EXHIBIT
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Hon. Nancy Case Shaffer
Superior Court for the County of Sonoma
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FILED
SUPERIOR COURT OF CALIFORNIA
COUNTY OF SONOMA

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BY M. Conley
Deputy Clerk

SUPERIOR COURT FOR THE STATE OF CALIFORNIA

COUNTY OF SONOMA

CALIFORNIA RIVERWATCH, Petitioner, v. COUNTY OF SONOMA, ET AL. Defendants.	Case No.: SCV-259242 ORDER GRANTING PETITION FOR WRIT OF MANDATE

This matter was tried to the court on March 23, 2017, the Honorable Nancy Case Shaffer presiding. The Law Office of Jack Silver and Jerry Bernhaut and Jack Silver appeared on behalf of Petitioner; the Office of Sonoma County Counsel and Bruce Goldstein and Verne Ball appeared on behalf of Respondent Sonoma County Regional Climate Protection Authority. At the conclusion of the hearing, the court ordered further briefing. The matter was deemed submitted on April 21, 2017, when all briefs were submitted.

I. SUMMARY OF RULING

The court finds that the Sonoma County Regional Climate Protection Authority's Final Programmatic EIR ("the PEIR") for Climate Action 2020 and Beyond, its Climate Action plan ("CAP") and the County of Sonoma's approval of the CAP violate CEQA, in that the inventory of greenhouse gas emissions is based on insufficient information; the PEIR fails to include effectively enforceable, clearly defined performance standards for the mitigation measures regarding Green House Gas ("GHG") emissions, identified as "GHG Reduction Measures;" and fails to develop and fully analyze a reasonable range of alternatives.

Accordingly, the approval of the PEIR was a prejudicial abuse of discretion by Respondent. Given the lack of information and other material defects, as a matter of law the PEIR cannot fulfill its basic CEQA purpose as an information document.

The court finds that there is insufficient information in the administrative record to support the factual conclusion that the CAP will achieve its fundamental purpose of reducing Respondent's countywide GHG emissions to the stated target of 25% below 1990 levels by 2020.

I. FACTS

Petitioner seeks a writ of mandate overturning Respondent's certification and of a Final Programmatic EIR (the PEIR) for its Climate Action Aplan (CAP) and the approval of the CAP on the grounds that the approvals violate CEQA.

A. The Project

The CAP Project is a planning-level document to guide analysis of the greenhouse gas (GHG) impacts of future projects in the county.

In 2006, the California legislature passed AB 32, the Global Warming Solutions Act (the Act) which, among other things, establishes a statewide goal of achieving 1990-level GHG impacts by 2020.

CEQA Guideline 15183.5 allows agencies to adopt an overall long-range plan such as a general plan or similar plan governing GHG analysis of subsequent projects. Respondent adopted the CAP in accord with Guideline 15183.5 as a method of providing an overall *tiered analysis* of GHG impacts in subsequent projects as a method of complying with the Act's mandate. (1 AR 4, 10.)

B. The Petition for Writ of Mandamus

Petitioner argues that the EIR fails to provide an accurate description of the existing conditions or a means for calculating GHG emissions; that the PEIR contains inadequate mitigation measures, alternatives analysis, or response to public comments.

Respondent opposes the petition, contending that Petitioner relies on non-existent requirements in 15183.5; that Petitioner fails to discuss the substantial evidence in the record, that the EIR sufficiently discusses existing conditions; that the PEIR properly discloses methodology; that the CAP is not a mitigation measure and does not need to contain mitigation measures; that substantial evidence supports the CAP emissions reduction estimates; that the alternatives analysis complies with CEQA; that Petitioner failed to exhaust administrative remedies on the responses to comments; and that Petitioner has demonstrated no prejudicial error.

II. ANALYSIS

A. Request for Judicial Notice

The court grants, in full, Respondents' request to take judicial notice of certain government and regulatory documents, including a statement from the Natural Resources Agency on amendments to the Guidelines regarding GHG emissions; the California Air Resources Board ("CARB") Climate Change Scoping Plan; the CARB draft 2030 Target Scoping Plan Update; the County of Napa CAP; Guideline 15183.5, AB32, and SB 97; and the lodgment of the record in this case.

B. CEQA

An EIR is required for a project which substantial evidence indicates may have a significant effect on the environment. (Guidelines for the Implementation of CEQA (Guidelines), 14 CCR section 15063(b)[1]; PRC sections 21100, 21151.) EIRs are, in the words

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[1]These are at 14 Cal Code Regs §§ 15000, *et seq*. Courts should at a minimum afford great weight to the Guidelines except when a section is clearly unauthorized or erroneous under CEQA. *Laurel Heights Improvement Ass'n v. Regents of Univ. of Cal.* (*Laurel Heights I*) (1988) 47 Cal.3d 376, 391, fn 2; *Sierra Club v. County of Sonoma* (1992) 6 Cal.App.4th 1307, 1315.

of the California Supreme Court, "the heart of CEQA." *Laurel Heights Improvement Assn. v. Regents of the University of California* (1988) 47 Cal.3d 376, 392 (*Laurel Heights I*).

The ultimate mandate of CEQA is "to provide public agencies and the public in general with *detailed information* about the effect [of] a proposed project" and to minimize those effects and choose possible alternatives. (emphasis added) (PRC 21061.) The public and public participation hold a "privileged position" in the CEQA process based on fundamental "notions of democratic decision-making." (*Concerned Citizens of Costa Mesa, Inc. v. 32nd District Agricultural Association* (1986) 42 Cal.3d 929, 936.)

As a fundamental benchmark that generally applies to all issues in CEQA the court, is that the court, in considering an issue, should look to see if "the public could discern... the 'analytic route the... agency traveled from evidence to action.'" (See ***Al Larson Boat** Shop Inc. v. Bd. of Harbor Commissioners* (1993) 18 Cal.App.4th 729, 749; see also *Topanga Assn. for a Scenic Community v. County of Los Angeles* (1974) 11 Cal.3d 506, 513-514, 522.)

The burden of investigation rests with the government and not the public. (*Lighthouse Field Beach Rescue v. City of Santa Cruz* (2005) 131 Cal.App.4th 1170, 1202.)

C. Standard of review

1. Preliminary Basis for Standard of Review

The standard of review is in dispute here. This dispute arises out of the divergent characterizations of the issues by the parties.

Public Resources Code section 21168 provides that when a court reviews a determination, finding, or decision of a public agency, "as a result of a proceeding in which by law a hearing is required to be given, evidence is required to be taken and discretion in the determination of facts is vested in a public agency … the court shall not exercise its independent judgment on the evidence but shall only determine whether the act or decision is supported by substantial evidence in the light of the whole record." However, review is *de novo* when the court must determine whether the agency has prejudicially abused its discretion either by failing to proceed in the manner required by law or by reaching a decision that is not supported by substantial evidence. (*Laurel Heights I, supra* 47 Cal.3d 392, fn.5.)

"[A] reviewing court must adjust its scrutiny to the nature of the alleged defect, depending on whether the claim is predominantly one of improper procedure or a dispute over the facts." *Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova* (2007) 40 Cal.4th 412, 435 ("*Vineyard*").

As the court explained in *Vineyard*:

> [A]n agency may abuse its discretion under CEQA either by failing to proceed in the manner CEQA provides or by reaching factual conclusions unsupported by substantial evidence. (§21168.5.) Judicial review of these two types of error differs significantly: while we determine de novo whether the agency has employed the correct procedures, "scrupulously enforc[ing] all legislatively mandated CEQA requirements" (*Citizens of Goleta Valley v. Board of Supervisors* (1990) 52 Cal.3d 553, 564...), we accord greater deference to the agency's substantive factual conclusions. In reviewing for substantial evidence, the reviewing court "may not set aside an agency's approval of an EIR on the ground that an opposite conclusion would have been equally or more reasonable," for, on factual questions, our task "is not to weigh conflicting evidence and determine who has the better argument."(*Laurel Heights I, supra,* 47 Cal.3d at p. 393....) [2]

While courts must give deference as to substantive factual decisions, courts demand strict compliance with "legislatively mandated CEQA requirements." (*Citizens of Goleta Valley v. Bd. of Supervisors* (1990) 52 Cal.3d 553, 564 (*Goleta II*).) A Respondent is entitled to no deference where the law has been misapplied, or where the decision was based on "an erroneous legal standard." (*East Peninsula Educ. Council, Inc. v. East Peninsula Unif. Sch. Dist.* (1989) 210 Cal.App.3d 155, 165.)

Courts must 'determine de novo whether the agency has employed the correct procedures, "scrupulously enforc[ing] all legislatively mandated CEQA requirements"....' (*Vineyard Area Citizens for Responsible Growth, supra,* 40 Cal.4th 435, citing *Goleta II,* 52 Cal.3d at 564.) *Failure to include required information is a failure to proceed in the manner*

[2] *Laurel Heights I* is *Laurel Heights Improvement Assn. v. Regents of University of California* (1988) 47 Cal.3d 376, 400 (*Laurel Heights I*

required by law and demands strict scrutiny. (*Sierra Club v. State Bd. of Forestry* (1994) 7 Cal.4th 1215, 1236; *Vineyard, supra,* 40 Cal.4th at 435.) The court reviews the PEIR here de novo.

Nevertheless, agency actions are presumed to comply with applicable law unless the petitioner presents proof to the contrary. (Evid. Code § 664; *Foster v. Civil Service Commission of Los Angeles County* (1983) 142 Cal.App.3d 444, 453.) The petitioner in a CEQA action thus has the burden of proving that an EIR is insufficient. (*Al Larson Boat Shop, Inc. v. Board of Harbor Commissioners* (1993) 18 Cal.App.4th 729, 740.)

