions as a result of implementation of the project activity (t CO_2-e) (MM-W/R); and

E_{FFC} is the cumulative total emission from fossil fuel combustion in stratum *i* (t CO_2-e).[15]

[15] Only include in equation if project activities include moving sediment and fossil fuel combustion emissions have been determined to be significant using module T-SIG.

Equations for project emissions and carbon stock changes are provided in the Methods Module (MM-W/R). In applying these equations *ex-ante*, Project Proponents shall provide estimates before the start of the crediting period and monitoring activities using peer-reviewed literature or biogeochemical models calibrated for project soil, climate and hydrologic conditions. Project Proponents should retain a conservative approach in making these estimates.

Table 13 can be used to estimate the N_2O emissions for rice cultivation for varying soil organic carbon content and fertilization rates in the Sacramento-San Joaquin Delta. Where fertilization rates are intermediate between 0 and 71 pounds N/acre, the project proponent can either conservatively use the high emissions estimate or estimate an emissions rate as a proportion of the rate for 71 pounds N per acre. For example for 5% soil carbon and a fertilization rate of 35 pounds N per acre, a project proponent may estimate the annual nitrous oxide emission rate at 0.25 t CO_2-e per acre (0.25 = 0.34 – ((0.34 - 0.16)/ (71/35))).

Table 3. Annual nitrous oxide emissions estimates for varying soil organic carbon content and fertilizer application rates (0 and 71 lbs. N per acre)[16].

Rate: 71 lbs. N per acre

Soil carbon content (%)	Annual N_2O emission (t CO_2-e/acre-year)	Standard error
5	0.34	0.03
6	0.28	0.02
7	0.22	0.02
8	0.15	0.01
9	0.09	0.01
10	0.03	0.02
11	0.04	0.03
12	0.05	0.04
13	0.07	0.05
14	0.08	0.06
15	0.09	0.06
16	0.10	0.07
17	0.11	0.08
18	0.13	0.09
19	0.14	0.05
20	0.15	0.05
21	0.11	0.04
22	0.07	0.02
23	0.02	0.01
24	-0.02	0.01
25	-0.06	0.11

[16] Ye, R. and Horwath, W.R., 2014. Influence of variable soil C on CH_4 and N_2O emissions from rice fields 2013-2014. Presentation at UC Davis.

Rate: 0 lbs. N per acre

Soil carbon content (%)	Annual N_2O emission (t CO_2-e/acre-year)	Standard error
5	0.16	0.09
6	0.13	0.08
7	0.11	0.06
8	0.08	0.05
9	0.06	0.03
10	0.03	0.02
11	0.04	0.02
12	0.04	0.02
13	0.05	0.03
14	0.05	0.03
15	0.06	0.03
16	0.07	0.04
17	0.07	0.04
18	0.08	0.04
19	0.08	0.05
20	0.09	0.04
21	0.07	0.03
22	0.05	0.02
23	0.04	0.02
24	0.02	0.01
25	0.00	0.04

PARAMETERS ORIGINATING IN OTHER MODULES

Parameter	ΔC_p
Units	Metric tons carbon dioxide equivalents (t CO_2-e)
Used in Equation	12
Description	Cumulative total of carbon stock changes under the project scenario up to time *t*
Module	Methods Module (MM-W/R)
Comment	Relevant information shall be included in the GHG Project Plan

Parameter	ΔGHG_{RC}
Units	t CO_2-e
Used in Equation	12
Description	Cumulative total of GHG emissions as a result of implementation of the project activity up to time *t*
Module	MM-W/R
Comment	Relevant information shall be included in the GHG Project Plan

Parameter	E_{FFC}
Units	t CO_2-e
Used in Equation	12
Description	Cumulative total emission from fossil fuel combustion in stratum *i*
Module	E-FCC
Comment	Relevant information shall be included in the GHG Project Plan

Wetland Implementation and Rice Cultivation in the Sacramento-San Joaquin Delta, San Francisco Estuary and the Coast of California – Methodology for Quantifying Greenhouse Gas Emissions Reductions, Version 1.0 – METHODS MODULES

Preface

The objective of this methodology is to describe quantification procedures for the reduction of greenhouse gas (GHG) emissions through conversion of land to wetlands and rice cultivation in the Sacramento-San Joaquin Delta, San Francisco Estuary and in coastal areas of California. The methodology has been written in a module format; Project Proponents can choose the applicable modules for their specific project and site. The Framework Module provides background and an over-arching description of the methodology requirements and modules. The remaining modules provide guidance for baseline and project scenario quantification, methods, modeling, calculation of uncertainty, and other quantification tools. Project Proponents should refer first to the Framework Module for applicability requirements and an outline of the specific modules necessary for their project type.

Contents

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(MM-W/R) Methodological Module for Estimation of Carbon Stock Changes and Emissions for Wetland and Rice Cultivation Projects in the San Francisco Estuary and Sacramento-San Joaquin Delta

Scope

This module provides direction for *ex-ante* and *ex-poste* estimation of soil carbon-stock changes and emissions for baseline and project conditions and data collection for inputs to biogeochemical models.

Applicability

This module is applicable for baseline conditions and project activities that include managed and tidal wetlands and rice cultivation in the San Francisco Estuary and Sacramento-San Joaquin Delta. The Framework Module (WR-MF) describes the applicable conditions and relevant project activities for the use of the methodology. If eddy covariance is used for project conditions, aqueous carbon losses from the wetland or contributions to the wetland must also be accounted for. Biogeochemical models documented in the peer-reviewed literature that are calibrated and validated for the project area can be used for estimating carbon stock changes for baseline and project conditions; the Model and Framework modules provide guidance for use of biogeochemical models.

Parameters and Estimation Methods

Table 1. Parameters, description and estimation methods.

Table 14a. Carbon stock changes

Parameter symbol	SI Unit	Description	Estimation methods
ΔC_{BSL}	Metric tons CO_2-e (t CO_2-e)	Cumulative total of carbon stock changes for the baseline scenario	• Biogeochemical modeling • Eddy-covariance • Subsidence measurements
ΔC_P	Metric tons CO_2-e (t CO_2-e)	Cumulative total of carbon stock changes for the project scenario	• Eddy-covariance • Modeling • Soil core collection and analysis using feldspar markers and tidal pins

Table 14b. Emissions

Parameter symbol	SI Unit	Description	Estimation methods
ΔGHG_{BSL}	Metric tons CO_2-e (t CO_2-e)	Cumulative net GHG emissions for the baseline scenario	• Chamber measurements • Biogeochemical modeling • Eddy-covariance measurements • Subsidence measurements
ΔGHG_P	Metric tons CO_2-e (t CO_2-e)	Cumulative net GHG emissions due to project activities	• Chamber measurements • Biogeochemical modeling • Eddy-covariance measurements
E_{FFC}	Metric tons CO_2-e (t CO_2-e)	Cumulative GHG emissions due to combustion of fossil fuel	• Module E-FFC-WR, provides guidance for fossil fuel emissions estimates.

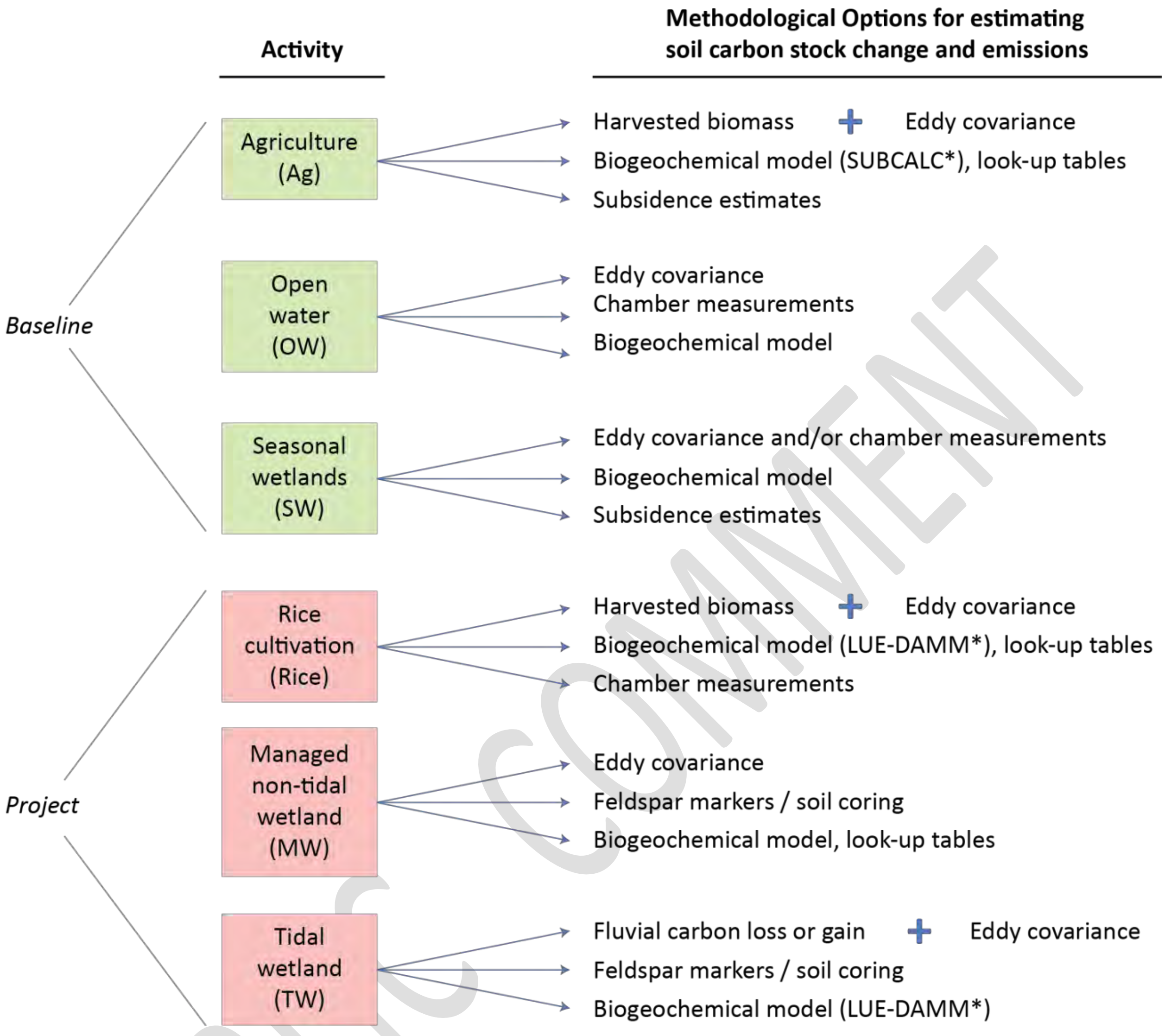

Figure 1. Relation of project and baseline activities to methods for determination of GHG emissions and soil carbon stock changes.

*** LUE-DAMM and SUBCALC models are described in the MODEL Module.**

This module also provides guidance for determination of the following parameters, which are inputs for biogeochemical models for project conditions. These parameters can be estimated using appropriate measurements documented in the peer-reviewed literature or estimates from proxy systems. If proxy measurements are used, documentation of sufficiently similar climate, soil chemical, hydrologic conditions, and vegetation conditions are required.

Table 2. Parameters used in biogeochemical models, description and estimation methods.

Parameter	SI Unit	Description	Estimation methods
$\Delta C_{ag\ biomass\ P}$	Metric tons CO_2-e (t CO_2-e)	Cumulative above-ground non-woody biomass carbon stock changes for project	Allometric equations, leaf area index, digital photography, destructive methods
$\Delta C_{bg\ biomass\ P}$	Metric tons CO_2-e (t CO_2-e)	Cumulative below-ground biomass carbon stock changes for project	Multiplication of accumulated above-ground biomass times published root:shoot ratio, destructive methods
$\Delta C_{litter\ P}$	Metric tons CO_2-e (t CO_2-e)	Litter carbon stock changes	Direct measurements using decomposition bags or indirect estimates from isotopic technique and/or modeled estimates based on environmental controls
$\Delta C_{cr\ BSL}$	Metric tons CO_2-e (t CO_2-e)	Crop residue remaining in field for baseline conditions	Destructive methods for harvest and determination of carbon content of biomass.

Methods

Figure 3 and Table 14 show the appropriate methods for both the project and baseline activities. The 'appropriate methods' listed can be used alone or in tandem with the other methods listed. The selection of methods depends on project and baseline conditions, data availability, and the requisite level of certainty.

Each method listed below is discussed with an introduction, method-specific applicability conditions, quality control and assurance procedures, and method-specific equations:

- Eddy covariance
- Chamber measurements
- Harvested grain and biomass
- Aqueous Carbon Loads
- Subsidence measurements
- Soil coring

Additionally, methods used for inputs to biogeochemical models are outlined below.

Eddy Covariance

Introduction

The eddy covariance (EC) technique[1] estimates fluxes of GHGs by relying on the concurrent determination and statistical analysis of vertical atmospheric velocity and the atmospheric concentration of the GHG (e.g. CO_2, CH_4, N_2O) of interest. These two values (GHG concentration and vertical atmospheric velocity) are multiplied to obtain a flux. Carbon dioxide and methane (CH_4) can be measured at the field scales of tens of acres using this method. The eddy covariance method is capable of measuring gaseous fluxes directly and for extended periods of time in a quasi-continuous manner. This approach is allowed for estimating carbon stock changes and emissions for baseline and project conditions. Soil carbon stock changes can be quantified by measuring the net ecosystem carbon exchange.

Eddy covariance measurements provide an effective way to determine the net exchange of CO_2 for a variety of ecosystems and have been used to measure baseline[2] and project carbon stock changes on Delta organic and highly organic mineral soils.

For agricultural baseline conditions (e.g. corn) on organic soils, CO_2 assimilation occurs as the result of plant photosynthetic uptake during the growing season and the crop is a net GHG remover during this time. During the non-crop period, oxidation of organic matter results in a net GHG emission. However, CO_2 assimilation into the harvested grain is removed and results in an overall annual GHG emission for the cropped system under drained conditions. In contrast, for a permanently flooded wetland and to a lesser extent, rice, flooding the soil during the warmest time of the year greatly reduces GHG emissions due to oxidation of soil organic matter and there is net CO_2 assimilation into the wetland vegetation resulting in a net GHG removal.

Several researchers have used eddy covariance to measure the carbon budget for agricultural, marsh and forest ecosystems. Hatala et al.[3] determined the rates of carbon stock changes in rice and a pasture on an organic soil in the Sacramento-San Joaquin Delta. Their rates of carbon capture in rice were slightly lower than those from a riparian cottonwood stand about 50 km east of their site where Kochendorfer et al.[4] measured a net carbon removal using eddy covariance. The magnitude of CO_2 uptake at the Hatala et al. rice paddy was well below that from a restored marsh in southern California, where net carbon captured measured with eddy covariance varied between 6.8 and 18.5 tons CO_2 per acre during an eight-year study[5], higher than historical rates of accumulation in disturbed ecosystems of

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[1] Baldocchi DD, Hicks BB, Meyers TP (1988) Measuring biosphere–atmosphere exchanges of biologically related gases with micrometeorological methods. *Ecology* **69**, 1331–1340.