2. Standard of Review: Substantial-Evidence Test

The substantial-evidence test applies to substantive issues in a decision certifying an EIR. The court must uphold the decision if it is supported by substantial evidence in the record as a whole. (*Bowman v. City of Petaluma* (1986) 185 Cal.App.3d 1065, 1075; see *River Valley Preservation Project v. Metropolitan Transit Dev. Bd.* (1995) 37 Cal.App.4th 154, 166; see *Santa Teresa Citizen Action Group v. City of San Jose* (2003) 114 Cal.App.4th 689, 703. The "substantial evidence" test requires the court to determine "whether the act or decision is supported by substantial evidence in the light of the whole record." (*Chaparral Greens v. City of Chula Vista* (1996) 50 Cal.App.4th 1134, 1143; *River Valley Preservation Project v. Metropolitan Transit Develop. Bd.* (1995) 37 Cal.App.4th 154, 168.)

When applying the substantial-evidence standard, the court must focus not upon the "correctness" of a report's environmental conclusions, but only upon its "sufficiency as an informative document."(*Laurel Heights I* 47 Cal.3d at 393.) The findings of an administrative agency are presumed to be supported by substantial evidence. *(Taylor Bus. Service, Inc. v. San Diego Bd. of Education* (1987) 195 Cal.App.3d 1331.) The court must resolve reasonable doubts in favor of the findings and decision. *(Id.)*

A claim that the EIR lacks *sufficient* information regarding an issue will be treated as an argument that the EIR is not supported by substantial evidence. (*Barthelemy v. Chino Basin Munic. Water Dist.* (1995) 38 Cal.App.4th 1609, 1620.) The petitioners in *Barthelemy* asserted that it was a failure to proceed in the manner required by law where an EIR did not include key information. The court rejected that argument.

a) The Definition of "Substantial Evidence"

Substantial evidence is "enough relevant information and reasonable inferences" to allow a "fair argument" supporting a conclusion, in light of the whole record before the lead agency. (14 CCR § 15384(a); PRC §21082.2; *City of Pasadena v. State of California* (2nd Dist.1993) 14 Cal.App.4th 810, 821-822.) Other decisions define "substantial evidence" as that with "ponderable legal significance," reasonable in nature, credible, and of solid value. (*Stanislaus Audubon Society, Inc., v. County of Stanislaus* (1995) 33 Cal.App.4th 144.)

Substantial evidence includes facts, reasonable assumptions predicated upon facts, and expert opinion supported by facts. (PRC §21082.2(c); see also Guidelines 15064(g)(5), 15384.) It does not include argument, speculation, unsubstantiated opinion or narrative, clearly incorrect evidence, or social or economic impacts not related to an environmental impact. (Guideline 15384.)

3. Prejudicial Abuse of Discretion

A court may only issue a writ in a CEQA case for an abuse of discretion, including making a finding without substantial evidence, if the error was *prejudicial*. (*Chaparral Greens v. City of Chula Vista* (1996) 50 Cal.App.4th 1134, 1143.) The court must defer to the agency's substantive conclusions an uphold the determination unless. ((Id)*; see* PRC § 21168, 21168.5, *Laurel Heights I, supra,* 47 Cal.3d at 392, fn.5; Remy, et al., Guide to the California Environmental Quality Act (10th Ed.1999) Chapter XI (D), p.590.)

4. Tiered EIRs

As discussed further below, the PEIR here is a tiered EIR prepared in accordance with Guideline 15183.5, which specifically allows for preparation of an overall, first-tier EIR and planning document to govern analysis of GHG emissions and control GHG emissions in order to comply with the statewide mandates to reduce GHG emissions.

A tiered EIR scheme allows an agency to produce a general EIR focusing on an overall plan or policy and later conduct more limited, narrow subsequent EIR review for individual projects within the broad plan or scope of the original, general EIR. (PRC 21068.5, 21093(a); Guideline 15152; *Koster v. County of San Joaquin* (1996) 47 Cal.App.4th 29, 36.) "Tiering" is defined in PRC 21068.5 as:

> coverage of general matters and environmental effects in an [EIR] prepared for a policy, plan, program or ordinance followed by narrower or site-specific [EIRs] which incorporate by reference the discussion in any prior [EIR] and which concentrate on the… effects which (a) are capable of being mitigated, or (b) were not analyzed… in the prior [EIR].

In other words, it is 'a process by which agencies can adopt programs, plans, policies, or ordinances with EIRs focusing on "the big picture" and can use streamlined CEQA review for individual projects that are consistent with such… [first tier plans]….' (*Koster v. County of San Joaquin* (3d Dist. 1996) 47 Cal.App. 4th 29, 36.) The later EIRs need not repeat the analysis or revisit the issues from the original EIR. (Guideline 15385.)

Guideline 15152 is the overall provision governing first-tier documents in general and in its detailed discussion demonstrates clearly what such documents must do, what they must include, and how they may be used.[i] Environmental impact reports "shall be tiered whenever feasible, as determined by the lead agency." (PRC 21093(b).) This "is needed in order to provide increased efficiency in the CEQA Process. It allows agencies to deal with broad environmental issues in EIRs at planning stage and then to provide more detailed examination of specific effects....These later EIRs are excused by the tiering concept from repeating the analysis of the broad environmental issues examined in the [first tier] EIRs." (Discussion following Guideline 15385.)

PRC 21094(c) states that "[f]or purposes of compliance with this section, an initial study shall be prepared to assist the lead agency in making the determinations required by this section."

C. GREENHOUSE GAS EMISSIONS

The Global Warming Solutions Act ("the Act") 'implements deep reductions in greenhouse gas emissions, recognizing that "[g]lobal warming poses a serious threat to the economic well-being, public health, natural resources, and the environment of California...." (Health & Saf.Code, § 38501, subd. (a).) Through this enactment, the Legislature has expressly acknowledged that greenhouse gases have a significant environmental effect.' (*Communities for a Better Environment v. City of Richmond* (2010) 184 Cal.App.4th 70, 91 (*CEB*).) Guideline 15183.5 governs tiering and streamlining the analysis of GHG emissions.[ii] Subdivision (b) sets forth the specific things such a plan should do.

1. The Role of the CAP in Subsequent GHG Analysis

A key issue is the ultimate role this CAP will play in subsequent GHG analysis of future projects. Here neither party clearly addresses the intended role and effect of the CAP in the review of subsequent projects.

The CAP at 1013-1016 generally indicates that the CAP is intended to eliminate any need to conduct any GHG analysis in future discretionary projects that comply with the CAP. Specifically, the introduction to the checklist of standards and measures, states that:

> Discretionary projects that utilize the checklist, as modified by the individual agency, and can demonstrate consistency with all applicable mandatory local or regional measures in the CAP, can conclude that their impacts related to [GHG] emissions would be less than significant under CEQA because the project would be consistent with a qualified GHG reduction plan under... Guidelines Section 15183.5.

The introduction then quotes 15183.5(b) and (b)(2) in part as follows:

> (b) Pursuant to sections 15064(h)(3) and 15130(d), a lead agency may determine that a project's incremental contribution to a cumulative effect is not cumulatively considerable if the project complies with the requirements in a previously adopted plan or mitigation program under specified circumstances.
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> ...
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> (b)(2) A plan for the reduction of greenhouse gas emissions, once adopted following certification of an EIR or adoption of an environmental document, may be used in the cumulative impacts analysis of later projects. An environmental document that relies on a greenhouse gas reduction plan for a cumulative impacts analysis must identify

> those requirements specified in the plan that apply to the project, and, if those requirements are not otherwise binding and enforceable, incorporate those requirements as mitigation measures applicable to the project.

It reiterates that the 'significance threshold for projects using the checklist for streamlining is "consistency with an applicable plan for the reduction of [GHG] emissions meeting the requirements of...15183.5" ' All of this indicates an intent that a future project complying with this CAP and its standards and measures need include no independent GHG analysis.

2. Respondent's Contention That Petitioner Imposes Non-Existent Requirements

Respondent argues, that Petitioner is improperly trying to impose requirements on the CAP that do not exist in Guideline 15183.5. This argument is expressly stated at the start of its brief and is repeated throughout its papers. This argument is itself groundless; it is contrary to the fundamental purpose of CEQA requirements.

First, Respondent contends that the Guideline merely gives a list of what such a plan "should" do; not what it "must" do. Although the Guideline does only state what such a plan "should" include, (see end note ii, Guideline 15183.5), it expressly states that it is a tiering mechanism and that it must comply with the standards for first-tier programs or plan EIRs. It is *titled* "*Tiering* and Streamlining the Analysis of Greenhouse Gas Emissions." (Emphasis added.) It beings by explaining that agencies may develop a GHG plan or standards in a plan using a tiering method, governed by the standards for tiering. It states that agencies *may* handle GHG analysis:

> at a *programmatic* [i.e., first-tier] level, such as in a general plan, a long range development plan, or a separate plan to reduce greenhouse gas emissions. *Later* project-specific environmental documents *may tier from* and/or incorporate by reference that existing programmatic review. Project-specific environmental documents *may* rely on an EIR containing a programmatic analysis of greenhouse gas emissions as provided in *section 15152 (tiering), 15167 (staged EIRs) 15168 (program EIRs)*, 15175-15179.5 (Master EIRs), 15182 (EIRs Prepared for Specific Plans), and 15183 (EIRs Prepared for General Plans, Community Plans, or Zoning).

(emphasis added.)

As noted above, the CAP also makes it clear that, as a first-tier document, it is to be used in such a manner that, if complied with, will excuse the analysis of a future project from revisiting GHG emissions. Therefore, the CAP, and any such plan prepared under 15183.5, must meet the requirements for all first-tier documents and thus must impose effectively enforceable requirements and measures with defied performance standards.

Second, although Respondent is correct that the requirements on which Petitioner relies are not necessarily in the Guideline itself, they are applicable to *all* CEQA review and, specifically, to first-tier documents, as explained above. Petitioner's further arguments, such as that the CAP must provide a clear, complete, and accurate GHG "inventory," i.e., the existing GHG emissions associated with activities in the county, are consistent with a standard CEQA mandate, which is that an environmental document must present clear, meaningful information sufficient to allow the agency and public to make an intelligent, informed decision, or, stated another way, sufficient to make clear the analytic route of the agency. (*Concerned Citizens of Costa Mesa, Inc. v. 32nd District Agricultural Association* (1986) 42 Cal.3d 929, 936; ***Al Larson Boat** Shop Inc. v. Bd. of Harbor Commissioners, supra,* 18 Cal.App.4th at 749; *Topanga Assn. for a Scenic Community v. County of Los Angeles* (1974) 11 Cal.3d 506, 513-514, 522. Therefore, it must be based on substantial evidence. (See section C.2., above.)

3. Existing Conditions

Petitioner first argues that the PEIR fails to describe existing conditions accurately because it limits the range of emissions from vehicles miles traveled (VMT) associated with land-use activities in the county and to and from 18 nearby regional locations. Petitioner contends that the baseline or current GHG emissions level associated with the county should include all VMT for trips associated with activities in the county, not only within the county and to and from the 18 nearby regional locations used in the PEIR and that Respondent thus understates the current GHG emissions. Respondent focuses on two general categories of VMT omitted from the PEIR: VMTs generated by goods exported from the county to locations beyond (produce, medical equipment, beer, and wine) , and tourist travel to Sonoma County.

a) CEQA Baselines and Quantifying Current GHG Levels

Ordinarily, an EIR must clearly and consistently describe the baseline, which is *normally* the *existing* environmental setting or conditions. The existing conditions, at the time the notice of preparation ("NOP") is published, "normally constitute the baseline physical conditions by which the lead agency determines whether an impact is significant." (Guideline 15125(a).) Guideline 15126.2(a) states that the agency "should normally limit its examination to changes in the existing physical conditions in the affected area as they exist at the time...environmental analysis is commenced."

Guideline 15183.5(b)(1)(A) sets forth special requirements for GHG first-tier plans such as the CAP. Such plans are required to "[q]uantify greenhouse gas emissions, both existing and projected over a specified time period, resulting from activities within a defined geographic area."

Respondent notes that the ordinary requirements governing determination of the "baseline" apply where there is a project that may alter this in of itself in order to determine the extent of any impact which a project will have. (See Guideline 15126.2(a).)

b) VMT Data

The CAP explanation of how it determined the GHG inventory is found at AR 1050, et seq. It used 2010 data because that year includes largely complete or complete activity data for all sectors as needed to calculate GHG levels; this is not challenged by Petitioner. (See AR 1052; Memorandum of Points and Authorities in Support of Petition for Writ of Mandate, 9:1-3.) The response to comment at AR 1084 explains that the VMTs were determined by considering the travel in the county plus travel between the county and 18 external "traffic analysis zones" ("TAZ").

Respondent relies on Guideline 15130(b) which provides that studies of cumulative impacts are guided by "standards of practicality and reasonableness." According to Guideline 15364, '"Feasible" means capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, legal, social, and technological factors.' Thus, "[a]n evaluation of the environmental effects of a proposed project need not be exhaustive, but the sufficiency of an EIR is to be reviewed in the light of what is reasonably feasible .... The courts have looked not for perfection but for adequacy, completeness, and a good faith effort at full disclosure." (Guideline 15151; see also *Citizens to Preserve the Ojai v. County of Ventura, supra,* 176 Cal.App.3d at 429.) Petitioner argues that an agency is "not required to engage in sheer speculation as to future environmental consequences [Citations], [but an] EIR [is] required to set forth and explain the basis for any conclusion that analysis of the cumulative impact of offshore emissions [is] wholly infeasible and speculative." (*Citizens to Preserve the Ojai, supra,* 176 Cal.App.3d at 430.)

Respondent correctly argues that ultimately GHG emissions must be considered in light of their cumulative worldwide impact because of their nature. The Supreme Court in *Center for Biological Diversity v. California Dept. of Fish and Wildlife* (2015) 62 Cal.4th 204, at 219-220, considered a challenge to an agency's GHG analysis. The Court explained:

> [W]e address two related aspects of the greenhouse gas problem that inform our discussion of CEQA significance.
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> First, because of the global scale of climate change, *any one project's contribution is unlikely to be significant* by itself. *The challenge for CEQA purposes is to determine whether the impact of the project's emissions of greenhouse gases is cumulatively considerable*, in the sense that "the incremental effects of [the] individual project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects." (§ 21083, subd. (b)(2); see Guidelines, § 15064, subd. (h)(1).) "With respect to climate change, an individual project's emissions will most likely not have any appreciable impact on the global problem by themselves, but they will contribute to the significant cumulative impact caused by greenhouse gas emissions from other sources around the globe. *The question therefore becomes whether the project's incremental addition of greenhouse gases is 'cumulatively considerable' in light of the global problem*, and thus

> significant." (Crockett, Addressing the Significance of Greenhouse Gas Emissions Under CEQA: California's Search for Regulatory Certainty in an Uncertain World (July 2011) 4 Golden Gate U. Envtl. L.J. 203, 207–208 (hereafter Addressing the Significance of Greenhouse Gas Emissions).)
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> Second, the global scope of climate change and the fact that carbon dioxide and other greenhouse gases, once released into the atmosphere, are not contained in the local area of their emission means that *the impacts to be evaluated are also global rather than local. For many air pollutants, the significance of their environmental impact may depend greatly on where they are emitted; for greenhouse gases, it does not.* For projects, like the present residential and commercial development, which are designed to accommodate long term growth in California's population and economic activity, this fact gives rise to an argument that a certain amount of greenhouse gas emissions is as inevitable as population growth. Under this view, a significance criterion framed in terms of efficiency is superior to a simple numerical threshold because CEQA is not intended as a population control measure.

(emphasis added.)

Consistent with the Supreme Court's discussion in that case, the EIR here expressly discusses the global nature of GHG emissions, explaining that "unlike other resource areas that are primarily concerned with localized project impacts… the global nature of climate change requires a broader analytic approach. Although this section focuses on GHG emissions generated as a result of the CAP, the analysis considered them in the context of potential state, national, and global GHG impacts." (AR 314.) It also noted global GHG concentrations. (AR 81, 106, 316.)

The PEIR analysis considered VMT for the county and the 18 TAZs in the region, and only for automobile traffic and "emissions that local governments have primary influence or control over." (AR 85.) It did not consider travel by other means such as by airplane or emissions over which the local entities have no direct control. (AR 85.) The PEIR explained at AR 82 and 85 that it was relying on the International Council for Local Environmental Initiatives (ICLEI) Protocol and that:

> the ICLEI Community Protocol does not require air travel emissions to be included in the basic emissions necessary for protocol-compliance GHG inventories because it recognizes that local governments have less control over such sources as air travel and that information is often not available to precisely describe an airport's emissions to a specific community.

Similarly, it noted that methodologies exist to estimate emissions further afield but associated with local activities but rejected these methodologies because the information might be difficult to obtain or are not "common" approaches. (AR 85-86.) For example, the response to the comment at AR 85-86 stated:

> [w]hile there are methodologies to estimate upstream emissions…, these methodologies are commonly used to prepare what is known as a "consumption-based" inventory, which estimate the life cycle "carbon footprint" of everything households (and…other consumers) consume. There are also methodologies to estimate "downstream" emissions associated with the transportation, end use, and disposal of goods produced in a jurisdiction, but such methodologies require highly detailed information about the entire downstream supply chain, including the ultimate geographical destination of goods that can be difficult to come by, especially if such data is privately held. While one could estimate emissions using a consumption-based approach of a "downstream" emissions method, these are not the common approach used for community emissions, or national emissions at present, and if used, would make it impossible to compare regional inventories.

As a result, the response contends, "nearly every" national, state, and local agency preparing a CAP has used the "activity-based" approach to calculate and define the GHG inventories. (AR 86.) Respondent asserts that by avoiding the methodologies which include upstream or downstream data, and instead using the ICLEI Protocol, the CAP inventory "can be compared to those other communities, using a common standard…." (Ibid.)

The question before the court is whether there is information in the record showing that Respondent might or might not feasibly have included the additional data as Petitioner contends, or whether Respondent did not need to include it.

Respondent's primary argument that it did not need to include additional emissions estimates is based on its assertion that CEQA only requires an agency to do what is feasible, and further that it need not, and should not, engage in speculation over data that is unknowable. The basic that a public agency is only required to do what is feasible, discussed above, is correct, but Respondent has not persuasively shown that it defeats Petitioner's arguments regarding the need for more information about MVT. The response to comments at AR 84-86 expressly admits that there are methodologies to quantify the additional sources of GHG emissions Petitioner identifies, but did not use them because they are not "commonly" used or the information "can be difficult to come by." This argument does not establish that Respondent had substantial evidence to support its approval.

The record, including the admissions in the PEIR shows that Respondent had a feasible ability to include the additional GHG data. Respondent compares the data used in this CAP to that used by other agencies. (AR 86; generally AR 84-86.) This is a logical explanation for employing the ICLEI Protocol used, but it does not demonstrate that it was "infeasible" to obtain the additional MVT data, especially given that Respondent acknowledges that the methodologies exist.

Had the EIR explained that it was unable to obtain the necessary information, or that there were no methodologies that it could have used to obtain/include it, Respondent's would have been justified in failing to obtain this data. However, here, Petitioner complains that Respondent appears merely to have avoided including greater, more complete, information based on the assumption that it would be "too much work."

The court grants the petition on this point.

D. MITIGATION MEASURES

Petitioner also argues that Respondent failed to adopt "definite, clearly defined and enforceable" mitigations measures. It contends that at least some of the mitigation measures and standards it sets forth are unclear, vague, and not fully enforceable. Petitioner points out that the EIR concludes that the CAP would be "beneficial" and would thus support applicable regulatory plans for reducing GHG emissions, so, it contends, no mitigation for GHG emissions is necessary. (AR 204.)