[2] Teh YA, Silver WL, Sonnentag O, Detto M, Kelly M, Baldocchi DD (2011) Large greenhouse gas emissions from a temperate peatland pasture. *Ecosystems* **14**, 311–325.

[3] Hatala JA, Detto M, Sonnentag O, Deverel SJ, Verfaillie J, Baldocchi DD (2012) Greenhouse gas (CO_2, CH_4, H_2O) fluxes from drained and flooded agricultural peatlands in the Sacramento-San Joaquin Delta. *Agriculture, Ecosystems and Environment* **150**,1-18.

[4] Kochendorfer J, Castillo EG, Haas E, Oechel WC, Paw UKT (2011) Net ecosystem exchange, evapotranspiration and canopy conductance in a riparian forest. *Agric.Forest Meteorol*. **151**, 544–553.

[5] Rocha AV, Goulden ML (2008) Large interannual CO_2 and energy exchange variability in a freshwater marsh under consistent environmental conditions. *J. Geophys. Res. Biogeosci*. **113**, G03026

the same region[6] . Hollinger at al.[7] used continuous eddy-covariance carbon flux measurements from 1997 to 2002 to evaluate the carbon budget for a maize and soybean rotation agricultural ecosystem. Their results indicated and net carbon sequestration of 7 and 0.5 metric tons CO_2 per acre per year for maize and soybean on mineral soils, respectively. However, these authors did not account for N_2O emissions.

Applicability Conditions

The following applicability conditions apply to the use of eddy covariance.

1. Stratification and eddy covariance footprint. The area of land that is included in the footprint of the eddy covariance measurement shall be quantified during the monitoring period and shall be shown to adequately represent the hydrologic, water quality and soil conditions and management practices for the stratum. For example, for baseline conditions, the agricultural crop and water- and land-management practices within the eddy covariance footprint shall be the same as for the entire stratum. Also, for baseline conditions, the average soil organic matter content within the eddy-covariance footprint shall not vary more than 20 % relative to the average soil organic matter content within the stratum.
2. Adjacent land uses. To avoid influences of adjacent land uses, the eddy covariance footprint shall be entirely within the stratum that includes project or baseline land uses.
3. Monitoring period. The monitoring period using eddy covariance techniques shall be sufficient to quantify annual variations in carbon stock changes and to enable the use of biogeochemical models. The Project Proponents shall demonstrate that annual values for carbon stock changes for baseline are representative. At least one year of monitoring is required for baseline conditions. The baseline scenario shall be developed for the entire life of the project using site-specific data and/or data and models documented in the peer-reviewed literature. For project conditions, continuous monitoring is required throughout the life of the project unless the use of biogeochemical models calibrated with the eddy covariance data are shown to adequately predict emissions and carbon stock changes. At this point, eddy covariance measurements can be terminated.

Quality Control and Quality Assurance Procedures

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[6] Canuel EA, Lerberg EJ, Dickhut RM, Kuehl SA, Bianchi TS, Wakeham SG (2009) Changes in sediment and organic carbon accumulation in a highly disturbed ecosystem: the Sacramento-San Joaquin River Delta (California, USA). *Mar. Pollut. Bull*. **59**, 154–163.

[7] Hollinger SE, Bernacchil CJ, Myers TP (2005) Carbon budget of mature no-till ecosystem in North Central Region of the United States, *Agricultural and Forest Meterology*, **130**, 59–69.

Table 3. Quality Control/Assurance for Eddy Covariance Measurements.

Quality Control/Assurance Topic	Considerations	Procedures
Temporal variability and frequency of measurements	GHG and energy fluxes shall be measured at each site with the EC method[8] using parameters determined to be adequate for accurate eddy covariance measurements in peat soils and wetlands. Carbon accumulation rates shall be compared with measurements reported for natural and disturbed ecosystems in the region.	Standard eddy covariance practice as described in the literature cited above shall be employed to measure the covariance between turbulence and C fluxes at 10 Hz intervals (every 0.1 s). These data shall be used to calculate half-hourly fluxes for net ecosystem exchange.
Filtering and removal of spurious data	Eddy covariance data typically contain gaps and artificial spikes.	The sampling rate and averaging interval will allow for a 5 Hz cut-off for the cospectra between turbulence and carbon fluxes. After computing the fluxes, flux values with anomalously high and low friction velocity ($u^* > 1.2$ m s−1 and $\lvert uw \rvert < 0.02$) shall be filtered to constrain the analysis to periods where the air near the sensors was well-mixed. The random instrumental noise in each half-hour fluxes shall be assessed using bootstrapping technique. Fluxes from wind directions outside of the footprint of the target land-use type shall be excluded from the dataset. For baseline and project conditions, missing data shall be treated conservatively so as to not overestimate the GHG benefit. Filtering software may be used to remove artificial spikes, which shall be greater than six standard deviations of the mean, within a one-minute window and diagnostic instrument values that corresponded with bad readings, which are often correlated with rain or fog events. Typically, no less than 10% of the original flux data is excluded through this procedure. The Project Proponents shall justify a conservative application of any larger percentages. The bootstrap technique will

[8] Baldocchi DD, Hicks BB, Meyers TP (1988) Measuring biosphere–atmosphere exchanges of biologically related gases with micrometeorological methods. *Ecology* **69**, 1331–1340.

		evaluate the covariances to calculate the standard deviation of calculated fluxes across the bootstrapped covariances.

Equations

$$\Delta GHG = T_p * [\sum_{i=1}^{n} (E_{CO_2,i} + E_{CH_4,i} + E_{N_2O,i}) + \sum_{i=1}^{n} Cgr_i + E_{aq,}] \qquad (13)$$

where:

ΔGHG is the cumulative net emissions of CO_2 and CH_4 during the reporting period (t CO_2-e);

$E_{CO_2,i}$ is the annual net emission of CO_2 (t CO_2-e yr^{-1});

$E_{CH_4,i}$ is the annual net emission of CH_4 (t CO_2-e yr^{-1});

$E_{N_2O,i}$ is the annual net emission of N_2O (t CO_2-e.yr^{-1}) ;

i is the stratum within the project boundary;

n is the number of strata within the project boundary;

E_{aq} is the annual net aqueous loss of carbon in drainage water (t CO_2-e yr^{-1});

T_p is the period of time which corresponds to the project reporting period in (yr.); and

Cgr_i is the carbon removal in harvested biomass in stratum i (t CO_2-e yr^{-1}).

The net aqueous loss of dissolved and particulate organic carbon can be calculated by subtracting the aqueous carbon input from the aqueous carbon export. Specifically,

$$E_{aq} = \left(Q_{export} \times [TOC] - Q_{import} \times [TOC]\right) \qquad (14)$$

Because eddy covariance measures the net ecosystem exchange,

$$\Delta GHG = \Delta C \qquad (15)$$

Where ΔC is the cumulative carbon stock change.

Chamber Measurements

Introduction

For project and baseline conditions, gaseous fluxes of CO_2, CH_4 and N_2O from wetland surfaces and open water for project or for baseline conditions can be measured using the static chamber method[9 10]. Measurements should ensure that temporal variations are accounted for, or be measured during the time of greatest anticipated flux in order to conservatively estimate net GHG emission reductions/removal enhancements. For agricultural baseline conditions, the chamber methods described in Livingston and Hutchinson[11], Mosier[12] and Rolston[13] are applicable. Chambers described in Lindau are appropriate for project conditions.[14,15,16,17]

Temperature inside the chamber shall be monitored. Gas must be mixed so that a concentration gradient does not occur. Mixing is normally accomplished by diffusion in small chambers, but a small fan may be required to ensure mixing in larger chambers. Gas samples are taken with plastic syringe and stainless steel hypodermic needles. Samples shall be collected at minimum at least three times to allow to allow a linear buildup of the concentration of the gas being measured) after chamber top placement. The overpressure created will ensure that atmospheric gases will not contaminate the sample gases. Silicone sealant is used to seal the injection hole in the rubber septum. The CH_4, CO_2, or N_2O concentrations of the gas samples can be measured on a gas chromatograph (GC). The flux of gases from the soil or wetland surface is calculated from the data obtained from the GC and can be then estimated using the equation:

$$f(gas) = \frac{V\Delta C}{A\Delta t} \qquad (16)$$

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[9] Livingston, G.P. and G.L. Hutchinson, 1995. Enclosure-based Measurement of Trace Gas Exchange: Application and Sources of Error. P. 14-51 In: P.A. Matson and R.C. Harris (eds.) Biogenic Trace Gases: Measuring Emissions from Soil and Water. Blackwell Science Ltd., London.

[10] Klinger, L.F., Zimmerman, P.R., Greenberg, J.P., Heidt, L.E., and Guenther, A.B., 1994. Carbon Trace Gas Fluxes Along a Successional Gradient in the Hudson Bay Lowland. J. Geophys. Res. 99 (D1):1469–1494.

[11] Livingston, G.P. and G.L. Hutchinson, 1995. Enclosure-based Measurement of Trace Gas Exchange: Application and Sources of Error. P. 14-51 In: P.A. Matson and R.C. Harris (eds.) Biogenic Trace Gases: Measuring Emissions from Soil and Water. Blackwell Science Ltd., London.

[12] Hutchinson, G. L., and A. R. Mosier, Improved soil cover method for field measurement of nitrous oxide fluxes, *Soil Sci. Soc. Am. J.*, *45*, 311–316, 1981.

[13] Rolston, D. E., Gas flux, in *Methods of Soil Analysis*, *Part 1*, *Agron.Monogr*., vol. 9, edited by A. Klute, pp. 1103–1119, Am. Soc. of Agron. and Soil Sci. Soc. of Am., Madison, Wis., 1986.

[14] Lindau, C.W., and R.D. DeLaune. 1991. Dinitrogen and nitrous oxide emission and entrapment in *Spartina alterniflora* saltmarsh soils following addition of N-15 labelled ammonium and nitrate. Estuarine Coastal Shelf Sci. 32:161–173. doi:10.1016/0272-7714(91)90012-Z.

[15] Miller, R.L., Hastings, L., Fujii, R., 2000. Hydrologic treatments affect gaseous carbon loss from organic soils, Twitchell Island, California, October 1995-December 1997. U.S. Dept. of the Interior, U.S. Geological Survey, Sacramento, Calif.

[16] Majumdar, D., 2013. Biogeochemistry of N_2O Uptake and Consumption in Submerged Soils and Rice Fields and Implications in Climate Change. Critical Reviews in Environmental Science and Technology 43, 2653-2684.

[17] Linquist, B.A., Adviento-Borbe, M.A., Pittelkow, C.M., van Kessel, C., van Groenigen, K.J., 2012b. Fertilizer management practices and greenhouse gas emissions from rice systems: A quantitative review and analysis. Field Crops Research 135, 10-21.

where:

f	is the GHG gas flux (g gas m^{-2} s^{-1});
V	is the volume of chamber headspace (m^3 gas volume);
A	is the soil surface area (m^2); and
$\Delta C/\Delta t$	is the change in gas concentration (g m^{-3} s^{-1}).

Locations of measurements shall be determined by known spatial variability and the required level of certainty. Chamber measurements shall account for heterogeneous landscapes within strata as described in Baseline and Project Modules. If present, baseline chamber measurements shall be conducted within upland and lowland areas, and drainage ditches[18]. Spatially weighted up-scaling methods are recommended for estimating annual GHG budgets across heterogeneous landscapes. Flux measurements shall be taken multiple times during the year for estimating seasonal or annual flux and temporal and spatial replication is important to reduce uncertainty.

Special care must be taken when estimating N_2O emissions using chambers. Fertilization and re-wetting events are especially important for N_2O budgets, where a single pulse event can account for >50% of the annual N_2O budget[19]. Therefore, in order to accurately estimate N_2O emissions using manual chambers, deployment must include fertilization, irrigation and precipitation events. These pulse events can encompass several days (1-30 days) and therefore must be evaluated at an appropriate time scale. Estimations of annual N_2O budgets from chamber measurements must account for the amount and frequency of fertilization, irrigation, and precipitation events in addition to lower-level N_2O emission rates that occur outside pulse events.

Applicability Conditions

The following applicability conditions apply to the use of chambers.

1. Stratification. The distribution of chamber measurement shall be shown to adequately represent the hydrologic, water quality and soil conditions and land- and water-management practices for the stratum.
2. Monitoring period. The monitoring period using chamber measurements shall be sufficient to quantify possible annual variations in emissions. The Project Proponents shall demonstrate that annual values for emissions for baseline are representative. At least one year of monitoring is required for baseline conditions. For project conditions, monitoring is required throughout the life of the project unless the use of biogeochemical models calibrated with site data are shown to adequately predict emissions. At this point, chamber measurements may be terminated.
3. When measuring N_2O emissions using chambers, deployment must include fertilization,

[18] Teh, Y.A., Silver, W.L., Sonnentag, O., Detto, M., Kelly, M., Baldocchi, D.D., 2011. Large greenhouse gas emissions from a temperate peatland pasture. Ecosystems 14, 311–325. These authors demonstrated that drainage ditches can account for <5% of the land area and contribute more than 84% of CH_4 emissions and 37% of ecosystem GWP in a Delta peat-land pasture.

[19] Wagner-Riddle C, Thurtell G, Kidd G, Beauchamp E, Sweetman R (1997) Estimates of nitrous oxide emissions from agricultural fields over 28 months. *Canadian Journal of Soil Science,* **77**, 135-144.

irrigation and precipitation events.

4. Monitoring must occur for baseline establishment and renewal. For project conditions, the monitoring frequency shall occur at least every 5 years for one year. Baseline field monitoring should be conducted seasonally for one year to determine the seasonal effects on greenhouse gas fluxes, or measurements can be made during the period of peak emissions (e.g., summer or fertilization events). Livingston and Hutchinson[20] and Crill et al.[21] provide guidance for minimizing measurement and flux estimation error in chamber measurements. Also, it is important to account for microsites and spatial variability as discussed above.

Quality Control and Quality Assurance Procedures

Quality assurance and control measures for chamber measurements are listed and discussed in Table 17.

[20] Livingston, G.P. and G.L. Hutchinson, 1995. Enclosure-based Measurement of Trace Gas Exchange: Application and Sources of Error. P. 14-51 In: P.A. Matson and R.C. Harris (eds.) Biogenic Trace Gases: Measuring Emissions from Soil and Water. Blackwell Science Ltd., London.

[21] Crill, P.M., Butler, J.H., Cooper, D.J., and Novelli, P.C., 1995, Standard analytical methods for measuring trace gases in the environment In: P.A. Matson and R.C. Harris (eds.) Biogenic Trace Gases: Measuring Emissions from Soil and Water. Blackwell Science Ltd., London.