Respondent argues that the CAP is not intended as a mitigation measure. No mitigation is needed because it is a plan to reduce GHG emissions in subsequent projects.

What Petitioner contends is not that the CAP and EIR need to adopt mitigation measures for the CAP itself, but instead that the CAP, in setting forth purported mitigation measures for future analysis and handling of GHG emissions, fails to present sufficient clearly defined and enforceable mitigation measures and standards.

Respondent points out this is not a "project" in the sense of an activity that will do anything that might create GHG emissions but instead is a plan for handling analysis and mitigation of GHG emissions in future projects. Therefore, there is clearly nothing about this Project to mitigate. Petitioner's contention that the PEIR should imposing sufficiently defined and enforceable mitigations measures, is a different issue.

Guideline 15183.5(b)(1)(D) and (E) are instructive. Subdivision (D) states that the plan should "*[s]pecify measures or a group of measures, including performance standards*, that substantial evidence demonstrates, if implemented on a project-by-project basis, would collectively achieve the specified emissions level. Subdivision (E) states that the plan should "[e]stablish a mechanism to monitor the plan's progress toward achieving the level and to require amendment if the plan is not achieving specified levels." (Emphasis added.)

1. Role and Purpose of Mitigation Measures in CEQA

Mitigation measures are needed, even required, where a project may have a significant impact and the purpose of the measures is to reduce any impact to less than significant. (PRC 21003.1(b); Guideline 15002(a)(3).)

2. Deferral of Mitigation

In general, it is improper for an agency to rely on *deferred* mitigation. (*Sundstrom v. County of Mendocino* (1988) 202 Cal.App.3d 296, 306; *Defend the Bay v. City of Irvine*

(2004) 119 Cal.App.4th 1261, 1275-1276.) An agency cannot find a significant impact to be mitigated to a less-than-significant level based on a deferred mitigation measure. (*Sundstrom v. County of Mendocino, supra,* 202 Cal.App.3d at 306. It is a violation of CEQA when an agency "simply requires a project applicant to obtain a biological report and then comply with any recommendations that may be made in the report. [Citation.]" (*Defend the Bay v. City of Irvine* (2004) 119 Cal.App.4th 1261, 1275; see also *Endangered Habitats League, Inc. v. County of Orange* (2005) 131 Cal.App.4th 777, 793.)

"Deferral of the specifics of mitigation is permissible where the local entity commits itself to mitigation and lists the alternatives to be considered, analyzed and possibly incorporated in the mitigation plan." (*Defend the Bay v. City of Irvine* (2004) 119 Cal.App.4th 1261, 1275-1276; see also *Sacramento Old City Assn. v. City Council* (1991) 229 Cal.App.3d 1011, 1028-1030.) This applies where "mitigation is known to be feasible, but where the practical considerations prohibit devising such measures early," so that "[w]here future action to carry a project forward is contingent on devising means to satisfy such criteria, the agency should be able to rely on its commitment as evidence that significant impacts will in fact be mitigated." (*Sacramento Old City Assn., supra*, 229 Cal.App.3d at 1028-1029.)

Because of the nature of first-tier tier EIRs, in particular, deferral of the specifics of mitigation measures, as long as they contain clear performance standards, is particularly appropriate and logical. (See, e.g., *Rio Vista Farm Bureau Center v. County of Solano* (1st Dist.1992) 5 Cal.App.4th 351 ("*Rio Vista Farm Bureau*"); *Al Larson Boat Shop Inc. v. Bd. of Harbor Commissioners, supra,* 18 Cal.App.4th 729.) In *Rio Vista Farm Bureau*, a first-tier "program EIR" serving as "primary planning document for hazardous waste management in the county" was found to contain sufficient mitigation measures adopted as policies to guide subsequent projects. The court rejected a challenge based on the assertion that the mitigation measures were "vague, inconclusive, and even inconsistent," finding the measures sufficient "given the broad, nebulous scope of the project under evaluation." (*Rio Vista Farm Bureau, supra,* 5 Cal.App.4th at 376.) The court found that the specificity of mitigation measures should be proportionate to the specificity of the underlying project, which in that case was a broad planning document to guide later site-specific projects.

The court in *Coastal Hills Rural Preservation v. County of Sonoma* (2016) 2 Cal.App.5th 1234, 1258, upholding the trial court's order denying a CEQA petition for writ of mandate, explained that although "CEQA usually requires mitigation measures to be defined in advance" and not deferred, "deferral [of mitigation measures] is permitted if, in addition to demonstrating some need for deferral, the agency (1) commits itself to mitigation; and (2) spells out, in its environmental impact report, the possible mitigation options that would meet "specific performance criteria" contained in the report."

In *Sundstrom*, *supra*, the county required future hydrological studies as conditions of a use permit and required that any mitigation measures that the study suggested would become mandatory. This was held to be improper because the impacts and mitigation measures were not determined.

The court in *Gentry v. City of Murrieta* (1995) 36 Cal.App.4th 1359 found an Negative Declaration defective because it improperly relied on deferred formulation of specific mitigation measures. There, the city required the applicant to comply with any existing ordinance protecting the Stephens' kangaroo rat and allowed the city to require a biological report on the rat and compliance with any recommendations in the report. The court found this to be insufficient because it, like the approval in *Sundstrom*, was based on compliance with a report that had not yet even been performed.

By contrast, the court in *Schaeffer Land Trust v. San Jose City Council* (1989) 215 Cal.App.3d 612, upheld an Negative Declaration for a general plan amendment for a parcel of land which, regarding traffic issues, required any future development to comply with applicable "level of service" standards. Unlike the other cases mentioned above, here the mitigation measures were delayed because the development and impacts were not concrete, but the mitigation was fixed to set standards which, by definition, ensured that there would be no significant impact. Mitigation with deferred specifics was found to satisfy CEQA where the lead agency had committed to mitigation meeting a specified range of criteria and project approval required the developer to obtain permits and adopt seven itemized measures in coordination and consultation with relevant agencies. *Defend the Bay, supra,* 1276.

In *Endangered Habitats League, Inc. v. County of Orange* (2005) 131 Cal.App.4th 777, 794, the court found a mitigation measure that required replacement habitat preservation to satisfy CEQA even though the specifics were not fully determined but where the approval set forth *specific possibilities and parameters that the mitigation needed to meet.*

3. The Role of the CAP in Subsequent GHG Analysis

The key issue here in determining the sufficiency of mitigation measures is the role this CAP is intended to play in s GHG analysis of future projects. As noted above, one aspect of first-tier plans and EIRs is that they may obviate the need for later projects falling within their ambit to conduct new CEQA review on certain issues where the future projects comply with the first-tier plan. Any later discretionary project that complies with its criteria, such as the standards and requirements it imposes, would not need to do further study of GAG emissions. Accordingly, the standards and requirements the CAP imposes for reducing or minimizing GHG emissions must be considered mitigation measures for purposes of CEQA and must comply with the CEQA requirements. This means that they must set forth clearly defined and enforceable performance standards to be met. Because of the intended streamlining, Petitioner correctly contends that the performance standards and measures set forth the PEIR must be clear, definite, and enforceable.

Here also, Respondent contends that Petitioner is imposing requirements and standards that do not exist in Guideline 15183.5. Respondent ignores the fundamental CEQA requirements which underlie Petitioner's claims. Respondent contends that Guideline 15183.5 does not require mitigation measures for the CAP or within the CAP imposed on future projects. This position not only conflicts with 15183.5 itself, it is fundamentally contrary to the principles of CEQA review.

It is axiomatic in CEQA that any measures or requirements imposed be sufficiently defined to be enforceable and that, in the context of tiering, any subsequent project may avoid analysis of an issue only if it complies with a first-tier document that satisfies CEQA requirements. As noted above, PRC 21094(a) states that where a prior first-tier EIR has been certified and applies to a subsequent project, the agency "*need not examine those effects which … were either (1) mitigated or avoided…* as a result of the prior [EIR] *or (2) examined at a sufficient level of detail in the prior [EIR] to enable those effects to be mitigated or avoided by site specific revisions, the imposition of conditions, or by other means….*" Accordingly, to obviate the need to address an issue or impact as part of a later project's CEQA review, a first-tier plan or program document and EIR must sufficiently analyze that issue or impact to determine that compliance with the document and its mitigations will mitigate or avoid the impact. The mitigation requirements in a first-tier document for avoiding or mitigating the impact *must* include performance standards that are mandatory and include specific, and effectively enforceable performance standards. (*Coastal Hills Rural Preservation v. County of Sonoma* (2016) 2 Cal.App.5th 1234, 1258.)

The prior discussion of Guideline 15183.5 addresses the impact of tiering mechanisms. Again, the CAP, and any such plan prepared under 15183.5, must meet the requirements for all first-tier documents and thus must impose effectively enforceable requirements and measures with defied performance standards.

Further, Guideline 15183.5 *does require the CAP to impose mitigation measures* on future projects. As both Respondent and the CAP itself acknowledge, and as noted above, subdivision (b) expressly states that "a lead agency may determine that a project's incremental contribution to a cumulative effect is not cumulatively considerable *if* the project complies with *the requirements* in a previously *adopted plan or mitigation program* under specified circumstances." This plan or mitigation program, i.e., the CAP, according to (b)(2), "*may* be used in the cumulative impacts analysis of later projects" which clearly means that it need not. However, (b)(2) continues to state that *if it is* so used for a later project, that project must comply with the requirements and mitigation measures from the CAP. Once again, in the Guideline's words, a later project that in fact "relies on [the CAP] for a cumulative impacts analysis *must* identify those *requirements specified in the plan* that apply to the project, and, *if* *those requirements are not otherwise binding and enforceable, incorporate those requirements as mitigation measures....*"

In countering Petitioner's complaint that some of the so-called measures or standards are too vague or loose or ill-defined to be properly enforceable, Respondent asserts that this will be "cured" because Guideline 15183.5(b)(2) states that any requirements that are not "binding and enforceable" will be incorporated as mitigation measures in the project's CEQA document. This "interpretation" does not withstand scrutiny. As explained above, a first-tier document, in order to be used to avoid revisiting analysis of an issue in a later project, must have sufficiently analyzed the issue and found any significant impact to be mitigated or avoided by complying with the document. That means that any requirement, such as mitigation, must have sufficiently defined, clear, and mandatory performance standards to be effectively enforceable and to have predictable results. If the requirements or measures are so ill-defined as to be unenforceable as a practical matter, and effectively meaningless, merely "incorporating" them into the later project's CEQA document will obviously not fix that problem. What the state in the Guideline must mean, therefore, is not that an ineffective measure may simply be incorporated into a later project's document, as Respondent asserts, but that a measure or requirement must be incorporated in the document *if it is not enforced independently, or through some other mechanism.*

4. The Measures in the CAP

The CAP sets forth requirements and standards or mitigation measures at AR 1015-1048.