Table 4. Quality Control/Assurance for Chamber Measurements

Quality Control/Assurance Topic	Considerations	Precautions and safeguards	Reference footnote
Temperature	Ambient temperature should be preserved within the chamber. Solar heating of the enclosure surface can rapidly lead to increasing chamber temperatures	Minimize deployment times, use shading of opaque materials, monitor chamber temperature	69
Deployment - development of a disturbance free seal	Leakage can occur in unsaturated-zone soils especially during high winds.	Use weighted skirts around chambers and /or baffled, double-walled enclosures. Avoid high winds. Estimate leakage with a tracer gas	69, 70
Deployment – surface compaction	Artificial gradients and mass inflow can be induced by surface compaction from foot traffic. Water-saturated soils are particularly susceptible.	Use of designated walkways, remote gas withdrawal from chambers.	69
Deployment – vegetative disturbance	Disturbance of vegetation can affect exchange processes under study and influence plant mediated gas transport	Avoid cutting roots or severing stems and leaves	69
Field sample handling and processing	Sample container leakage and accuracy	Analyze gas samples within a few hours, analyze standards frequently	69
Laboratory analysis	Potential for analytical error	Follow acceptable analytical protocol for trace gas analysis	69
Flux estimation	Time for concentration change measurements, chamber dimensions	Minimize sources of variability in sampling handling and analysis using maximum possible measurement period and number of independent samples. Two samples are insufficient. Determine chamber volume precisely.	69
Spatial variability and stratification	Previous measurements in Delta rangelands have	Locations of measurements shall be	

	demonstrated substantial spatial variability.	determined by known spatial variability and the required level of certainty. Chamber measurements must account for heterogeneous landscapes. Spatially-weighted up-scaling methods are recommended for estimating annual GHG budgets across heterogeneous landscapes	

Equations

Cumulative GHG emissions for baseline (ΔGHG_{BSL})

Where chambers are used to estimate cumulative GHG emissions shall be estimated using the following equation.

$$\Delta GHG_{BSL} = \left(\frac{1}{n}\sum_{t=1}^{n} fGHG_{BSL,t}\right) \times T_{pp} \times CF \qquad (17)$$

where:

ΔGHG_{BSL} is the cumulative net GHG emissions for the baseline scenario (t CO_2-e);

$fGHG_{P,t}$ is the rate of GHG emissions from the project area at monitoring event t prior to project activity (t CO_2-e per unit of time);

T_{pp} is the period of time which corresponds to the pre-project reporting period (yr.);

n is the number of baseline monitoring events;

t is the monitoring event; and

CF is the factor for converting from the measurement time scale to the time scale of T_{pp}.

The flux of greenhouse gases from the project area under baseline conditions at time t is:

$$fGHG_{BSL,t} = \sum_{i=1}^{n} fGHG_{CH_4\_BSL,i,t} \cdot GWP_{CH_4} + \sum_{i=1}^{n} fGHG_{N_2O\_BSL,i,t} \cdot GWP_{N_2O} \qquad (18)$$ [22]

where:

$fGHG_{BSL,t}$ is the rate of GHG emissions from the project area at monitoring event t prior to project activity, measured using chambers (t CO_2-e per unit of time);

$fGHG_{CH_4\_BSL,i,t}$ is the rate of CH_4 emissions from the project area in stratum i at monitoring event t (t CO_2-e per unit of time);

GWP_{CH_4} is the global warming potential for CH_4 (per most recent version of the ACR Standard) (t CO_2-e);

$fGHG_{N_2O\_BSL,i,t}$ is the rate of N_2O emissions from the project area in stratum i at monitoring event t (t CO_2-e per unit of time);

GWP_{N_2O} is the global warming potential for N_2O (per most recent version of ACR Standard) (t CO2-e);

n is the number of strata within the project boundary;

i is the stratum within the project boundary; and

t is the monitoring event.

Cumulative GHG emissions for the project scenario ($\Delta \boldsymbol{GHG_p}$)

Where chambers are used, total project GHG emissions should be extrapolated from average instantaneous measurements using the following equation:

$$\Delta GHG_P = \left(\frac{1}{n}\sum_{t=1}^{n} fGHG_{P,t}\right) \times T_p \times CF \qquad (19)$$

where:

ΔGHG_P is the cumulative total of GHG emissions as a result of implementation of the project activity (t CO_2-e);

[22] CO_2 emissions due to organic matter oxidation cannot easily measured straightforwardly using chambers.

$fGHG_{P,t}$ is the rate of GHG emissions from the project area at monitoring event t, measured using chambers (t CO_2-e per unit of time);

n is the number of monitoring events;

t is the monitoring event;

CF is the factor for converting from the measurement time scale to the time scale of T_p); and

T_p is the period of time which corresponds to the project reporting period (yr.).

The flux of greenhouse gases from the project area under the project scenario at time t is:

$$fGHG_{P,t} = \sum_{i=1}^{n} fGHG_{CH_4\_i,t} \cdot GWP_{CH_4} + \sum_{i=1}^{n} fGHG_{N_2O\_i,t} \cdot GWP_{N_2O} + \sum_{i=1}^{n} fGHG_{CO_2\_i,t} \quad (20)$$

where:

$fGHG_{P,t}$ is the rate of GHG emissions from the project area at monitoring event t, measured using chambers (t CO_2-e per unit of time);

$fGHG_{CH_4\_i,t}$ is the rate of CH_4 emissions from the project area in stratum i at monitoring event t (t CO_2-e per unit of time);

GWP_{CH_4} is the global warming potential for CH_4 (per most recent version ACR Standard) (t CO_2-e);

$fGHG_{N_2O\_i,t}$ is the rate of N_2O emissions from the project area in stratum i at monitoring event t (t CO_2-e per unit of time);

GWP_{N_2O} is the global warming potential for N_2O (most recent version of ACR Standard) (t CO_2-e);

$fGHG_{CO_2\_i,t}$ is the rate of project CO_2 emissions from the project area in stratum i at monitoring event t (t CO_2-e per unit of time);

n is the number of strata within the project boundary;

i is the stratum within the project boundary; and

t is the monitoring event.

Harvested Grain and Biomass

Introduction

The carbon in harvested grain and biomass represents an essential part of the net ecosystem exchange for baseline agricultural and rice project conditions when determined by eddy covariance (Equation 13). Harvested grain or biomass is determined by 1) collection of grain or biomass in representative plots within the stratum and 2) determination of the carbon and moisture content on the collected material using literature and laboratory analysis of the material and 3) estimation of total carbon removed in grain and/or biomass for the stratum. Alternatively, the Project Proponent may obtain information from the farmer about the weight of the harvested grain and/or biomass and use literature values and laboratory-determined values for the carbon and moisture content of the harvested grain and/or biomass to estimate Cgr_i, the carbon dioxide harvested or removed grain or biomass for the crop in stratum i (t CO_2-e) (Equation 21). The moisture content of the harvested material shall be determined at harvest. Methods described in Karlra[23] and McGeehan and Naylor[24] are applicable for determination of moisture content and carbon content.

Applicability Conditions

1. Stratification. The distribution of determination of Cgr_i shall be shown to adequately represent the hydrologic, water quality and soil conditions and land- and water-management practices for the stratum.
2. Monitoring. Annual estimates of Cgr_i are sufficient. For multiple harvests (such as for hay or grain crops), the annual estimate shall equal the sum of all harvests.
3. Monitoring must occur for baseline establishment and renewal. For project conditions, the monitoring frequency shall occur at least every 5 years over a period of one year.
4. The Project Proponent shall demonstrate using maps and photographs that yield plots are representative of the entire stratum.

Quality Control and Assurance Procedures

1. Where yield plots are used, plots shall be replicated three times within each stratum and the entire plot shall be harvested.
2. The average yield and standard deviation from the three replicate plots shall be used in uncertainty calculations in the uncertainty module (X-UNC).

Equations

For agricultural baseline conditions and rice project conditions, carbon removal in harvested biomass shall be estimated using the following equation[25]:

[23] Karlra, Yash P. (ed.), 1998, Handbook of Reference Methods for Plant Analysis, CRC Press.
[24] McGeehan, S.L. and D.V. Naylor. 1988. Automated instrumental analysis of carbon and nitrogen in plant and soil samples. *Commun. Soil Sci. Plant Anal.* 19:493-505.
[25] E.g. Steven E. Hollinger, Carl J. Bernacchi, Tilden P. Meyers, 2005, Carbon budget of mature no-till ecosystem in North Central Region of the United States, Agricultural and Forest Meteorology 130 (2005) 59–69..

$$C_{gr} = W \times fC \times Y \qquad (21)$$

where:

C_{gr} is the carbon removal in harvested biomass (t CO_2-e per unit area);

W is the moisture content expressed as a fraction;

fC is the fraction of carbon in the grain or biomass[26]; and

Y is the yield (t per unit area).

The use of Equations 13 and 21 assumes that 100% of the harvested biomass is eventually consumed and oxidized to CO_2 and CH_4 which is released back into the atmosphere.

Aqueous Carbon Loads

Introduction

For baseline and project conditions, aqueous carbon loads ($E_{aq,}$) represent part of the overall carbon budget as determined by eddy covariance (Equation 13). Aqueous carbon can enter and exit the project area to and from adjacent channels as dissolved and particulate organic carbon. The total organic carbon (TOC) concentration is equal to the sum of particulate and dissolved organic carbon. Loads are equal to the water flow times the concentration of total organic carbon in the water. The project Proponent shall utilize methods published in the peer-reviewed literature for determining concentrations, flow and loads in tidal[27] [28] and non-tidal[29] systems. For flow measurements, methods include manual flow and acoustic velocity meters. Methods for total dissolved organic carbon determination in drain-water samples are described in Deverel et al.[30]

Specifically, for non-tidal managed wetlands, subsurface and surface drainage flow shall be measured and calculated continuously using traditional flow measurements using manually operated flow meters and tracking stage at a control device such as a weir with a water level recorder. Dissolved and particulate organic carbon concentrations shall be determined at intervals that adequately represent the temporal variability but not less than bimonthly. Alternatively, flow can be measured using

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[26] Loomis, R.S., Conner, D.J., 1992. Crop Ecology: Productivity and Management in Agricultural Systems. Cambridge Univ. Press, New York, NY, 538 pp.

[27] Ganju NK, Schoellhamer DH, Bergamaschi ABA (2005) Suspended Sediment Fluxes in a Tidal Wetland: Measurement, Controlling Factors, and Error *Analysis Estuaries* **28**(6), 812–822.

[28] Bergamaschi BA, Fleck JA, Downing BD, Boss E, Pellerin B, Ganju NK, Schoellhamer DH, Byington AA, Heim WA, Stephenson M, and Fujii R, (2011) Methyl mercury dynamics in a tidal wetland quantified using in situ optical measurements*, Limnol. Oceanogr*., **56**(4), 2011, 1355–1371.

[29] E.g. Deverel, Steven J., David A. Leighton and Mark R. Finlay. Processes Affecting Agricultural Drainwater Quality and Organic Carbon Loads in California's Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science. Vol. 5, Issue 2 [May 2007]. Article 2. http://repositories.cdlib.org/jmie/sfews/vol5iss2/art2.

[30] Deverel, Steven J., David A. Leighton and Mark R. Finlay. Processes Affecting Agricultural Drainwater Quality and Organic Carbon Loads in California's Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science. Vol. 5, Issue 2 [May 2007]. Article 2. http://repositories.cdlib.org/jmie/sfews/vol5iss2/art2.

continuous recording acoustic Doppler technology. For tidal systems, a similar approach can be used except that flow is bidirectional depending on tidal influences.

Applicability Conditions

1. Stratification. The determination of $E_{aq,}$ shall be shown to adequately represent the hydrologic, water quality and soil conditions and land- and water-management practices for the stratum.
2. Monitoring. Measurements shall adequately represent the temporal variability in concentrations and loads.
3. For non-tidal systems, the temporal variability is determined by hydrologic management and season variability. Monthly measurements are generally sufficient to characterize the temporal variability.
4. Tidal fluxes of dissolved and particulate organic carbon shall be estimated or measured at a time scale that allow determination of the net annual loss or gain of organic carbon to or from the wetland.

Quality Assurance

The uncertainty in manual flow measurements shall be determined as per guidance in Sauer and Meyer[31] and incorporated in into the uncertainty equations in the uncertainty module (X-UNC). Uncertainty in acoustic velocity measurements shall be evaluated using information described in Laenen and Curtis[32]. Analytical uncertainty for dissolved organic carbon shall be determined using field duplicate and blank samples and laboratory QA/QC samples and shall be incorporated into the flow measurement uncertainty.

Equations

See Equation 14.

Subsidence Measurements

Introduction

Subsidence is caused by the oxidation of organic soils[33]. As organic soils are drained for agricultural use and exposed to oxygen, they oxidize and disappear. Subsidence is estimated as the difference between elevations at two points in time. For the baseline scenario, subsidence measurements can be converted to carbon stock changes using methods described in Couwenberg and Hooijer[34] and here. Couwenberg and Hooijer described a simple approach to determining total net carbon loss from subsidence records.

[31] Sauer, V.B. and R.W. Meyer. 1992. Determination of error in individual discharge measurements. Open-File Report 92-144. U.S. Geological Survey.

[32] Laenan, Antoniua and Curtis, R.E., Accuracy of acoustic velocity metering systems for measurements of low velocity in open channels, US Geological Survey Water Resources Investigation Report 89-4090.

[33] Deverel S.J. and Leighton D.A., 2010, Historic, Recent, and Future Subsidence, Sacramento-San Joaquin Delta, California, USA. San Francisco Estuary and Watershed Science 8(2). http://www.escholarship.org/uc/item/7xd4x0xw.

[34] Couwenberg J, Hooijer A (2013) Towards robust subsidence-based soil carbon emission factors for peat soils in south-east Asia, with special reference to oil palm plantations, *Mires and Peat*, **12**, 1–13.

If subsidence measurements are used, it is assumed that the soil carbon pool is decreasing via oxidation, and emissions are accounted for by ΔGHG using equation shown below. Where there are elevation measurements in organic or highly organic mineral soils, at two or more points in time, the difference in elevation and soil carbon density can be used to estimate historic baseline emissions by multiplying the elevation change by the soil carbon density. Soil carbon density is equal to the soil carbon content multiplied by the soil bulk density. Data for soil organic matter content for Delta and San Francisco Estuary soils is described in Callaway et al.[35] Deverel and Leighton[36] and Drexler et al.[37]. Soil carbon content is equal to 50% of the soil organic matter content. Drexler et al. provided data for soil bulk density for eight Delta islands.

Applicability Conditions

1. Locations of measurements shall be determined by strata, known spatial variability and the required level of certainty as per guidance in the T-PLOT module. The determination of ΔGHG_{BSL} (Equation 22) shall be shown to adequately represent the hydrologic, water quality and soil conditions and land- and water-management practices for the stratum.
2. Project Proponents shall be conservative in estimating the depth of subsidence from elevation measurement differences by calculating the minimum possible difference between elevations measured at two points in time.
3. All elevation measurements for subsidence calculations shall be referenced to stable benchmarks.
4. Project Proponents shall insure and document the consistent use of vertical datums for elevations measured during different years.
5. Project Proponents shall use conservative values for soil organic carbon and bulk density values that result in conservative estimates for subsidence.

Quality Control and Quality Assurance Procedures

Uncertainty in subsidence estimates stem from 1) elevation measurements and 2) soil carbon and bulk density determinations. For elevation measurements, uncertainty is dependent on methods used which shall be documented and incorporated into uncertainty calculations in the uncertainty module (X-UNC). For example, Deverel and Leighton determined elevations at locations on Bacon Island in 2006 where elevations were measured by University of California researchers in 1978. The vertical closure error for the 1978 survey with traditional surveying equipment was 0.07 m. For the 2006 survey which utilized real time kinematic, static and fast-static Global Positioning System measurements vertical closure error was 0.002 m. Therefore, the conservatively estimated subsidence at any point along the survey route followed in 1978 and 2006 is equal to the elevation determined in 1978 minus the closure error minus

[35] Callaway, John C., Borgnis, Evyan L. Turner, R. Eugene & Milan, Charles S., 2012, Carbon Sequestration and Sediment Accretion in San Francisco Bay Tidal Wetlands, Estuaries and Coasts, (2012) 35:1163–1181.
[36] Deverel S.J. and Leighton D.A., 2010, Historic, Recent, and Future Subsidence, Sacramento-San Joaquin Delta, California, USA. San Francisco Estuary and Watershed Science 8(2). http://www.escholarship.org/uc/item/7xd4x0xw.
[37] Drexler JZ, de Fontaine CS, Deverel SJ. 2009. The legacy of wetland drainage on the remaining peat in the Sacramento–San Joaquin Delta, California, USA.Wetlands 29:372–386.

the 2006 elevation plus the closure error. Table 18 shows an example calculation. Elevation errors in topographic-map elevations range from about 0.3 to 1 m.

Table 5. Example subsidence calculation for point 44027 on Figure 2 in Deverel and Leighton.

Year	Elevation (m)	Closure Error (m)	Depth of Subsidence (m)
1978	-3.98	0.07	
2006	-5.26	0.002	1.21 ((-3.98 – 0.07)-(-5.26+0.002)

Data presented in Drexler et al.[38] provide ranges of estimates for organic matter content and bulk density for eight Delta islands.

Equations

If measured by determining the depth of subsidence over a known period of time, ΔGHG_{BSL} represents the cumulative net emissions (t CO_2-e) due to the oxidation of organic soils as estimated by the depth of subsidence using the following equation

$$\Delta GHG_{BSL} = \frac{44}{12} \times \sum_{i=1}^{n} (S_i \times BD_i \times fC_i \times A_i) \qquad (22)$$

where:

S is the depth of land subsidence (m);

BD is the dry bulk density of the peat (t m^{-3});

fC is the fraction of carbon in the peat on a dry weight basis;

$\frac{44}{12}$ is the ratio of molecular weights of CO_2 to carbon (dimensionless);

A is the area of the stratum (m^2);

i refers to the stratum within the project boundary; and

n is the number of strata within the project boundary.

Because the subsidence estimate represents the GHG emission due to organic carbon loss

$$\Delta GHG_{BSL} = \Delta C_{BSL} \qquad (23)$$

[38] Drexler JZ, de Fontaine CS, Deverel SJ. 2009. The legacy of wetland drainage on the remaining peat in the Sacramento–San Joaquin Delta, California, USA.Wetlands 29:372–386.

Soil Coring

Introduction

Carbon stock changes in the soil carbon pool in managed non-tidal wetlands and tidal wetlands can be measured in soil cores by determining the carbon accumulated above feldspar markers or sediment pins pounded into the ground to refusal[39] placed at the start of project activities. The material located above the feldspar marker or sediment pin/sediment interface shall be analyzed for total carbon or organic matter content and bulk density. Any compaction that occurs should be measured and accounted for. The change in carbon stocks in soil cores shall be determined by quantifying the carbon density above a marker horizon defined by a feldspar marker.

Feldspar markers should be placed at the start of the project activity. Feldspar marker horizons are prepared by spreading a thin aqueous slurry (~1 cm) layer of feldspar clay on the wetland[40] surface. Soil carbon content can be determined using elemental analysis using a CHN analyzer[41] or estimated from the loss-on-ignition method[42] (LOI). Results throughout the Sacramento-San Joaquin Delta and San Francisco Estuary[43] [44] [45] demonstrate a statistically significant relation between soil carbon content and LOI. These regression relations yield similar results for determination of soil organic carbon from LOI and can be used to calculate the carbon content of the harvested cores on a mass carbon per mass of soil basis. Alternatively, a relationship can be established between loss on ignition of organic matter and organic carbon content by determining both and conducting simple regression analysis. Then the organic carbon content can be estimated using the cheaper/simpler analysis of LOI.
To estimate carbon density in mass per unit volume, multiply the carbon content times the bulk density. The bulk density shall be determined using methods reported in Calloway et al.[46] and Blake and Hartge[47].

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[39] US Geological Survey. 2012. Sediment pin standard operating procedures. Unpublished protocols. USGS, Western Ecological Research Center, San Francisco Bay Estuary Field Station, Vallejo, CA. http://www.tidalmarshmonitoring.org/pdf/USGS-WERC-Sediment-Pin-SOP.pdf

[40] Cahoon, D. R. and R. E. Turner, 1989. Accretion and Canal Impacts in a Rapidly Subsiding Wetland. Feldspar marker horizon technique. Estuaries 12: 260-268.

[41] Nelson, D.W. and Sommers, L.E., 1982, Total carbon, organic carbon, and organic matter *in (*Page, A.L., ed.) Methods of Soil Analysis, American Society of Agronomy, Madison, WI.

[42] Ball,D.F. 1964. Loss-on-ignition as an estimate of organic matter and organic carbon in non-calcareous soils. Journal of Soil Science 15: 84–92. Craft, C.B., E.D. Seneca, and S.W. Broome. 1991. Loss on ignition and Kjeldahl digestion for estimating organic carbon and total nitrogen in estuarine marsh soils: calibration with dry combustion. Estuaries 14: 175–179.

[43] Drexler JZ, de Fontaine CS, Deverel SJ. 2009a. The legacy of wetland drainage on the peat resource in the Sacramento-San Joaquin Delta, California, USA. Wetlands 29:372–386.

[44] Callaway, J.C., Borgin, E.L., Turner, R. Eugene, Milan, Charles Sl, 2012, Carbon Sequestration and Sediment Accretion in San Francisco Bay Tidal Wetlands, Estuaries and Coasts (2012) 35:1163–1181.

[45] Craft, C.B., E.D. Seneca, and S.W. Broome. 1991. Loss on ignition and Kjeldahl digestion for estimating organic carbon and total nitrogen in estuarine marsh soils: calibration with dry combustion. Estuaries 14: 175–179.

[46] John C. Callaway & Evyan L. Borgnis, R. Eugene Turner & Charles S. Milan, 2012, Carbon Sequestration and Sediment Accretion in San Francisco Bay Tidal Wetlands, Estuaries and Coasts (2012) 35:1163–1181.

[47] Blake, G.R. and Hartge, K.H., 1986, Bulk density in Klute, Arnold (ed). Methods of Soil Analysis, Physical and Mineralogical Methods, American Society of Agronomy, Madison, WI.

Specific steps for core collection:

Step 1. Collect soil core samples and measure the depth of the feldspar marker or measure the sediment accumulated at the sediment pin and collect a soil core sample to the depth of accumulated sediment. See quality assurance section below for discussion of compaction and compaction avoidance.

Step 2. Aggregate samples from plots as per guidance provided in the uncertainty module for estimating the number of samples and uncertainty.

Step 3. For bulk density analysis, a single core shall be collected next to the core collected for determination of soil carbon content. Bulk density shall be determined as per methodology described in Blake and Hartge. Soil samples need to be thoroughly dried until their weight no longer changes and then the weight of each section needs to be divided by the volume.

Step 4. The mass of carbon per unit volume is calculated by determining the product of the carbon concentration and bulk density (g/cm^3).

Applicability Conditions

Locations of measurements shall be determined by strata, known spatial variability and the required level of certainty as outlined in the T-PLOT module. The determination of ΔC_p (Equation 24) shall be shown to adequately represent the hydrologic, water quality and soil conditions and land- and water-management practices for the stratum.

Quality Control and Quality Assurance Procedures

The primary quality control/quality considerations are related to 1) accurate depth of the core and 2) spatial variability in determinations of ΔC_p. Compaction during core collection is estimated by measuring the difference in elevation inside and outside of the coring tube to the nearest millimeter. Example coring devices include McAuley[48], Livingstone[49] or Hargis[50] coring devices that allow cores to be taken with minimal or no compaction. Strata and known spatial variability shall determine the number of samples and the required level of certainty as described in the T-PLOT tool.

If inorganic carbon is present in soil samples, there may be interference in the determination of soil organic carbon. Total inorganic carbon can be determined and subtracted from the organic carbon determination.

Equations

Where soil coring is used to estimate cumulative carbon stock changes in t CO_2-e,

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[48] Bricker-Urso S, Nixon SW, Cochran JK, Hirschberg DJ, Hunt C (1989) Accretion Rates and Sediment Accumulation in Rhode Island Salt Marshes. *Estuaries* **12**, 300-317.

[49] Wright Jr HE (1991) Coring tips. Journal of Paleolimnology **6**:37–49.

[50] Hargis TG, Twilley RR (1994) Improved coring device for measuring soil bulk density in a Louisiana deltaic marsh. Journal of Sedimentary Research Section A: *Sedimentary Petrology and Processes* **64**, 681–683.

$$\Delta C_p = (\frac{1}{N} * \sum_{i=1}^{n} (D_i \ * \ CD_i)) \qquad (24)$$

where:

$D_{i,}$ is the depth of the soil accumulated above a feldspar marker;

$CD_{i,}$ is the carbon density of the soil accumulated above a feldspar marker (product of the soil carbon content on a weight basis and soil bulk density);

i is the stratum within the project boundary (1,2,3,…M); and

N is the number of cores collected with stratum i.

In this case, CH_4 emissions are measured using chambers or eddy covariance as described above.

Methods used for inputs to biogeochemical models

The methods described in this section shall be used solely to determine inputs to biogeochemical models. The Project Proponents shall demonstrate that the estimated atmospheric GHG removal by above- and below-ground biomass is not additive to the determination of the overall carbon stock change calculation.

Above- and Below Ground Biomass and Litter Decomposition for Use in Biogeochemical Modeling
Rates of carbon accumulation in above- and below-ground biomass can be measured using direct measurements (allometric determinations and harvesting) and indirect methods, which include use of remote sensing techniques. Litter decomposition can be estimated using traditional litterbags, isotopic analysis and modeling.

Estimating Above- and Below Ground Biomass Using Allometric and Destructive Methods
The mean carbon stock in aboveground and below-ground biomass per unit area is estimated based on field measurements of the wetland plants in fixed area plots using allometric equations and destructive methods such as those described in Miller and Fujii[51] (Table 19). The number and size of plots shall ensure adequate representation of the area being measured by utilizing guidance provided in the module T-PLOTS. The allometric method can be used to estimate aboveground biomass by using equations that express aboveground biomass as a function of plant height and diameter. Miller and Fujii used extensive destructive biomass harvest to determine parameters in allometric equations for the

[51] Miller, Robin L. and Fujii, Roger, 2010, Plant community, primary productivity, and environmental conditions following wetland re-establishment in the Sacramento-San Joaquin Delta, California, Wetlands Ecol Manage (2010) 18:1–16.

predominant species (*Typha and Schoenoplectus spp)* in managed non-tidal wetlands in the Sacramento-San Joaquin Delta. The following table provides the equations from Miller and Fujii.

Table 6. Allometric equations for above ground biomass estimates expressed in grams of biomass per square meter).

Species	SI Unit	Equation
Schoenoplectus acutus	Biomass weight in grams per square meter	$\log_{10} weight = (0.5028 * \ln height) + (0.3471 * \ln diameter) - 1.7654$ $r^2 = 0.924$
Schoenoplectus acutus	Biomass weight in grams per square meter using only height	$\log_{10} weight = (0.7947 * \ln height) - 3.2177$ $r^2 = 0.824$
Typha. Species	Plant biomass weight in grams per square meter	$\log_{10} weight = -2.188 + (0.601 * \ln height) + (0.2128 * \ln diameter) + (0.2721 * \ln leaf\ number) - 0.484$ $r^2 = 0.9$

Miller and Fujii reported root biomass measurements and root:shoot ratios ranging from 0.6 ± 0.2 to 1.7 ± 0.4 for *Schoenoplectus acutus* and 0.7 ± 0.1 to 1.0 ± 0.3 for *Typha sp*. Values varied seasonally and with water depth. Average values for both species were not significantly different; 0.9 ± 0.1 for *Schoenoplectus acutus* and 0.8 ± 0.1 for *Typha sp.* For the purposes of this methodology for constructed wetland activities where these species are present, these values are appropriate for multiplication times the above-ground biomass weight. Destructive methods such as those described in Miller and Fujii can also be used to determine root biomass.

Estimating Above- and Below Ground Biomass Using Remote Sensing Methods

Spectral information from remotely sensed imagery can be used to estimate above-ground biomass. This spectral information can be used to not only estimate above-ground biomass but the fraction of photosynthetically active material driving photosynthesis as well as the timing and duration of the growing season.

Phenocam

Phenocams are digital cameras that are automated to record images of canopy cover throughout the year. These images can then be processed to calculate a greenness index (GI) which can be empirically related to above-ground leaf area index (LAI) based on field measurements where LAI is defined as half the total developed area of green leaves per unit ground surface area. LAI can be directly measured using destructive field sampling or measured using a LAI sensor such as the LAI-2200C Plant Canopy Analyzer (LI-COR, Lincoln, NE, USA)[52]. Measurements must be collected three times per month during the growing season. LAI can be used to estimate gross primary productivity for project conditions (managed and tidal wetlands and rice), which is an input to biogeochemical models.

[52] Sonnentag, O., et al. (2011) Tracking the structural and functional development of a perennial pepperweed (Lepidium latifolium L.) infestation using a multi-year archive of webcam imagery and eddy covariance measurements. Agricultural and Forest Meteorology 151.

Satellite images

Satellite-derived LAI products give information across large spatial scales (e.g. 1km for MODIS) with fairly high temporal resolution (e.g. 8-16 days for MODIS). The drawbacks to this method include poor small-scale resolution associated with high uncertainty at the field scale as well as data gaps associated with cloud cover[53]. Satellite-derived LAI products are therefore ideal for projects encompassing large spatial scales (multiple square kilometers) and may need to be supplemented with direct measurements.

Litter Decomposition

Litter decomposition represents a large term in the global carbon budget, playing a critical role in regulating soil carbon dynamics across multiple scales of space and time[54]. To accurately predict litter carbon stock changes, litter decomposition rates (k) must be measured or estimated for project conditions. Litterbags are the most widely used method for direct k calculations and have been used and replicated around the world for decades[55] and can be used within this methodology. The analysis of natural abundances of ^{13}C isotopes[56] as well as labeling experiments with isotopically enriched litter[57] are also effective ways to estimate litter carbon stock changes over time. Laboratory microcosm studies show large discrepancy in relation to field litterbag and isotopic studies and shall not be used. Modeled decomposition rates on the long-term inter-site decomposition experiment team (LIDET)[58] can be used to provide conservative estimates of decomposition.