Respondent primarily argues that under Guideline 15183.5(b)(2), any measure which the CAP imposes and which is "not otherwise binding and enforceable" must be incorporated into future projects. As addressed above, this argument is not meritorious. Guideline 15183.5(b)(2) expressly requires that:

"A*n environmental document that relies on a greenhouse gas reduction plan for a cumulative impacts analysis must identify those requirements specified in the plan that apply to the project, and, if those requirements are not otherwise binding and*

> *enforceable, incorporate those requirements as mitigation measures* applicable to the project. *If there is substantial evidence that the effects* of a particular project *may be cumulatively considerable notwithstanding the project's compliance with the specified requirements in the plan* for the reduction of greenhouse gas emissions, *an EIR must be prepared* for the project.

(emphasis added.)

Petitioner singles out three of the specific measures or requirements in the CAP for discussion as demonstrating a lack of meaningful enforceability and clear standards.

a) 5-R4 (AR 1026)

The first is 5-R4 (AR 1026.) This "trip-reduction ordinance" requires employers with 50+ employees to offer one of several options to employees in order to reduce GHG emissions: "pre-tax transit expenses, transit or vanpool subsidy, free or low cost shuttle, *or an alternative benefit*." (Emphasis added.) It is the latter to which Petitioner objects, arguing that it is vague and undefined either in what it must be like or what it must achieve, so that there is no way to enforce this. As a result, Petitioner contends, a project could offer as "alternative benefit" which no-one can at this point predict, and argue that it need not do GHG analysis because it has "complied" with this measure. Respondent contends that an alternative of purchasing GHG offsets is considered and this is correct but this is not the definition of "an alternative benefit," which is left open and could be anything. Petitioner is correct on this point.

Respondent contended that Petitioner failed to exhaust administrative remedies on this specific issue.

According to PRC section 21177, "[a] person shall not maintain an action or proceeding unless that person objected to the approval of the project orally or in writing during the public comment period provided by this division or prior to the close of the public hearing on the project before the filing of the notice of determination." This does not, however, bar an association or organization formed after approval from raising a challenge which one of its constituent members had raised, directly or by agreeing with or supporting another's comments. (PRC section 21177(c).) Moreover, someone may file a legal challenge based on an issue as long as "any person" raised that issue during the review process. PRC section 21177(a); see *Friends of Mammoth v. Board of Supervisors* (1972) 8 Cal.3d 247, 267-268. It also does not apply to any grounds of which the agency did not give required notice and for which there was no hearing or opportunity to be heard. PRC section 21177(e).

A party challenging decision under CEQA cannot, to exhaust administrative remedies, rely merely on "general objections" or "unelaborated comments." *Sierra Club v. City of Orange* (2008) 163 Cal.App.4th 523, 535; *Coalition for Student Action v. City of Fullerton* (1984) 153 Cal.App.3d 1194, 1197. However, "[l]ess specificity is required to preserve an issue for appeal in an administrative proceeding than in a judicial proceeding…." *Citizens Association for Sensible Development of Bishop Area v. County of Inyo* (1985) 172 Cal.App.3d 151, 163.

Petitioner responds that only the substance of the issue must be raised at the administrative level, relying on *Save Our Residential Environment v. City of West Hollywood* (1992) (Cal.App.4th 1745, 1750.) And further that less specificity is required to exhaust an issue in an administrative proceeding that in a judicial one, relying on *Woodword park Homeowners Assn. v. City of Fresno* (2007) 150 Cal.appp.4th 683, 712 and *Brothers Real Estate Group v. City of Los Angeles* (2008) 153 Cal.App.4th 1385, 1395. The court finds that Petitioner did articulate this as a basic contention in the underlying administrative proceedings. (AR 66 and AR 67.)

b) 4-L-1 (AR 1024)

Petitioner's attack 4-L-1, at AR 1024, which requires consistency with applicable "adopted policies" on mixed-use and transit-oriented development, such as zoning codes, general plans, etc., and states that agencies must "support mixed use [sic] development in city-centers and transit-oriented development locations through their General Plans, etc." is not persuasive. Petitioner contends that this is too vague because "mixed-use" has been interpreted to allow hotels and tourist destinations built downtown or near rail stations. Petitioner focuses on one portion of this requirement that is open-ended. Nothing indicates that the type of use that could be allowed in a mixed-use development, whether store, museum, eatery, office, or hotel, has any bearing on GHG emissions. Petitioner cites no evidence or explanation in support of this claim and does not explain how this is material. What matters is that there are clear, adopted standards mandating such development and Petitioner does not challenge that portion of the measure at all.

It is possible that the measure could be found too vague and Petitioner may be challenging it on that basis as well. Petitioner refers to it when mentioning how an "undefined alterative… lacks the required specificity" and Petitioner again mentions it on the following page with reference to "tentative plans" for future mitigation in ill-defined subsequent regulation to be adopted. This, merely requires each jurisdiction to "identify such appropriate areas and include unspecified policies and incentives to encourage development near high-quality transit service." It requires the jurisdiction to define requirements and identify potential incentives, giving a list of the types that these "may include," the last being "other related items." Again, this does not give any clear performance standards regarding how to achieve this or what the parameters are. As Petitioner argues, for the third measure, the court in *Communities for a Better Environment v. City of Richmond,* 184 Cal.App.4th 70, 92, found a measure insufficiently specific where it required reduction of mobile emission sources though "transportation smart" development because "reliance on tentative plans for future mitigation… significantly undermines CEQA's goals of full disclosure and informed decision making." Under this analysis, this measure is also defective.

c) 2-L-1 (AR 1021)

Lastly, Petitioner argues that 2-L-1, at AR 1021, is defective. This measure mandates that the project "comply with local requirement(s) for rooftop solar PV on new residential development. It states that each jurisdiction "will define which new development must provide rooftop solar [PV] by defining qualifying criteria… and the amount of solar required…." As Petitioner argues, this sets no standards at all, just like 4-L-1, but instead merely general principles and future possibilities. This violates CEQA.

Petitioner further argues that the measures in general do not guarantee any likelihood of implementation. This is clear from the ones discussed above. Petitioner cites 1-R2 as another example. It states that two named agencies "will work with the participating communities to implement energy efficient retrofits. Actions may include: Implementing a… weatherization program, expanding energy efficiency outreach/education campaigns…, promoting the smart grid," etc. Again, none of this goes beyond stating wishful thinking, good intentions, and an intent to "work" with others. Measures that fall into this category violate CEQA as well.

Petitioner also generally attacks the measures as lacking meaningful enforceability. Petitioner also contends that of all of them, only 1-S1 and 1-S2 are actually enforceable because they govern building energy and lighting efficiency, both controlled by state regulation. The court finds a few others in addition to 1-S1 and 1-S2 to be similarly enforceable. These include 1-L1, based on Windsor's building code, 1-L2, requiring LED lights in new development.

Aside from those few, Petitioner is correct that most are not enforceable, either because they are too vague and lacking in meaningful mandatory requirements such as those already discussed, which only "require" some "alternative" that is not specified or governed by set parameters. Others, such as 1-L3 through2-L2, state mitigation measures but then state that these are "voluntary," or "encouraged," or only necessary where "applicable" based on circumstances or criteria that are not defined. Others again rely on other jurisdictions such as the cities creating applicable requirements that in some unspecified manner promote the stated, vague, open-ended policies that lack any parameters or requirements. These are too numerous to list them all here but this general characteristic dominates almost all of the measures from what I have read.

Accordingly, the court grants the petition with respect to mitigation. Because the record does not provide adequate information about extraterritorial emissions the agency and the public could not and the court cannot determine whether the CAP would achieve its stated goal to reduce GAG impacts to pre-1990 levels by 2020.

E. ALTERNATIVES

Petitioner asserts that Respondent violated CEQA by adopting as the "environmentally superior alternative" the Zero Net Energy Buildings Alternative because it fails to address GHG emissions from transportation while Respondent declined to evaluate an alternative with a moratorium on, or significant reduction of, new or expanded vineyards, wineries and tourist destinations. (AR 94; 426-427.)

Respondent contends that the analysis is sufficient because Petitioner believes that reducing or stopping growth, and in particular growth that involves travel of people and goods to and from the county, is necessary, and Petitioner cannot impose such mandates on R; Respondent considered a range of alternatives; and choosing the moratorium alternative would require the court to "dramatically substitute" its judgment for Respondent's.

CEQA requires all EIRs to consider alternatives to the project. (*Friends of the Old Trees v. Dept. of Forestry & Fire Protection* (1st Dist.1997) 52 Cal.App.4th 1383, 1393-1395 (*Friends of Old Trees*).)

1. Importance and Central Role of Alternatives Analysis

PRC section 21002 states that "it is the policy of the state that public agencies should not approve projects as proposed if there are feasible alternatives or feasible mitigation measures available which would substantially lessen the significant environmental effects...." An agency may not approve a project that will result in significant impacts *unless it first finds that mitigation measures or alternatives are infeasible*. (PRC section 21081; Guidelines 15091, 15093.)