Predicting root decomposition at wetland sites is greatly improved by estimating decomposition rates of wetland roots separately from all other litter. The LIDET databases can be used to generate conservative root decomposition estimates. The same methods shall be employed to estimate k values under baseline and project conditions. If models are used, they shall be constrained by main drivers of decomposition, such as geographic factors (latitude and altitude), climatic factors (temperature, precipitation, evapotranspiration) and litter quality (C:N ratios, lignin content) and calibrated using data for the project or demonstrably equivalent conditions.

[53] Garrigues, S., *et al.* (2008) Validation and intercomparison of global Leaf Area Index products derived from remote sensing data. *Journal of Geophysical Research: Biogeosciences* 113, G02028.
[54] Zhang D, Hui D, Luo Y, Zhou G (2008) Rates of litter decomposition in terrestrial ecosystems: global patterns and controlling factors. *Journal of plant ecology*, 2, 85-93.
[55] Olson JS (1963) Energy stores and the balance of producers and decomposers in ecological systems. Ecology 44:322–31.
[56] Silva LCR, Corrêa RS, Doane TA, Pereira EIP, Horwath WR. (2013) Unprecedented carbon accumulation in mined soils: the synergistic effect of resource input and plant species invasion *Ecological Applications* 23 (6), 1345-1356 2013.
[57] Qiao Y, Miao M, Silva LCR, Horwath WR (2014) Understory species regulate litter decomposition and accumulation of C and N in forest soils: A long-term dual-isotope experiment *Forest Ecology and Management.*
[58] Bonan GB, Hartman MD, Parton WJ, Wieder WR (2013) Evaluating litter decomposition in earth system models with long-term litterbag experiments: an example using the Community Land Model version 4 (CLM4). *Glob Chang Biol* **19**(3):957-74.

(Model –W/R) Wetland Restoration and Rice Methodological Module-Biogeochemical Model Module

Scope

This module allows for the *ex-ante* and *ex-post* estimation of greenhouse gas (GHG) removals and emissions reductions for managed wetlands in the project scenario. For project conditions, this module uses a validated process-based biogeochemical model, the Peatland Ecosystem Photosynthesis, Respiration, and Methane Transport model (PEPRMT, pronounced "peppermint"), that can be used for *ex-ante* estimation of CO_2 and CH_4 exchange from wetlands in the Sacramento-San Joaquin Delta. This model has been calibrated and validated using a multi-year data set collected in a 14-acre mature restored wetland on Twitchell Island. Future updates to this model, including calibrations to restored wetlands of different ages (1-17 yr) and a rice paddy, will be made publically available (https://github.com/pattyoikawa/PEPRMT.git).

For baseline conditions, the SUBCALC model (Deverel and Leighton, 2010) may be used to estimate baseline CO_2 emissions. SUBCALC simulates microbial oxidation or agricultural organic soils using Michaelis–Menten kinetics. Parameters for the model Michaelis–Menten equations were developed from field data (Deverel and Rojstaczer, 1996). Inputs for the model are described in Deverel and Leighton and include soil organic matter content, average soil annual temperature at 30 cm, depth to groundwater, soil bulk density. We plan to integrate the SUBCALC and PEPRMT models for predicting both CO_2 and CH_4 from diverse land use types in the Delta.

Applicability Conditions and Methodological Requirements

The following conditions must be met for this module to be used:

1. For project areas that are converted to flooded conditions, separate model simulations must be run for baseline and project conditions.
2. The participating wetlands shall be in the Delta area of organic soils where the models have been successfully calibrated.
3. The model described here is applicable to fully vegetated wetlands or strata.
4. Wetlands or strata with open water require separate validation[59].
5. Net aqueous loss of carbon must be negligible or estimated using other methods (see Methods Module MM-W/R). Sites with significant import and/or export of dissolved forms of carbon (such as tidal wetlands) are not appropriate sites for employing the LUE-DAMM.
   For each model run, appropriate input parameter files must be available to the verifier.

[59] Conditions 3 and 4 represent different conditions that may occur in the same wetland or stratum due to hydrologic conditions or the stage of development. The model described in this module was developed for fully vegetated conditions.

Parameters

Parameter	SI Unit	Description
ΔC_{BSL}	t CO_2-e	Cumulative total of carbon stock changes and greenhouse gas emissions for the baseline scenario. This parameter feeds into Equation 1 in the Framework Module.
ΔC_{actual}	t CO_2-e	Cumulative total of carbon stock changes and greenhouse gas emissions for the project scenario. This parameter feeds into Equation 1 in the Framework Module.

Project Model Description

The PEPRMT model requires leaf area index (LAI), meteorological data, initial soil organic carbon content (SOC), and water table height. See Data and Parameters Monitored section for description and requirement for each input.

Model Calibration and Validation

In order to use this model in systems in which it has not been calibrated such as rice fields in the Sacramento Valley, it needs to be calibrated and validated using at least 2 years of semi-continuous ecosystem exchange data of CO_2 and CH_4. Other model input variables will also need to be recorded during this time. Two years is the minimum in order for sufficient data for both parameterization and validation (recommended 70% data used for parameterization and 30% for validation). Model calibration and validation do not need to be conducted within project bounds but must be conducted in and documented for a similarly managed system with similar soil qualities and climate conditions.

Table 7. Project emissions sources included in the project boundary

Source	Gas
Net GHG emissions due to C uptake, ecosystem respiration and methanogenesis	CO_2, CH_4

Quantification of Project Emissions and Carbon Stock Changes

Project emissions of CO_2 and CH_4 may be estimated using the PEPRMT model, which must be run separately for each wetland site, strata or cohort. Flux rates derived from the PEPRMT model, net ecosystem exchange of CO_2 (NEE; g CO_2 acre^{-1} day^{-1}) and net ecosystem exchange of CH_4 (R_{CH4}; g CH_4 acre^{-1} day^{-1}) will be used to derive annual sums of CO_2 and CH_4 for each project year and project site:

$$[CO_2]_{project,y,i} = \sum_{t=1} NEE_{project,t} * A \qquad (25)$$

$$[CH_4]_{project,y,i} = \sum_{t=1} R_{CH_4project,t} * A \qquad (26)$$

where:

$[CO_2]_{project,y,i}$ is the cumulative project net CO_2 ecosystem exchange (*NEE*) from wetland stratum *i* over reporting time period which may vary from 0.5 to 2 years;

$[CH_4]_{project,y,i}$ is the cumulative project net CH_4 ecosystem exchange (R_{CH4}) from wetland stratum *i* over reporting time period which may vary from 0.5 to 2 years;

$NEE_{project,t}$ is the project net CO_2 ecosystem exchange flux rate at time *t* for wetland stratum *i* (g CO_2 acre^{-1} day^{-1});

$R_{CH4project,t}$ is the project net CH_4 ecosystem exchange flux rate at time *t* for wetland stratum *i* (g CH_4 acre^{-1} day^{-1}); and

A is the area in wetland stratum *i*

Project annual net GHG exchanges for each year and site are then used to calculate total project net emissions:

$$\Delta C_{actual} = \frac{44}{12} * [CO_2]_{project,y,i} + 25 * \frac{16}{12} * [CH_4]_{project,y,i} \qquad (27)$$

where:

ΔC_{actual} is the cumulative total of carbon stock changes and greenhouse gas emissions for the project scenario wetland site (t CO_2-e);

$[CO_2]_{project,y,i}$ is the cumulative project net CO_2 ecosystem exchange (*NEE*) from wetland stratum *i* over reporting time period which may vary from 0.5 to 2 years;

$[CH_4]_{project,y,i}$ is the cumulative project net CH_4 ecosystem exchange (R_{CH4}) from wetland stratum *i* over reporting time period which may vary from 0.5 to 2 years;

44/12 is the ratio of molecular weight of CO_2 to carbon (dimensionless); and

16/12 is the ratio of molecular weight of CH_4 to carbon (dimensionless).

The current *ACR Standard* provides reference for the Global Warming Potential for methane on a 100-yr timescale.

Project Model description: The Peatland Ecosystem Photosynthesis, Respiration, and Methane Transport model (PEPRMT)

I. CO_2 ecosystem PEPRMT model

In order to predict net ecosystem exchange of CO_2 (NEE) both gross primary productivity (GPP) and ecosystem respiration (R_{eco}) need to be simulated:

$$NEE = GPP + R_{eco} \qquad (28)$$

To predict GPP, we employ a simple and widely-used light use efficiency model called the LUE model (Monteith, 1977):

$$GPP = PAR * \varepsilon * fPAR(LAI) * f(T) \qquad (29)$$

where GPP is a function of available photosynthetically active radiation (*PAR*), plant light use efficiency (*ε*), the fraction of PAR absorbed by canopy (*fPAR*) which is a function of leaf area index (*LAI*), and a temperature function (*f(T)*). The light use efficiency and temperature function are calibrated to each ecosystem, as these vary among plant species (Yuan *et al.*, 2007). The temperature function assumes photosynthesis increases exponentially with temperature until it reaches an optimum (e.g. 25°C), above which photosynthesis is inhibited:

$$f(T_k) = 1 * \left(\frac{H_d * exp\left(\frac{H_a(T_k - T_{opt})}{T_k * R * T_{opt}}\right)}{H_d - H_a\left(1 - exp\left(\frac{H_d(T_k - T_{opt})}{T_k * R * T_{opt}}\right)\right)} \right) \qquad (30)$$

where R is the universal gas constant, T_k is air temperature, H_a is the rate of exponential increase below the optimum temperature, and H_d is the rate of decrease above the optimum temperature (Medlyn *et al.*, 2002). From these equations, photosynthetic rates are computed every 30 min and up-scaled to the ecosystem using LAI.

Ecosystem respiration (R_{eco}) is the total CO_2 respired by both plants and soil. In order to predict R_{eco} we employ a simple respiration model based on enzyme kinetics which was adapted from the Dual Arrhenius Michaelis-Menten kinetics (DAMM) model (Davidson *et al.*, 2012). This model assumes R_{eco} is a function of the size and availability of 2 soil C pools, temperature, and water table height (WT). The 2 soil carbon pools are regulated by initial soil carbon conditions (i.e. soil organic carbon (SOC)) and recently-fixed photosynthetic C, which is predicted using GPP. According to enzyme kinetics, respiration increases exponentially with temperature. Water table and soil moisture influence the availability of oxygen in the soil, an important substrate for aerobic respiration. Specifically, R_{eco} is predicted using an Arrhenius equation paired with Michaelis-Menten equations to address substrate availability of 2 C pools:

$$R_{eco} = \left(\frac{Vmax_{SOC} * [C_{SOC}]}{kM_{SOC} + [C_{SOC}]} + \frac{Vmax_{labile} * [C_{labile}]}{kM_{labile} + [C_{labile}]} \right) * f(WT) \qquad (31)$$

where R_{eco} is the total respiration rate for the given ecosystem (μmol CO_2 m^{-2} s^{-1}), V_{max} (μmol CO_2 m^{-2} s^{-1}) is the maximum rate of enzyme kinetics for the respective C pools when substrate concentrations are not limiting (where labile refers to recently-fixed photosynthetic C and soil organic carbon (SOC) refers to older more recalcitrant forms of C), *C* is the soil C content for the respective C pools (µmol C m^{-2}), and *kM* is the half-saturation concentration for the respective substrates (µmol C m^{-2}). Under flooded conditions, soil respiration is inhibited due to depleted O_2. Soil CO_2 emission rates under anaerobic conditions have been previously reported to decrease by 32-65%[60] due to the use of alternative electron acceptors, and were recently reported to be reduced by 50% in a Delta rangeland site (McNicol & Silver, 2014). Therefore the water table function (*f (WT)*) describes elevated rates of respiration when the water table falls below the soil surface due to introduction of O_2 to the soil.

C pool sizes are dynamic. For example, both pools are reduced in response to respiration rates. The SOC pool is enhanced at the end of the year when vegetation senesces and contributes to the SOC pool, estimated as a function of LAI. The labile pool is a function of *GPP* (explained above). Initial SOC conditions for the simulated region is another driver for model simulation and must be sampled at the beginning of the project (5-10 soil profile samples to assess average SOC in the top 1m of soil; see Tables 21-23 for complete list of drivers, parameters and state variables).

Following the Arrhenius function, V_{max_x} is the maximum rate of enzyme reaction for each soil C pool (i.e. SOC and labile soil C):

$$V_{max_x} = a_x * e^{-Ea_x/RT} \tag{32}$$

where V_{max_x} is predicted using the pre-exponential factor (a_x), the activation energy of the enzymatic reaction with the substrate (Ea_x), air temperature (T) and the universal gas constant (R).

II. CH_4 ecosystem PEPRMT model

In order to predict net CH_4 emissions, both methane oxidation and production need to be simulated. Again, we employ a simple model based on enzyme kinetics where CH_4 production is a function of the size and availability of two soil C pools, temperature, and water table height, and CH_4 oxidation is a function of the availability of CH_4, temperature, and water table height. Both processes are predicted to increase exponentially with temperature. However, high water table conditions enhance CH_4 production and limit oxidation and low water table heights inhibit CH_4 production and increase oxidation. Two transport pathways are also modeled, plant–mediated CH_4 transport and hydrodynamic CH_4 flux. Both of these transport pathways are dependent on water table height and concentration gradients of CH_4 between the water and atmosphere. Plant-mediated transport is also a function of GPP.

The biogeochemical model for CH_4 production and oxidation is based on the DAMM model foundation. Similarly to the R_{eco} DAMM model, CH_4 production is predicted using an Arrhenius equation paired with Michaelis-Menten equations estimating the concentration of two C substrates at the enzyme reaction site:

$$R_{CH4} = \frac{Vmax_{labile} * [C_{labile}]}{kM_{labile} + [C_{labile}]} * \frac{Vmax_{SOC} * [C_{SOC}]}{kM_{SOC} + [C_{SOC}]} * f(WT) \tag{33}$$

To account for the inhibition of CH_4 production by the presence of O_2, an O_2 effect parameter is applied when the water table falls below the soil surface. Previous research has indicated that CH_4 production

[60] Wright AL, Reddy KR (2001) Heterotrophic microbial activity in northern Everglades wetland soils, *Soil Sci Soc Am J*, 65:1856–1864.

rates can take multiple days to recover following re-saturation, due to the slow recharge of alternative electron acceptors (Kettunen *et al.*, 1999, Moore & Dalva, 1993). A previous analysis at the West Pond wetland confirmed that lowering the water table can have sustained negative effects on CH_4 emission, lasting up to 20 days (Sturtevant *et al.*, 2015). We added a lag effect into the model, where CH_4 production is inhibited for 20 days following a drop in the water table.

Similarly, CH_4 oxidation follows the DAMM model foundation, where there is only 1 substrate pool: CH_4:

$$O_{CH4} = \frac{Vmax_{CH4} * [CH_4]}{kM_{CH4} + [CH_4]} * f(WT) \tag{34}$$

To account for the inhibition of CH_4 oxidation when the water table is above the soil surface, a water table function (*f(WT)*) is applied when the water table is above the soil surface.

Hydrodynamic flux is predicted using the Poindexter model, which was parameterized and validated at the same mature wetland site as the model described here (Poindexter *et al. submitted*). This predicts transfer of CH_4 stored in the water directly to the atmosphere given the concentration gradient between CH_4 in water and CH_4 in the atmosphere as well as a gas transfer velocity:

$$F_{hydro} = k_{hydro} * \left([CH4_{water}] - [CH4_{surface}]\right) \tag{35}$$

Where k_{hydro} is the gas transfer velocity through the water (0.04 m d^{-1}). Concentrations of CH_4 in the water or soil ([CH_{4water}]; µmol m^{-3}) are modeled based on production and oxidation rates of CH_4. After accounting for methane solubility in water, dissolved concentrations of methane at the surface ([$CH_{4surface}$]; µmol m^{-3}) are so small they are assumed to be zero.

Plant-mediated flux is predicted following the Dynamic Land Ecosystem Model (DLEM) (Tian *et al.*, 2010). This predicts plant-mediated transport of CH_4 given the concentration gradient between CH_4 in water and CH_4 in the atmosphere as well as plant transport efficiency and plant activity:

$$F_{plant} = \left(k_{plant} * \left([CH_{4_{water}}] - [CH_{4_{atm}}]\right) * \frac{GPP}{GPP_{max}}\right) * V_{oxi} \tag{36}$$

where k_{plant} is the gas transfer velocity through plants, assumed to be constant (0.24 m d^{-1}) (Kettunen, 2003). Concentrations of CH_4 in the soil and water ([CH_{4water}]; µmol m^{-3}) are modeled based on production and oxidation rates of CH_4. Again, after accounting for methane solubility in water, dissolved concentrations of methane in the atmosphere ([CH_{4atm}]; µmol m^{-3}) are so small they are assumed to be zero. Plant activity is assessed using GPP, where the most plant transport is expected to occur when GPP is at its highest point. Finally, a fraction of CH_4 transported through plants is assumed to be oxidized at a constant rate (V_{oxi} =0.35) (van der Nat & Middelburg, 1998b).

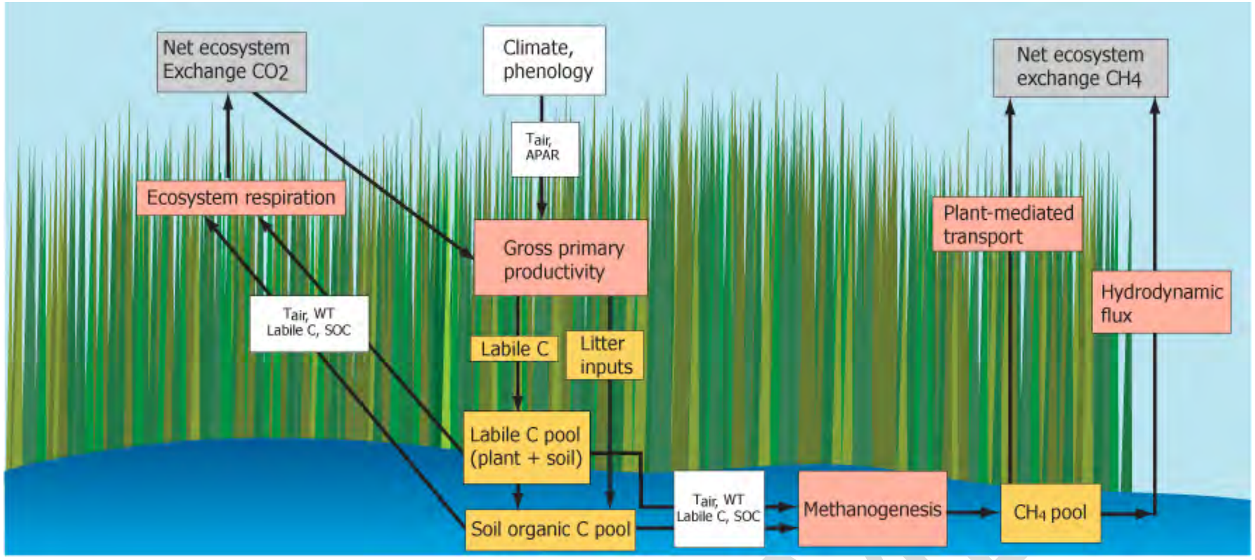

Figure 2. Conceptual diagram of PEPRMT model. Model inputs and drivers (air temperature (T_{air}), absorbed photosynthetically active radiation (APAR), water table height (WT), labile soil C, and soil organic carbon (SOC)) are shown in white boxes; model outputs are shown in grey boxes. Processes and pools modeled within PEPRMT are shown in pink and orange boxes, respectively.

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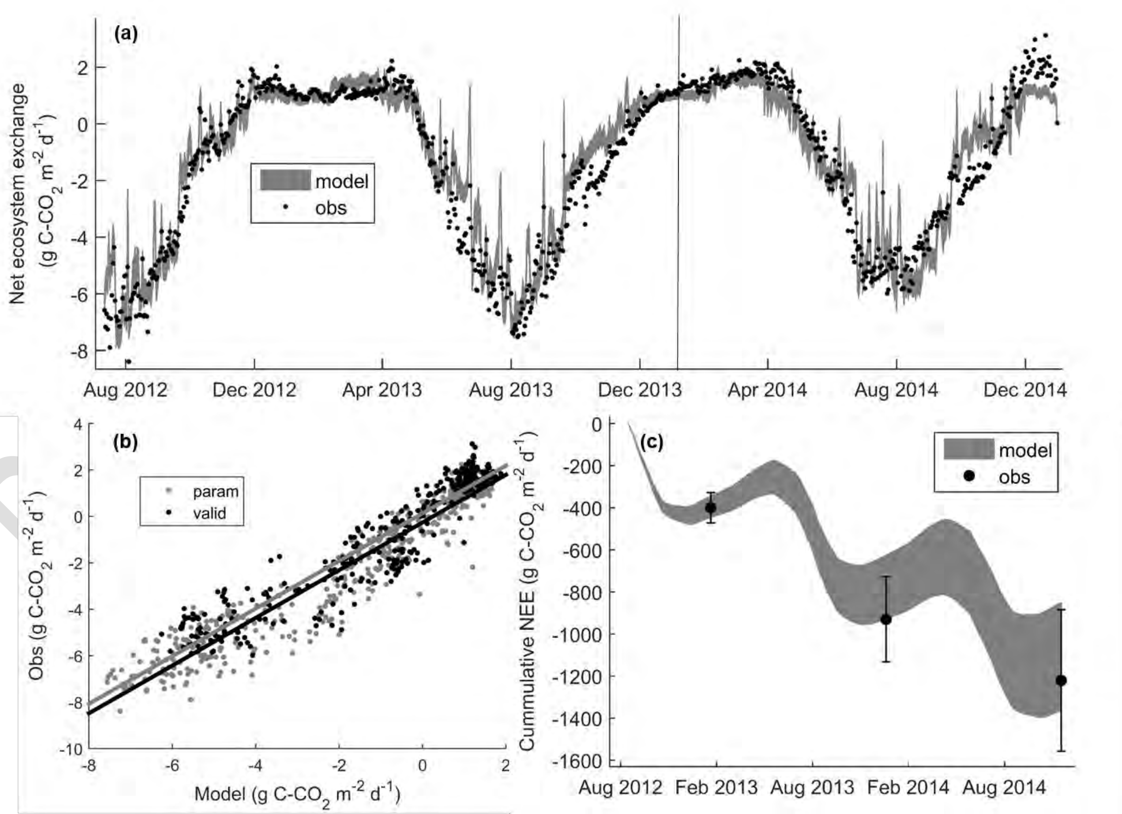

Figure 3. (a) PEPRMT modeled and observed net ecosystem exchange of CO_2 (NEE) from July 2012 to December 2014 at West Pond wetland. Data to the left of the black vertical line were used in model parameterization and data to the right were used in model validation. (b) Data model agreement was high during the parameterization period (param) (slope=1, intercept=0.26; r2 = 0.92; RMSE = 0.85) and during the validation period (valid) (slope=1, intercept=0.13; r2 = 0.90; RMSE = 0.86). (c) Similar integrated observed and modeled NEE fluxes were observed during the validation period (observed: -290 ± 134g C-CO2 m-2 yr-1; modeled: -329.5 ± 105 g C-CO2 m-2 yr-1) as well as across the entire observation period (observed: -1220.6 ± 336g C-CO2 m-2 yr-1; modeled: -1107.0 ± 257 g C-CO2 m-2 yr-1). Errors are 90% confidence intervals. Observed error is the sum of random and gap-filling errors. Model error is calculated based on variance across accepted posterior model parameters.

Approximately 60% of observed data were used to parameterize the model (July 2012–December 2013), and 40% were used for model validation (January 2014–December 2014). PEPRMT model simulations explained 90% of the variation in observed CO_2 fluxes. Observed and modeled cumulative CO_2 budgets for the validation period were similar (observed: -290 ± 134g C-CO_2 m^{-2} yr^{-1}; modeled: -329.5 ± 105 g C-CO_2 m^{-2} yr^{-1}).

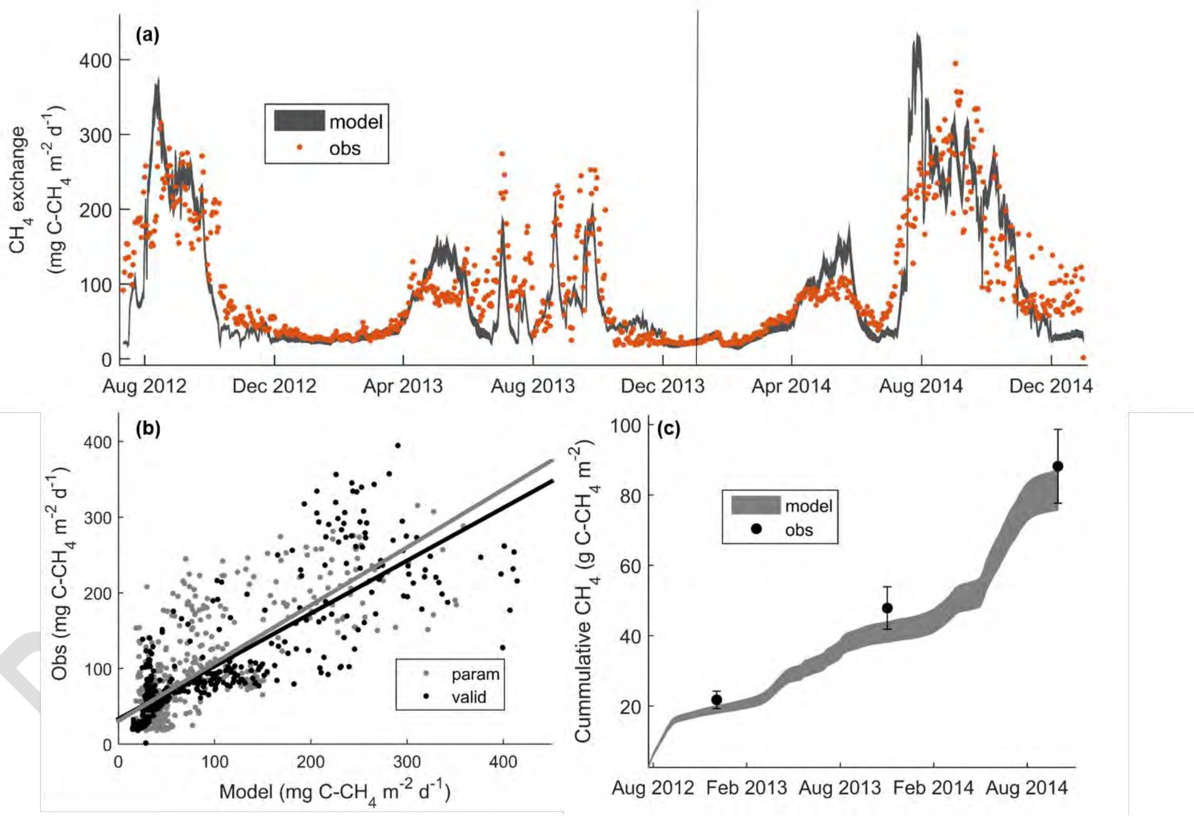

Figure 4. (a) PEPRMT modeled and observed ecosystem exchange of CH_4 in West Pond wetland. Data to the left of the black vertical line were used in model parameterization and data to the right were used in model validation. (b) Data-model agreement was high during the parameterization period (param) (slope = 0.76, intercept = 31; r^2 = 0.60; RMSE = 48.6) and during the validation period (valid) (slope = 0.7, intercept = 33; r^2 = 0.67; RMSE = 57.2). (c) Similar integrated observed and modeled CH_4 fluxes were observed during the parameterization period (observed: 47.9 ± 6 g C- CH_4 m^{-2}; modeled: 41.0 ± 3.0 g C- CH_4 m^{-2}) and validation period (observed: 40.3 ± 4.5 g C-CH_4 m^{-2} yr^{-1}; modeled: 40.4 ± 2.8 g C- CH_4 m^{-2} yr^{-1}). Across the entire observation period budgets were similar (observed:

88.2± 10.5 g C- CH_4 m^{-2}; modeled: 81.4± 6.0 g C-CH_4 m^{-2}). Errors are 90% confidence intervals. Observed error is the sum of random and gap-filling errors. Model error is calculated based variance across accepted posterior model parameters.

PEPRMT model simulations explained 65% of the variation in observed CH_4 fluxes. Observed and modeled cumulative CH_4 budgets for the validation period were very similar (observed: 40.3 ± 4.5 g C-CH_4 m^{-2} yr^{-1}; modeled: 40.4 ± 2.8 g C- CH_4 m^{-2} yr^{-1}).