The Supreme Court decided that considering alternatives is one of the most important functions of an EIR. (*Wildlife Alive v. Chickering* (1976) 18 Cal.3d 190, 197.) In fact, "[t]he core of the EIR is the mitigation and alternatives sections." (*Citizens of Goleta Valley v. Bd. of Supervisors* (1990) 52 Cal.3d 553, 564, 566 (*Goleta II*).)

Without evidence regarding why the alternatives are insufficient to meet the project or CEQA goals, meaningful analysis is impossible. An EIR must "explain in meaningful detail the reasons and facts supporting [the] conclusion." (*Marin Municipal Water Dist. v. KG Land*

Corp. California (1991) 235 Cal.App.3d 1652, 1664.) Failure to provide sufficient analysis or alternatives makes it impossible for the court to "intelligently examine the validity of the... action." (*Topanga Assn. for a Scenic Community v. County of Los Angeles* (1974) 11 Cal.3d 506, 513-514, 522.)

The alternatives must be discussed in the EIR itself, provided for public review, and subject to analysis, and the agency cannot cure defects by providing analysis in its official response. (See *Friends of the Old Trees, supra*, 52 Cal.App.4th at 1403-1405.)

2. Authority on Analyzing Alternatives and Feasibility

The discussion should evaluate the relative merits of each alternative 14 CCR §15126.6(a). Respondents need not analyze or adopt alternatives that are not feasible. 14 CCR ' 15126.6(c), (f); *Citizens of Goleta Valley v. Bd. of Supervisors* (1990) 52 Cal.3d 553, 564, 566 (*Goleta II*). However, the document *must* consider alternatives that *are* feasible. *EPIC v. Johnson* (1985) 170 Cal.App.3d 604, 610; *Friends of the Old Trees, supra*, 52 Cal.App.4th 1404.

Ultimately, determining if alternatives are suitable involves a three-part test governed by the "rule of reason" as set forth in Guideline 15126.6. (See *Citizens of Goleta Valley v. Bd. of Supervisors* (1990) 52 Cal.3d 553, 564, 566 (*Goleta II*); *Save San Francisco Bay Association v. San Francisco Bay Conservation and Development Commission* (1992) 10 Cal.App.4th 908, 919.) The analysis must consider alternatives that 1) may "attain most of the basic objectives of the project," 2) reduce or avoid the project's impacts, and 3) are "potentially feasible." (Guideline 15126.6(a), (f).)

The analysis of alternatives is required to set forth facts and "*meaningful* analysis" of these alternatives rather than "'just the agency's bare conclusions or opinions.'" (*Laurel Heights I, supra*, 47 Cal.3d 376, 404-405; *Goleta II, supra*, 52 Cal.3d 569; *Preservation Action Council v. City of San Jose* (2006) 141 Cal.App.4th 1336, 1353.) All analysis must include "detail sufficient to enable those who did not participate... to understand and to consider meaningfully" the alternatives. (*Laurel Heights I, supra*, 404-405.)

As notes above, "feasible" means able to be "accomplished in a successful manner within a reasonable period... taking into account economic, environmental, social, and technological factors." (PRC section 21061.1.)

When the agency determines that alternatives are infeasible, it "shall describe the specific reasons for rejecting identified...project alternatives." (Guideline 15091(a), (c).) The analysis of alternatives is required to set forth facts and "*meaningful* analysis" of these alternatives rather than "'just the agency's bare conclusions or opinions.'" (*Laurel Heights I, supra*, 47 Cal.3d 376, 404-405; *Goleta II, supra*, 52 Cal.3d 569; *Preservation Action Council v. City of San Jose* (2006) 141 Cal.App.4th 1336, 1353.) All analysis must include "detail sufficient to enable those who did not participate... to understand and to consider meaningfully" the alternatives. (*Laurel Heights I, supra*, 404-405.)

The agency must make findings identifying specific considerations making an alternative infeasible and the specific benefits of the Project that outweigh the relative harm. (PRC § 21002.1(b), 21081, Guideline 15092(b); *Preservation Action Council, supra*, 1353.)

On the other hand, as usual, the requirement is one of reasonableness and a "crystal ball" inquiry is not necessary. (*Residents Ad Hoc Stadium Committee v. Bd. of Trustees* (3d Dist.1979) 89 Cal.App.3d 272, 286.) The key, as with most aspects of an EIR is that the agency must provide enough information about the analytical path taken to allow the court to "intelligently examine the validity of the administrative action." (*Topanga Assn. for a Scenic Community v. County of Los Angeles* (1974) 11 Cal.3d 506, 513-514, 522.) However, no "ironclad rule" other than the "rule of reason" governs the decision. (Guideline 15126.6(a).)

An agency cannot find an alternative infeasible simply because the developer does not want to do it. (*Uphold Our Heritage v. Town of Woodside* (2007) 147 Cal.App.4th 587, 601.) In fact, the analysis must include alternatives that are reasonable "even if they substantially impede the project or are more costly." (*San Bernardino Valley Audubon Society v. County of San Bernardino* (1984) 155 Cal.App.3d 738, 750; see also *Preservation Action Council v. City of San Jose* (2006) 141 Cal.App.4th 1336.)

An EIR or decision thereon also cannot merely state that an alternative is infeasible simply because it is too expensive or will not lead to sufficient return without providing supporting analysis. (*Preservation Action Council v. City of San Jose* (2006) 141 Cal.App.4th 1336.) "The fact that an alternative may be more expensive or less profitable is not sufficient to show that the alternative is financially infeasible. What is required is evidence that the *additional costs or lost profitability* are sufficiently *severe as to render it impractical* to proceed with the project." (*Citizens of Goleta Valley v. Board of Supervisors* (1988) 197 Cal.App.3d 1167, 1181; *Uphold Our Heritage, supra*, 599; (emphasis added).)

An alternative should be capable of "substantially lessening" adverse impacts but it need only have fewer impacts and it need not be impact free. PRC 21002; Guideline 15126.6(a); *Citizens of Goleta Valley v. Board of Supervisors (Goleta II)* (1990) 52 Cal.3d 553, 566.

3. Reasonable Range

An EIR must describe a reasonable range of alternatives to the proposed project or its location that would feasibly achieve most of the project's objectives, while reducing or avoiding any of its significant effects. (Guideline 15126.6(a), (d).)

The EIR "shall focus on alternatives… which are capable of avoiding or substantially lessening any significant effects of the project, even if these alternatives would impede to some degree the attainment of the project objective, or would be more costly." (Guideline 15126.6(b).)

The EIR must set forth the alternatives necessary to permit a reasoned choice and in a manner that will allow "meaningful evaluation." (Guideline 15126.6(a), (d), (f); *Goleta II;* see also *Laurel Heights I, supra*; see also *San Bernardino Valley Audubon Soc., Inc. v. County of San Bernardino* (1984) 155 Cal.App.3d 738, 750-751 (the detail must allow a reasonable choice "so far as environmental aspects are concerned.").)

If an EIR excludes certain alternatives, it should identify the alternatives and set forth the reasons. (*Goleta II, supra,* 569; Guideline 15126.6(b).) The court in determining if the

EIR included a reasonable range of alternatives may consider the entire record to determine if alternatives were properly excluded from consideration. (*Goleta II, supra*, 569.)

Alternatives that would eliminate or reduce significant environmental impacts *must* be considered even if they would cost more or "to some degree" impede attainment of the project's objectives. (Guideline 15126.6(b).)

4. Detail of Relevant Decisions on the Adequacy of Alternatives

In *Friends of the Old Trees, supra*, 52 Cal.App.4th 1383, an extreme case, there was no discussion of alternatives in the versions submitted for public review. The agency argued that the fact it considered mitigation should suffice, while the real party marked a box selecting a certain method of cutting. The court also noted that the *public* brought forth "the only true alternatives," and that these were discussed only after the document was approved. (*Friends of the Old Trees, supra,* 52 Cal.App.4th 1405.) The court found the discussion inadequate. (*Id.*, 1403-1405.)

In *Citizens of Goleta Valley v. Board of Supervisors (Goleta I),* (1988) 197 Cal.App.3d 1167, the EIR considered a smaller hotel to be an economically infeasible alternative to the proposed hotel at issue. Because the EIR lacked *evidence* that the smaller hotel was economically infeasible, the court considered it error to deny the writ of mandate. The court found that although the EIR contained estimated figures of costs, the record did not reveal any *evidence* which *analyzed* the alternative in terms of comparative costs, comparative profits or losses, or comparative economic benefit to the project proponent, residents, or the community at large. (*Id.*, 1180.)

The court in *Uphold Our Heritage v. Town of Woodside* (2007) 147 Cal.App.4th 587, at 599, addressed a project to demolish an historic mansion in order to construct a new, smaller single-family residence. The court found that evidence that alternatives of historic rehabilitation or rehabilitation with a new addition, would cost between $4.9 million and $10 million was not substantial evidence that alternatives were not economically feasible since there was no evidence of the likely cost of a proposed replacement home or average cost of building the proposed 6,000 square foot home in the city. It also found that whether the developer wanted to do the alternative was irrelevant to determining if it is not feasible.

San Joaquin Raptor/Wildlife Rescue Center v. County of Stanislaus (Arambel and Rose Development, Inc.) (1994) 27 Cal.App.4th 713, also dealt with alternatives analysis. The court found, in the context of a proposed housing development, that the discussion of housing density alternatives was inadequate. The DEIR stated that a lower density would "lessen the impacts," but failed to identify which impacts it meant or to what degree. The court ruled that " [s]uch a bare conclusion without an explanation of its factual and analytical basis is insufficient." *Id.*, at 736. The court went on to state:

> That lower density might not be "economically feasible," is not sufficient justification for the failure to give basic information as to density alternatives which were considered and rejected. Contrary to [respondent's] argument, [petitioners] are not required to show there are reasonable alternatives. *It is the project proponent's responsibility to provide an adequate discussion of alternatives....* If the project proponent concludes there are no feasible alternatives, it must explain in *meaningful detail* in the EIR the basis for that conclusion. Thus, even if alternatives are rejected, an EIR *must explain why* each suggested alternative either does not satisfy the goals of the proposed project, does not offer substantial environmental advantages or cannot be accomplished.