Data and Parameters Monitored

Data Unit / Parameter	Meteorological data
Description	Air temperature and in-coming radiation
Units	Degree Celsius and µmol radiation m^{-2} s^{-1}
Data source	California Irrigation Management Information System (CIMIS) website (http://wwwcimis.water.ca.gov/cimis/data.jsp)
Description of measurement methods and procedures to be applied	
Frequency of monitoring/recording	30 min
QA/QC procedures	
Verification requirements	
Comments	

Data Unit / Parameter	Initial soil organic carbon
Description	Amount of existing soil organic carbon at beginning of project
Units	g C m^{-3} soil
Data source	Soil survey data (NRCS SSURGO) or direct sampling (5-10 soil profile samples averaged across top 1m soil; replicate spatially as needed)
Description of measurement methods and procedures to be applied	If data from NRCS SSURGO is used, the uncertainty in the spatial resolution of soils properties (including soil organic matter) must be accounted for in model inputs.
Frequency of monitoring/recording	Once at beginning of project
QA/QC procedures	
Verification requirements	
Comments	

Data Unit / Parameter	Water table height

Description	Distance from surface of soil to water table—for project conditions
Units	cm
Data source	Direct or automated measurement
Description of measurement methods and procedures to be applied	Measure by hand distance of water height to soil surface or install pressure transducer to continuously monitor water table height (such as Campbell Scientific CS451-L)
Frequency of monitoring/recording	Daily-weekly
QA/QC procedures	
Verification requirements	
Comments	

Data Unit / Parameter	**Leaf area index**
Description	One-sided green leaf area per ground surface area
Units	m^2 leaf area m^{-2} ground area
Data source	Destructive field sampling, LAI sensor (e.g. LAI-2200C Plant Canopy Analyzer), or remote sensing
Description of measurement methods and procedures to be applied	Destructive sampling: remove all leaves in a known surface area (e.g.40cm x 40cm), measure leaf area of all removed leaves. Repeat across landscape (ideally 5 measurements per plant cover type). LAI sensor: collect 10 measurements along a transect through each plant cover type Remote sensing: Phenocams, or digital cameras that are automated to record images of canopy cover throughout the year, can be used to calculate a greenness index (GI) which can be empirically related to LAI based on field measurements (Richardson *et al.*, 2009, Ryu *et al.*, 2012, Sonnentag *et al.*, 2011). Other forms of remote sensing may also be available such as satellite images provided by MODIS.
Frequency of monitoring/recording	Measurements must be collected frequently during the growing season (2x per month); monthly measurements during the non-growing seasons are also required
QA/QC procedures	See Methods Module(MM-W/R)
Verification requirements	
Comments	

Table 8. Photosynthesis PEPRMT model parameters, descriptions and values

Parameters, state variables, and driver variables	Description	Value
Parameters		
ε	Light use efficiency (g C MJ^{-1})	0.94
H_a	Activation energy for photosynthesis (kJ mol^{-1})	21.5
H_d	Inhibition of photosynthesis at high temperatures (kJ mol^{-1})	110
R	Universal gas constant	0.00831
T_{opt}	Optimum temp for photosynthesis	25ºC
State variables		
NEE	Net ecosystem exchange CO_2 (µmol m^{-2} s^{-1})	
GPP	Gross ecosystem primary productivity (µmol m^{-2} s^{-1})	
Driver variables		
Air temperature	ºC	
PAR	Photosynthetically active radiation (µmol m^{-2} s^{-1})	
LAI	Leaf area index	

Table 9. Respiration PEPRMT model parameters, descriptions and values

Parameters, state variables, and driver variables	Description	Value
Parameters		
kM_{labile}	Michaelis-Menten constant for labile C (g C cm^{-3} soil)	$1.7*10^{-6}$
kM_{SOC}	Michaelis-Menten constant for SOC (g C cm^{-3} soil)	$6.3*10^{-6}$
α_{labile}	Pre-exponential factor for labile C (µmol C cm^{-3} soil s^{-1})	2

α_{SOC}	Pre-exponential factor for SOC (µmol C cm^{-3} soil s^{-1})	2
Ea_{labile}	Activation energy for labile C (kJ mol^{-1})	18
Ea_{SOC}	Activation energy for SOC (kJ mol^{-1})	17.8
C_{SOC}	Initial SOC pool (mol C m^{-3})	*measured*
State variables		
R_{eco}	Ecosystem respiration (µmol m^{-2} s^{-1})	
C_{SOC}	SOC pool	
Driver variables		
Air Temp	ºC	
PAR	Photosynthetically active radiation (µmol m^{-2} s^{-1})	
WT	Water table height	
GPP	Gross ecosystem primary productivity (µmol m^{-2} s^{-1})	

Table 10. CH_4 PEPERMT model parameters, descriptions and values

Parameters, state variables, and driver variables	Description	Value
Parameters		
kM_{labile}	Michaelis-Menten constant for labile C (g C cm^{-3} soil)	$2.3*10^{-5}$
kM_{SOC}	Michaelis-Menten constant for SOC (g C cm^{-3} soil)	$1.7*10^{-5}$
kM_{CH4}	Michaelis-Menten constant for CH_4 oxidation (g C cm^{-3} soil)	$2.3*10^{-5}$
α_{labile}	Pre-exponential factor for labile C (µmol C cm^{-3} soil s^{-1})	$6*10^{8}$
α_{SOC}	Pre-exponential factor for SOC (µmol C cm^{-3} soil s^{-1})	$6*10^{7}$
a_{CH4}	Pre-exponential factor for CH_4 oxidation (µmol C cm^{-3} soil s^{-1})	$6*10^{7}$
Ea_{labile}	Activation energy for labile C (kJ mol^{-1})	71.1

Ea_{SOC}	Activation energy for SOC (kJ mol^{-1})	67.1
Ea_{CH4}	Activation energy for CH_4 oxidation (kJ mol^{-1})	75.4
C_{SOC}	Initial SOC pool (mol C m^{-3})	*measured*
k_{plant}	Gas transfer velocity through plants (Kettunen et al. 2003)	0.24 m d^{-1}
V_{oxi}	Fraction of CH_4 oxidized during plant transport	0.35
k_{hydro}	Gas transfer velocity through water (Poindexter et al. submitted)	0.04 m d^{-1}

State variables

R_{CH4}	CH_4 production (μmol m^{-2} d^{-1})
O_{CH4}	CH_4 oxidation (μmol m^{-2} d^{-1})
N_{CH4}	Net CH_4 emission (μmol m^{-2} d^{-1})
C_{CH4}	Soil CH_4 pool

Driver variables

Air Temp	ºC
PAR	Photosynthetically active radiation (μmol m^{-2} s^{-1})
WT	Water table height
GPP	Gross ecosystem primary productivity (μmol m^{-2} s^{-1})

References

Davidson EA, Samanta S, Caramori SS, Savage K (2012) The Dual Arrhenius and Michaelis–Menten kinetics model for decomposition of soil organic matter at hourly to seasonal time scales. Global Change Biology, 18, 371-384.

Deverel, S.J., Leighton, D.A., 2010. Historic, recent, and future subsidence, Sacramento-San Joaquin Delta, California, USA. San Francisco Estuary and Watershed Science 8.

Deverel SJ, Rojstaczer S. 1996. Subsidence of agricultural lands in the Sacramento—San Joaquin Delta, California: role of aqueous and gaseous carbon fluxes. Water Resources Research 32(8):2359–23672

Hall DGM, Reeve MJ, Thomasson AJ, Wright VF (1975) Water retention, porosity and density of field soils. Tech. Monogr. No. 9 Soil Survey, Harpenden, U.K.

Mcnicol G, Silver WL (2014) Separate effects of flooding and anaerobiosis on soil greenhouse gas emissions and redox sensitive biogeochemistry. Journal of Geophysical Research: Biogeosciences.

Medlyn B, Dreyer E, Ellsworth D et al. (2002) Temperature response of parameters of a biochemically based model of photosynthesis. II. A review of experimental data. Plant, Cell & Environment, 25, 1167-1179.

Monteith JL (1977) Climate and efficiency of crop production in Britain. Philosophical Transactions of the Royal Society of London Series B-Biological Sciences, 281, 277-294.

Richardson AD, Braswell BH, Hollinger DY, Jenkins JP, Ollinger SV (2009) Near-surface remote sensing of spatial and temporal variation in canopy phenology. Ecological Applications, 19, 1417-1428.

Ryu Y, Verfaillie J, Macfarlane C et al. (2012) Continuous observation of tree leaf area index at ecosystem scale using upward-pointing digital cameras. Remote Sensing of Environment, 126, 116-125.

Sonnentag O, Detto M, Vargas R, Ryu Y, Runkle BRK, Kelly M, Baldocchi DD (2011) Tracking the structural and functional development of a perennial pepperweed (Lepidium latifolium L.) infestation using a multi-year archive of webcam imagery and eddy covariance measurements. Agricultural and Forest Meteorology, 151.

Tian H, Xu X, Liu M, Ren W, Zhang C, Chen G, Lu C (2010) Spatial and temporal patterns of CH4 and N2O fluxes in terrestrial ecosystems of North America during 1979–2008: application of a global biogeochemistry model. Biogeosciences, 7, 2673-2694.

Wright A, Reddy K (2001) Heterotrophic microbial activity in northern Everglades wetland soils. Soil Science Society of America Journal, 65, 1856-1864.

Yuan W, Liu S, Zhou G et al. (2007) Deriving a light use efficiency model from eddy covariance flux data for predicting daily gross primary production across biomes. Agricultural and Forest Meteorology, 143, 189-207.

(EFFC –W/R) Wetland Restoration and Rice Methodological Module-Estimation of Emissions from Fossil Fuel Combustion

Project proponents will employ the currently approved method module for estimating GHG emissions fossil fuel combustion approved by ACR:

http://americancarbonregistry.org/carbon-accounting/standards-methodologies/restoration-of-degraded-deltaic-wetlands-of-the-mississippi-delta/e-ffc.pdf

Tools

(X-UNC) Methodological Module Tool for estimation of uncertainty for wetland construction and restoration and rice cultivation in the Sacramento-San Joaquin Delta and San Francisco Estuary

SCOPE, APPLICABILITY AND PARAMETERS

Scope

This module provides guidance for calculating uncertainty for estimation of emissions and GHG removals from wetland construction and restoration activities and rice cultivation activities implemented in the Sacramento-San Joaquin Delta and San Francisco Estuary where water quality ranges from fresh to saline conditions.

Applicability

This module is mandatory and provides guidance for the calculation of the following sources of uncertainty:

- Baseline and project emissions
- Baseline and project changes in soil carbon stocks

Where an uncertainty value is not known or cannot be accurately calculated, a Project Proponents shall justify that it is using an indisputably conservative value for carbon stock changes or emissions and an uncertainty of 0% may be used for this component.

Parameters

This module provides procedures to determine the following parameters:

Parameter	Description
UNC	Total (project and baseline) uncertainty (%)
$Uncertainty_{BSL,SS,i}$	Percentage uncertainty of the combined carbon stocks and greenhouse gas sources for the uncertainty baseline case in stratum *i*
$Uncertainty_{P,SS,i}$	Percentage uncertainty of the combined carbon stocks and greenhouse gas sources for the project scenario case in stratum *i*

Either as default values given in IPCC Guidelines for greenhouse gas (GHG) inventories[61] good practice for land use[62], expert judgment[63], or estimates based on sound sampling design and statistical analysis shall provide the basis for uncertainty calculations. Uncertainties arising from the measurement and monitoring of carbon pools and the changes in carbon pools shall always be quantified. Indisputably conservative estimates can also be used instead of uncertainties in which case the uncertainty is assumed to be zero. However, this section provides a procedure to combine uncertainty information

[61] Eggleston S, Buendia L, Miwa K, Ngara T, Tanabe K (2006) IPCC Guidelines for National Greenhouse Gas Inventories.

[62] Penman J, Gytarsky M, Hiraishi T, Krug T, Kruger D, Pipatti R, Buendia L, et al. (2003) IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry.

[63] Justification should be supplied for all values and parameters measured or derived from expert judgment.

and conservative estimates resulting in an overall project scenario uncertainty.

To calculate total project uncertainty the following equation shall be applied:

$$\text{Total (Project and Baseline) } UNC = \sqrt{{UNC_{BSL}}^2 + {UNC_P}^2} \qquad (37)$$

Where:

UNC is the total (project and baseline) uncertainty (%);

UNC_{BSL} is the baseline uncertainty (%); and

UNC_P is the project uncertainty (%).

The allowable uncertainty under this methodology is ±10% of the mean carbon stock change at the 90% confidence level. Where this precision level is met, no deduction shall result for uncertainty. Where uncertainty exceeds 10% of the mean carbon stock change, the deduction shall be equal to the amount that the uncertainty exceeds the allowable level, as indicated in the Framework Module (WR-MF).

ESTIMATION OF BASELINE UNCERTAINTY

It is important that the process of project planning consider uncertainty. *A priori* estimations of statistical power[64] can be used to ensure proper spatiotemporal replication[65] and determine procedures, such as stratification and allocation of resources to allow the number of measurement plots to reduce uncertainty. It is good practice to consider uncertainty at an early stage to identify the data sources with the highest risk to allow the opportunity to conduct further work to improve representativeness and optimize project practices over time. Estimation of uncertainty for pools and emissions sources for each measurement pool requires calculation of both the mean and the 90% confidence interval. In all cases, uncertainty should be expressed at the 90% confidence interval as a percentage of the mean.

The uncertainty in the baseline scenario is defined as the square root of the summed errors in each of the carbon pools listed in the Framework Module. For modeled results, the uncertainty in the input inventory data and model structural uncertainty shall be considered as discussed below. The total baseline uncertainty in each pool can be weighted by the size of the pool so that projects may reasonably target a lower precision level for pools that comprise only a small proportion of the total stock as follows:

$$Uncertainty_{BSL,SS,i} = \frac{\sqrt{(U_{BSL,SS1,i} * E_{BSL,SS1,i})^2 + (U_{BSL,SS2,i} * E_{BSL,SS2,i})^2 + \cdots + (U_{BSL,SSn,i} * E_{BSL,SSn,i})^2}}{E_{BSL,SS1,i} + E_{BSL,SS2,i} + \cdots + E_{BSL,SSn,i}} \qquad (38)$$

[64] Park, H. M. 2010. Hypothesis testing and statistical power of a test. Technical Working Paper. University Information Technology Services (UITS) Center for Statistical and Mathematical Computing, Indiana University. http://www.indiana.edu/~statmath/stat/all/power/power.pdf.

[65] Silva LCR, Corrêa RS, Doane TA, Pereira EIP, Horwath WR (2013) Unprecedented carbon accumulation in mined soils: the synergistic effect of resource input and plant species invasion. Ecological Applications 23:1345–1356.

where:

$Uncertainty_{BSL,SS,i}$ is the percentage uncertainty of the combined carbon stocks and greenhouse gas sources for the uncertainty baseline case in stratum *i* (%);

$U_{BSL,SS,i}$ is the percentage uncertainty (expressed as 90% confidence interval as a percentage of the mean where appropriate) of carbon stocks and greenhouse gas sources for the baseline case in stratum *i* (1,2…n represent different carbon pools and/or GHG sources) (%);

$E_{BSL,SS,i}$ is the carbon stock in stratum *i* (1,2…n represent different carbon pools and/or GHG sources) for the baseline case (t CO_2-e); and

i is the stratum within the project boundary (1,2,3,…M).

ESTIMATION OF PROJECT UNCERTAINTY

As with baseline uncertainty, it is important that the process of project planning consider uncertainty. Procedures including stratification and the allocation of sufficient number of measurement locations can help minimize uncertainty. It is good practice to consider uncertainty at an early stage to identify the data sources with the highest risk to allow the opportunity to conduct further work to diminish uncertainty. Estimation of uncertainty for pools and emissions sources for each measurement pool requires calculation of both the mean and the 90% confidence interval. In all cases, uncertainty should be expressed at the 90% confidence interval as a percentage of the mean. The uncertainty in the project scenario should be defined as the square root of the summed errors in each of the carbon pools. For modeled results, follow guidelines discussed below. The errors in each pool can be weighted by the size of the pool so that projects may reasonably target a lower precision level for pools that comprise only a small proportion of the total stock as follows:

$$Uncertainty_{P,SS,i} = \frac{\sqrt{(U_{P,SS1,i} * E_{P,SS1,i})^2 + (U_{P,SS2,i} * E_{P,SS2,i})^2 + \cdots + (U_{P,SSn,i} * E_{P,SSn,i})^2}}{E_{P,SS1,i} + E_{P,SS2,i} + \cdots + E_{P,SSn,i}} \quad (39)$$

where:

$Uncertainty_{P,SS,i}$ is the percentage uncertainty of the combined carbon stocks and greenhouse gas sources for the project scenario in stratum *i* (%);

$U_{P,SS,i}$ is the percentage uncertainty (expressed at the 90% confidence interval) as a percentage of the mean where appropriate, of carbon stocks and greenhouse gases for the project scenario in stratum *i* (%); and

$E_{P,SS,i}$ is the carbon stock in stratum *i* for the project carbon pools 1, 2, 3 … *M* strata (t CO_2-e).

ESTIMATING UNCERTAINTY ASSOCIATED WITH EDDY COVARIANCE MEASUREMENTS

When calculating uncertainty associated with using eddy covariance to estimate emission reductions, this protocol requires project proponents to account for random measurement error and error associated with gap-filling procedures used to calculate annual sums. Systematic bias error is also discussed here but can be conservatively excluded from uncertainty deductions if quality assurance and quality control measures are appropriately followed as discussed in the emissions and carbon-stock Methods Modules (E-E and CP-S).

Random Measurement Error

Random measurement error can create substantial noise or scatter in the data and can occur due to spectral filtering effects, turbulent transport, instrumentation, and footprint issues[66]. Errors can be reduced by using high sampling rates (at least 1Hz; ideally 10Hz), measuring continuously during each project year, measuring gas concentration and wind speed high enough above the vegetation, minimizing separation between sensors (<20cm), and minimizing flow distortion in the sensor array and mast[67].

Two general approaches are allowed for estimating the random error (ε_{random}),. A project proponent may use a documented and validated empirical model demonstrated to be an accurate predictor of the observed eddy covariance data. The residual between observed and modeled fluxes can give an estimate of error as long as model error is shown to be minimal[68]. The project proponent may also use a daily-differencing approach where data points collected under the same environmental conditions in successive days (x_1, x_2) are compared and the random measurement error is estimated as the standard deviation of the differences between x_1 and x_2[69,70]. This method can be used in combination with Monte Carlo methods to estimate the 90% confidence interval due to random error in gap-filled net ecosystem exchange at the annual time step. It is important to note that random error associated with eddy covariance measurements typically follows a double-exponential (Laplace) distribution and not the normal (Gaussian) distribution, therefore maximum likelihood estimation techniques should be used to estimate random error confidence intervals as opposed to least squares optimization with requires normally distributed error and constant variance. Alternatively, the project proponent may also use peer-reviewed methods for estimating the random error in eddy-covariance methods.

Estimations of Random and Gap-Filling Errors Over Long Time Scales

[66] Richardson, A.D. et al., 2012. Eddy covariance: a practical guide to measurement and data analysis. Springer.
[67] Massman, W.J., 2000. A simple method for estimating frequency response corrections for eddy covariance systems. Agricultural and Forest Meteorology, 104(3): 185-198.
[68] Richardson, A.D. and Hollinger, D.Y., 2005. Statistical modeling of ecosystem respiration using eddy covariance data: maximum likelihood parameter estimation, and Monte Carlo simulation of model and parameter uncertainty, applied to three simple models. Agricultural and Forest Meteorology, 131(3): 191-208.
[69] Liu, M. et al., 2009. Uncertainty analysis of CO_2 flux components in subtropical evergreen coniferous plantation. Science in China Series D: Earth Sciences, 52(2): 257-268.
[70] Richardson, A.D. et al., 2006. A multi-site analysis of random error in tower-based measurements of carbon and energy fluxes. Agricultural and Forest Meteorology, 136(1): 1-18.

To estimate uncertainty of annual sums for emissions and carbon stock changes associated with gap-filling using eddy covariance, project proponents shall use accepted and peer-reviewed methodologies. Monte Carlo or resampling techniques are recommended. System failure and data filtering can lead to gaps in the data which need to be filled in order to calculate annual sums. Most sites experience 35% data loss[71]. If more than 60% of eddy covariance data need to be gap filled, uncertainty in measurements and annual sums are excessively high and alternate measurement methods for measuring emissions and carbon stock changes must be used. There are several approaches for filling data gaps[72]. Generally, the longer the time scale of integration the smaller the uncertainty due to larger sample sizes and the dampening of outliers. Resampling techniques allowing accounting for uncertainties associated with gap-filling.

Project proponents may use the bootstrap resampling technique for estimating error associated with gap-filled annual sums ($\varepsilon_{gapfill}$) he or other appropriate peer-reviewed method. In this method, artificial datasets (of 1000-10000 data points) are created from the observed data using Monte-Carlo techniques Models used for filling gaps are then applied to those data sets. These datasets are used to calculate annual values and the variation across those data is used to estimate a 90% confidence interval around the annual carbon stock changes or GHG emissions[73].

Random measurement error and gap-filling error are calculated using the root-sum-square method[74] and collectively constitute the total eddy covariance uncertainty expressed as a 90% confidence interval around the annual sum, U_{EC}.

$$U_{EC} = \sqrt{\varepsilon_{random}{}^2 + \varepsilon_{gapfill}{}^2} \qquad (40)$$

where $\varepsilon_{gapfill}$ is the 90% confidence interval associated with gap-filled annual sums and ε_{random} is the 90% confidence interval of the total random measurement uncertainty described above.

Systematic Measurement Error

Systematic measurement errors create a constant bias in the data. These errors do not need to be deducted from emission reductions using eddy covariance techniques if they are appropriately avoided or corrected for as per guidelines in the emissions and carbon-stock modules. Systematic errors or biases in the data can be avoided by calibrating instruments properly and meeting assumptions of the eddy covariance technique such as requirements of flat homogeneous terrain and ample turbulence.

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[71] Eva Falge, Dennis Baldocchi, Richard Olson, Peter Anthoni, Marc Aubinet, Christian Bernhofer, George Burba, Reinhart Ceulemans, Robert Clement, Han Dolman, Andre Grainer, Thomas Grunwald, David Hollinger, Niels-Otto Jensen, Gabriel Katul, Petri Keronen, Andrew Kowalski, Chun Ta Lai, Beverly E. Law, Tilden Meyers, Jon Moncrieff, Eddy Moors, J. William Munger, Kim Pilegaard, Ullar Rannik, Corinna Rebmann, Andrew E. Suyker, John Tenhunen, Kevin Tu, Shashi Verma, Timo Vesala, Kell Wilson, and Steve Wofsy, 2001, Gap filling strategies for defensible annual sums of net ecosystem exchange, Agricultural and Forest Meteorology, 107 (2001) 43–69.
[72] Moffat, A.M. et al., 2007. Comprehensive comparison of gap-filling techniques for eddy covariance net carbon fluxes. Agricultural and Forest Meteorology, 147(3): 209-232.
[73] Hirano, T. et al., 2012. Effects of disturbances on the carbon balance of tropical peat swamp forests. Global Change Biology, 18(11): 3410-3422. Also Lui et al. 2009.
[74] Lui et al. 2009.

These errors are also related to advection, drainage effects, storage[75] and roving flux footprints[76] Previous work in the Delta has demonstrated flux footprint issues can create large errors eddy flux measurements[77]. Other systematic biases can be avoided by correcting for high-frequency losses and density fluctuations associated with long tube lengths in closed path systems. For further discussion of systematic errors associated with eddy covariance measurements and how to avoid and correct for them see Richardson et al[78] and the Methods Module.

Estimating uncertainty in biogeochemical modeling

When using process-based biogeochemical models to estimate emission reductions, this protocol requires project proponents to account for model structural error and error associated with data inputs. The uncertainty associated with model inputs and model structural uncertainty shall be incorporated into Equations 2 and 3.

Error Associated with Data Inputs

Project proponents shall estimate random measurement and sampling error associated with data inputs for biogeochemical models[79,80]. Where measurements are replicated in time and space within strata, pools and locations, sampling error can be calculated using the standard error of the mean value of the replicate measurements. For example, initial measurements of soil organic carbon must be replicated across strata. Those measurements will be averaged and the standard error of the mean is used to estimate the spatial uncertainty in soil organic carbon measurements. The estimated uncertainty shall be incorporated into the model uncertainty estimate.

To estimate random measurement error, measurements shall be replicated in the same location during the same timeframe. For example, if LAI is measured using a LAI-2200C Plant Canopy Analyzer (LI-COR, Lincoln, NE, USA), the variance across measurements replicated in the same location can be used to calculate the random error associated with LAI data. Random measurement and sampling errors together comprise the total error associated with each data input. The percent error associated with data inputs (U_{inputs}) is estimated by taking the product of the random and sample errors. Errors are expressed as 90% confidence intervals.

[75]Aubinet, M. et al., 2005. Comparing CO_2 storage and advection conditions at night at different CARBOEUROFLUX sites. Boundary-Layer Meteorol, 116(1): 63-93.
[76] Aubinet, M. et al., 2005. Comparing CO_2 storage and advection conditions at night at different CARBOEUROFLUX sites. Boundary-Layer Meteorol, 116(1): 63-93; and Göckede, M., Markkanen, T., Hasager, C.B. and Foken, T., 2006. Update of a footprint-based approach for the characterisation of complex measurement sites. Boundary-Layer Meteorol, 118(3): 635-655.
[77] Baldocchi, D. et al., 2012. The challenges of measuring methane fluxes and concentrations over a peatland pasture. Agricultural and Forest Meteorology, 153(0): 177-187.
[78] Richardson, A.D. et al., 2012. Eddy covariance: a practical guide to measurement and data analysis. Springer.
[79] Keenan, T.F., Carbone, M.S., Reichstein, M. and Richardson, A.D., 2011. The model–data fusion pitfall: assuming certainty in an uncertain world. Oecologia, 167(3): 587-597, Richardson, A.D. et al., 2010. Estimating parameters of a forest ecosystem C model with measurements of stocks and fluxes as joint constraints. Ibid., 164(1): 25-40.
[80] Richardson, A.D. et al., 2010. Estimating parameters of a forest ecosystem C model with measurements of stocks and fluxes as joint constraints. Oecologia, 164(1): 25-40.

$$U_{inputs} = \prod_i (\sigma_{random_i} + \sigma_{sample_i}) \quad (41)$$

where:

σ_{random_i} is the 90% confidence interval associated with measurements of model inputs in stratum *i*; and

σ_{sample_i} is the 90% confidence interval associated with sample collection in stratum *i*.

Meteorological drivers for the model such as air temperature and available light do not add significant error to the model estimations of emissions and therefore do not need to be accounted for in estimating emission reductions.

Model Structural Error

Model structure uncertainty (U_{struct}) shall be estimated by validation of the model against a year of data that is independent from the data used to calibrate the model. A minimum of 1 year of data will be used for estimates of uncertainty. There are numerous ways of estimating model output uncertainty such as bootstrapping methods discussed above. In addition a $\chi 2$ statistic can be used to determine the uncertainty of the model output. Project proponents shall document appropriate peer reviewed methods and parameters for calculating model uncertainty. As new data and updated model versions become available model structural uncertainty shall be re-evaluated.

Uncertainty Deductions to Emission Reductions

Model uncertainty must be calculated for each year when the carbon stock changes and emissions are estimated. Model estimated uncertainty deductions to emission reductions shall be calculated as follows:

$$ER_{corr} = \sqrt{{U_{inputs}}^2 + {U_{struct}}^2} \quad (42)$$

where:

ER_{corr} is the total model uncertainty expressed as a 90% confidence interval around the annual sum (t CO_2-e);

U_{inputs} is the total uncertainty from model inputs expressed as a 90% confidence interval (t CO_2-e); and

U_{struct} is the model structure uncertainty expressed as a 90% confidence interval (t CO_2-e).

DATA AND PARAMETERS MONITORED

Data /parameter:	$E_{BSL,SS}$
Data unit:	t CO_2-e

Used in Equations:	38
Description	Carbon stock (e.g. soil organic carbon, and emissions if determined significant) for the baseline case.
Source of data:	The terms denoting significant carbon stocks or GHG emissions from Baseline Modules used to calculate emission reductions
Measurement procedures (if any):	
Monitoring frequency:	The monitoring must occur within five years before the start of the project activity and when the baseline is revisited.
Quality Assurance / Quality Control	
Any comment:	Baseline stocks and sources are estimated ex-ante for each baseline period.

Data /parameter:	$E_{P,SS}$
Data unit:	t CO_2-e
Used in Equations:	39
Description	Description: Carbon stock (e.g. soil organic carbon, and emissions if determined significant) for the project case.
Source of data:	The terms denoting significant carbon stocks, or GHG emissions used to calculate net emission reductions from the following relevant modules.
Measurement procedures (if any):	
Monitoring frequency:	Monitoring frequency may range from 5 to 20 years and can be fixed to coincide with the crediting period.
Quality Assurance / Quality Control	
Any comment:	The ex-ante estimation shall be derived directly from the estimations originating in the relevant modules:

Data /parameter:	$U_{BSL,SS}$
Data unit:	%
Used in Equations:	38
Description	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)
Source of data:	Calculations arising from field measurement data.
Measurement procedures (if any):	Uncertainty in pools derived from field measurement with 90% confidence interval calculated as the standard error of the averaged plot measurements in each stratum multiplied by the t value for the 90% confidence level. For emission sources and wetland loss conservative parameters should be used sufficient to allow the uncertainty to be set as zero.
Monitoring frequency:	The monitoring must occur within five years before the start of the project activity and when the baseline is revisited.

Quality Assurance / Quality Control	
Any comment:	Baseline stocks and sources are estimated ex-ante for each baseline period.

Data /parameter:	$U_{P,SS}$
Data unit:	%
Used in Equations:	39
Description	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)
Source of data:	Calculations arising from field measurement data.
Measurement procedures (if any):	Uncertainty in pools derived from field measurement with 90% confidence interval calculated as the standard error of the averaged plot measurements in each stratum multiplied by the t value for the 90% confidence level. For emission sources and wetland loss conservative parameters should be used sufficient to allow the uncertainty to be set as zero.
Monitoring frequency:	Monitoring frequency may range from 5 to 20 years and can be fixed to coincide with the crediting period.
Quality Assurance / Quality Control	
Any comment:	*Ex-ante* the uncertainty in the with-project carbon stocks and sources shall be equal to the calculated baseline uncertainty

(T-RISK) Methodological Module Tool for estimation of non-permanence risk for wetland construction and restoration and rice cultivation in the Sacramento-San Joaquin Delta and San Francisco Estuary

The project will employ the non-permanence risk tool currently approved by ACR as referenced in the *ACR Standard*.

(T-SIG) Methodological Module Tool for significance testing for wetland construction and restoration and rice cultivation in the Sacramento-San Joaquin Delta and San Francisco Estuary

The currently acceptable significance testing tool is the Clean Development Mechanism (CDM) tool for testing significance of GHG emissions which can be found at:

http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-04-v1.pdf/history_view

(T-PLOT) Methodological Module Tool for the calculation of the number of sample plots for measurements for wetland construction and restoration and rice cultivation in the Sacramento-San Joaquin Delta and San Francisco Estuary

The currently acceptable tool is the Clean Development Mechanism (CDM) tool for calculation of the number of sample plots for measurements which can be found at:

http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-03-v2.1.0.pdf/history_view