Id., at 737 (emphasis added).

5. Whether Feasibility Finding Is Necessary

As noted above, PRC sections 21002, 21081, and Guidelines 15091, 15093 together forbid approval of a project that *will result in significant impacts without first finding that any environmentally superior alternatives are infeasible*. Petitioner argues that Respondent failed to consider an alternative that is environmentally superior.

6. The Alternatives Analysis for the CAP

The alternatives analysis is at AR 425-438. The PEIR explains that it developed and analyzed only *one* other alternative, the Carbon Offset Alternative, in addition to the chosen Zero Net Energy Buildings plan and the mandatory no-project alternative. It expressly rejected a growth moratorium, reduced density, greater density, increased Sonoma Clean Power, expanded transit service, 1990 Levels by 2020 (AB32), and 80% Below 1990 Levels by 2020.

The real issue here is whether the Respondent, in rejecting formulating other alternatives, has considered a reasonable range, as required, and whether Respondent has provided sufficient explanation of infeasibility or other reasoning to support not considering other proposed alternatives.

Respondent's analysis is insufficient. Respondent considered almost no range at all, and only one other alternative that essentially is one that does nothing other than to authorize Respondent to buy GHG offsets for all GHG impacts from projects. Although Respondent argues to the contrary, this alternative seems both infeasible and at the same time would not actually do anything to control or limit actual GHG production. As an alternative, this appears to be one of form, but not of substance.

By contrast, the moratorium or reduced-development alternative which Petitioner proposes, and which was presented to Respondent in public comments (see, e.g., AR 93-94, response to comment) along with others noted but rejected without being developed, include real solutions that differ significantly from the chosen CAP. At least some, like the moratorium or growth limit, also address issues of GHG production from travel. While it is logical that some may be infeasible or incompatible with goals of growth, this is not alone, without explanation or support, a basis for not even considering those alternatives, or modified versions. For example, Respondent noted a moratorium on growth of wineries or housing "until the jobs-housing balance in the County is more equitable," but this does not even address the issues of Petitioner's proposed moratorium, it is arbitrarily limited, and it does not even seem to make much sense. There is no evidence or explanation for what it would be or why Respondent could not consider a similar, but different one, such as Petitioner proposed. That is the purpose of actually developing and considering alternatives. Given that there are available alternatives that differ drastically from what Respondent has considered and given that Respondent has, in effect, considered only one other option that is perhaps only nominally an alternative, this analysis fails to consider a reasonable range of alternatives, or even any range at all.

The court Grants the petition on this issue.

F. RESPONSE TO PUBLIC COMMENTS

Petitioner next argues that Respondent's response to public comments was insufficient in violation of Guideline 15088(c).

The "evaluation and response to public comments is an essential part of the CEQA process." (Discussion following CEQA Guideline 15088.) The final EIR must include evaluation and responses to all comments received in the public-comment period. PRC section 21091(d)(2)(A). Guideline 15088 governs responses to comments and subdivision (c) governs the substance of such responses. It requires responses to address issues "in detail" and demonstrate "why specific comments and suggestions were not accepted." Most importantly, perhaps, the responses must explain the reasons for rejecting suggestions with a "good faith, reasoned analysis" and must not rely on "[c]onclusory statements unsupported by factual information." Guideline 15088(c).

1. Exhaustion of Administrative Remedies

Respondent first contends that Petitioner failed to exhaust administrative remedies on this issue. The court has found, above, that Petitioner exhausted its administrative remedies.

Petitioner's argument here is collateral and not persuasive. Although Petitioner points out that a few responses may not sufficiently resolve issues, that is of little importance in of itself. What matters are the fundamental defects that have not been cured as discussed above: failure to properly determine GHG inventory, or demonstrate that Respondent could not practically have done more or did not need to do more; ill-defined mitigation measures lacking enforceable criteria or parameters; and lack of reasonable range of alternatives.

The court denies the Petition with respect to the comments..

G. WHETHER RESPONDENTS' ERROR WAS PREJUDICIAL

Respondent contends that even if Petitioner demonstrated error, it was not prejudicial. As noted at the outset, in order for the court to issue a writ of mandate, it must find not only error, i.e., a violation of CEQA, but that error was prejudicial. (*Chaparral Greens v. City of Chula Vista* (1996) 50 Cal.App.4th 1134, 1143; *see* PRC 21168, 21168.5, *Laurel Heights I, supra* 47 Cal.3d 392, fn.5; Remy, et al., Guide to the California Environmental Quality Act (10th Ed.1999) Chapter XI(D), p.590.)

Respondent's failure to impose meaningful, effectively enforceable mitigation measures, when presenting compliance with the CAP as a way for future projects to avoid any other GHG analysis, is fundamentally and on its face, prejudicial. The failure to present a reasonable range of alternatives or to properly inventory GHG emissions as required are also on, their face, prejudicial because they prevent informed decision making or public review, the very bases of CEQA. (*Sierra Club v. State Bd. of Forestry* (1994) 7 Cal.4th 1215, 1228-1230, 1235-1237 (failure to put critical information in an environmental document was in of itself a prejudicial abuse of discretion partly because it "frustrated the purpose of the public comment provisions"); *Save Cuyama Valley v. County of Santa Barbara* (2013) 213 Cal.App.4th 1059, at 1073 ("[a]n error is prejudicial when an agency fails to comply with a mandatory CEQA procedure or when a report omits information and thereby precludes informed decision making); *Lighthouse Field Beach Rescue v. City of Santa Cruz* (2005) 131 Cal.App.4th 1170, 1182,; *Schoen v. Dept. of Forestry & Fire Protection* (1997) 58 Cal.App.4th 556, 565 ("We cannot overlook a prejudicial error by surmising that the project would have gone forward anyway.").)

Based on the foregoing,

NOW, THEREFORE,

ORDER

1. The Petition for Mandamus is granted as stated above.

Dated: 7/20/17

By: [signature]
NANCY CASE SHAFFER
Judge of the Superior Court

END NOTES

[i] (a) "Tiering" refers to using the analysis of general matters contained in a broader EIR (such as one prepared for a general plan or policy statement) with later EIRs and negative declarations on narrower projects; incorporating by reference the general discussions from the broader EIR; and concentrating the later EIR or negative declaration solely on the issues specific to the later project.
(b) Agencies are encouraged to tier the environmental analyses which they prepare for separate but related projects including general plans, zoning changes, and development projects. This approach can eliminate repetitive discussions of the same issues and focus the later EIR or negative declaration on the actual issues ripe for decision at each level of environmental review. Tiering is appropriate when the sequence of analysis is from an EIR prepared for a general plan, policy, or program to an EIR or negative declaration for another plan, policy, or program of lesser scope, or to a site-specific EIR or negative declaration. Tiering does not excuse the lead agency from adequately analyzing reasonably foreseeable significant environmental effects of the project and does not justify deferring such analysis to a later tier EIR or negative declaration. However, the level of detail contained in a first tier EIR need not be greater than that of the program, plan, policy, or ordinance being analyzed.
(c) Where a lead agency is using the tiering process in connection with an EIR for a large-scale planning approval, such as a general plan or component thereof (e.g., an area plan or community plan), the development of detailed, site-specific information may not be feasible but can be deferred, in many instances, until such time as the lead agency prepares a future environmental document in connection with a project of a more limited geographical scale, as long as deferral does not prevent adequate identification of significant effects of the planning approval at hand.
(d) Where an EIR has been prepared and certified for a program, plan, policy, or ordinance consistent with the requirements of this section, any lead agency for a later project pursuant to or consistent with the program, plan, policy, or ordinance should limit the EIR or negative declaration on the later project to effects which:
(1) Were not examined as significant effects on the environment in the prior EIR; or
(2) Are susceptible to substantial reduction or avoidance by the choice of specific revisions in the project, by the imposition of conditions, or other means.
(e) Tiering under this section shall be limited to situations where the project is consistent with the general plan and zoning of the city or county in which the project is located, except that a project requiring a rezone to achieve or maintain conformity with a general plan may be subject to tiering.

(f) A later EIR shall be required when the initial study or other analysis finds that the later project may cause significant effects on the environment that were not adequately addressed in the prior EIR. A negative declaration shall be required when the provisions of Section 15070 are met.

(1) Where a lead agency determines that a cumulative effect has been adequately addressed in the prior EIR, that effect is not treated as significant for purposes of the later EIR or negative declaration, and need not be discussed in detail.

(2) When assessing whether there is a new significant cumulative effect, the lead agency shall consider whether the incremental effects of the project would be considerable when viewed in the context of past, present, and probable future projects. At this point, the question is not whether there is a significant cumulative impact, but whether the effects of the project are cumulatively considerable. For a discussion on how to assess whether project impacts are cumulatively considerable, see Section 15064(i).

(3) Significant environmental effects have been "adequately addressed" if the lead agency determines that:

(A) they have been mitigated or avoided as a result of the prior environmental impact report and findings adopted in connection with that prior environmental report; or

(B) they have been examined at a sufficient level of detail in the prior environmental impact report to enable those effects to be mitigated or avoided by site specific revisions, the imposition of conditions, or by other means in connection with the approval of the later project.

(g) When tiering is used, the later EIRs or negative declarations shall refer to the prior EIR and state where a copy of the prior EIR may be examined. The later EIR or negative declaration should state that the lead agency is using the tiering concept and that it is being tiered with the earlier EIR.

(h) There are various types of EIRs that may be used in a tiering situation. These include, but are not limited to, the following:

(1) General plan EIR (Section 15166).

(2) Staged EIR (Section 15167).

(3) Program EIR (Section 15168).

(4) Master EIR (Section 15175).

(5) Multiple-family residential development/residential and commercial or retail mixed-use development (Section 15179.5).

(6) Redevelopment project (Section 15180).

(7) Projects consistent with community plan, general plan, or zoning (Section 15183).

One specific example of a first-tier EIR is a "program" EIR as set forth in Guideline 15168. This details the nature and requirements and uses of such a first-tier EIR, in a manner similar to that set forth in 15152, and gives another good picture of how they are to be used and what they must do to be so used in compliance with CEQA. It states, in full,

(a) General. A program EIR is an EIR which may be prepared on a series of actions that can be characterized as one large project and are related either:

(1) Geographically,

(2) As logical parts in the chain of contemplated actions,

(3) In connection with issuance of rules, regulations, plans, or other general criteria to govern the conduct of a continuing program, or

(4) As individual activities carried out under the same authorizing statutory or regulatory authority and having generally similar environmental effects which can be mitigated in similar ways.

(b) Advantages. Use of a program EIR can provide the following advantages. The program EIR can:

(1) Provide an occasion for a more exhaustive consideration of effects and alternatives than would be practical in an EIR on an individual action,

(2) Ensure consideration of cumulative impacts that might be slighted in a case-by-case analysis,

(3) Avoid duplicative reconsideration of basic policy considerations,

(4) Allow the lead agency to consider broad policy alternatives and program wide mitigation measures at an early time when the agency has greater flexibility to deal with basic problems or cumulative impacts,

(5) Allow reduction in paperwork.

(c) Use With Later Activities. Subsequent activities in the program must be examined in the light of the program EIR to determine whether an additional environmental document must be prepared.

(1) If a later activity would have effects that were not examined in the program EIR, a new initial study would need to be prepared leading to either an EIR or a negative declaration.

(2) If the agency finds that pursuant to Section 15162, no new effects could occur or no new mitigation measures would be required, the agency can approve the activity as being within the scope of the project covered by the program EIR, and no new environmental document would be required.

(3) An agency shall incorporate feasible mitigation measures and alternatives developed in the program EIR into subsequent actions in the program.

(4) Where the subsequent activities involve site specific operations, the agency should use a written checklist or similar device to document the evaluation of the site and the activity to determine whether the environmental effects of the operation were covered in the program EIR.

(5) A program EIR will be most helpful in dealing with subsequent activities if it deals with the effects of the program as specifically and comprehensively as possible. With a good and detailed analysis of the program, many subsequent activities could be found to be within the scope of the project described in the program EIR, and no further environmental documents would be required.

(d) Use With Subsequent EIRS and Negative Declarations. A program EIR can be used to simplify the task of preparing environmental documents on later parts of the program. The program EIR can:

(1) Provide the basis in an initial study for determining whether the later activity may have any significant effects.

(2) Be incorporated by reference to deal with regional influences, secondary effects, cumulative impacts, broad alternatives, and other factors that apply to the program as a whole.

(3) Focus an EIR on a subsequent project to permit discussion solely of new effects which had not been considered before.

(e) Notice With Later Activities. When a law other than CEQA requires public notice when the agency later proposes to carry out or approve an activity within the program and to rely on the program EIR for CEQA compliance, the notice for the activity shall include a statement that:

(1) This activity is within the scope of the program approved earlier, and

(2) The program EIR adequately describes the activity for the purposes of CEQA.

[ii] (a) Lead agencies may analyze and mitigate the significant effects of greenhouse gas emissions at a programmatic level, such as in a general plan, a long range development plan, or a separate plan to reduce greenhouse gas emissions. Later project-specific environmental documents may tier from and/or incorporate by reference that existing programmatic review. Project-specific environmental documents may rely on an EIR containing a programmatic analysis of greenhouse gas emissions as provided in section 15152 (tiering), 15167 (staged EIRs) 15168 (program EIRs), 15175-15179.5 (Master EIRs), 15182 (EIRs Prepared for Specific Plans), and 15183 (EIRs Prepared for General Plans, Community Plans, or Zoning). (b) Plans for the Reduction of Greenhouse Gas Emissions. Public agencies may *choose to analyze and mitigate significant greenhouse gas emissions in a plan for the reduction of greenhouse gas emissions or similar document.* A plan to reduce greenhouse gas emissions may be used in a cumulative impacts analysis as set forth below. Pursuant to sections 15064(h)(3) and 15130(d), a lead agency may determine that a project's incremental contribution to a cumulative effect is not cumulatively considerable if the project complies with the requirements in a previously adopted plan or mitigation program under specified circumstances.

(1) *Plan Elements. A plan for the reduction of greenhouse gas emissions should:*

(A) Quantify greenhouse gas emissions, both existing and projected over a specified time period, resulting from activities within a defined geographic area;

(B) Establish a level, based on substantial evidence, below which the contribution to greenhouse gas emissions from activities covered by the plan would not be cumulatively considerable;

(C) Identify and analyze the greenhouse gas emissions resulting from specific actions or categories of actions anticipated within the geographic area;

(D) Specify measures or a group of measures, including performance standards, that substantial evidence demonstrates, if implemented on a project-by-project basis, would collectively achieve the specified emissions level;

(E) Establish a mechanism to monitor the plan's progress toward achieving the level and to require amendment if the plan is not achieving specified levels;

(F) Be adopted in a public process following environmental review.

(2) Use with Later Activities. A plan for the reduction of greenhouse gas emissions, once adopted following certification of an EIR or adoption of an environmental document, may be used in the cumulative impacts analysis of later projects. An environmental document that relies on a greenhouse gas reduction plan for a cumulative impacts analysis must identify those requirements specified in the plan that apply to the project, and, if those requirements are not otherwise binding and enforceable, incorporate those requirements as mitigation measures applicable to the project. If there is substantial evidence that the effects of a particular project may be cumulatively considerable notwithstanding the project's compliance with the specified requirements in the plan for the reduction of greenhouse gas emissions, an EIR must be prepared for the project.

(c) Special Situations. As provided in Public Resources Code sections 21155.2 and 21159.28, environmental documents for certain residential and mixed use projects, and transit priority projects, as defined in section 21155, that are consistent with the general use designation, density, building intensity, and applicable policies specified for the project area in an applicable sustainable communities strategy or alternative planning strategy need not analyze global warming impacts resulting from cars and light duty trucks.

A lead agency should consider whether such projects may result in greenhouse gas emissions resulting from other sources, however, consistent with these Guidelines.

PROOF OF SERVICE BY MAIL

I certify that I am an employee of the Superior Court of California, County of Sonoma, and that my business address is 600 Administration Drive, Room 107-J, Santa Rosa, California, 95403; that I am not a party to this case; that I am over the age of 18 years; that I am readily familiar with this office's practice for collection and processing of correspondence for mailing with the United States Postal Service; and that on the date shown below I placed a true copy of Order Granting Petition for Writ of Mandate in an envelope, sealed and addressed as shown below, for collection and mailing at Santa Rosa, California, first class, postage fully prepaid, following ordinary business practices.

Date: July 20, 2017

JOSÉ OCTAVIO GUILLÉN
Court Executive Officer

By: Missy Lemley
Missy Lemley, Deputy Clerk

-ADDRESSEES-

✓ JERRY BERNHAUT
708 Gravenstein Hwy N # 407
Sebastopol Ca 95472-2808

BRUCE D GOLDSTEIN
COUNTY COUNSEL
575 Administration Dr Rm 105a
Santa Rosa Ca 95403

EXHIBIT
2

Population by Race

	Population	Percent
Total Population	**486,550**	**100%**
White	298,900	61%
Hispanic	124,069	25%
Asian	22,218	5%
Black	18,758	4%
Two or More	13,754	3%
American Indian	6,083	1%
Pacific Islander	1,820	<1%
Other	948	<1%

Source: SANDAG, Current Estimates (2010)

Population by Age and Sex

	Total	Male	Female	Percent Female
Total Population	**486,550**	**246,427**	**240,123**	**49%**
Under 5	32,170	15,872	16,298	51%
5 to 9	30,497	15,672	14,825	49%
10 to 14	31,495	15,498	15,997	51%
15 to 17	20,727	10,863	9,864	48%
18 and 19	16,317	9,794	6,523	40%
20 to 24	44,457	27,841	16,616	37%
25 to 29	31,295	16,305	14,990	48%
30 to 34	27,085	13,526	13,559	50%
35 to 39	27,977	13,570	14,407	51%
40 to 44	30,208	14,391	15,817	52%
45 to 49	35,905	17,294	18,611	52%
50 to 54	37,364	18,245	19,119	51%
55 to 59	32,568	15,838	16,730	51%
60 and 61	11,918	5,838	6,080	51%
62 to 64	15,675	7,625	8,050	51%
65 to 69	19,458	9,513	9,945	51%
70 to 74	13,561	6,629	6,932	51%
75 to 79	11,075	5,328	5,747	52%
80 to 84	8,705	3,824	4,881	56%
85 and Older	8,093	2,961	5,132	63%
Under 18	114,889	57,905	56,984	50%
65 and older	60,892	28,255	32,637	54%
Median	**36.6**	**34.2**	**39.0**	

Source: SANDAG, Current Estimates (2010)

Population by Marital Status

	Number	Percent
Total population age 15 and over	**392,388**	**100%**
Never Married	112,805	29%
Married, excluding separated	216,007	55%
Separated	6,160	2%
Widowed	19,744	5%
Divorced	37,672	10%

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B12001

Pop. by Household / Group Quarters Status

	Number	Percent
Total population	**486,550**	**100%**
Household	458,853	94%
Group Quarters - Military	16,571	3%
Group Quarters - Other	11,126	2%
Group Quarters - College	0	0%

Source: SANDAG, Current Estimates (2010)

Population by Age and Race

	Total	Hispanic	White	Black	American Indian	Asian	Pacific Islander	Other	Two or More
Total Pop.	**486,550**	**124,069**	**298,900**	**18,758**	**6,083**	**22,218**	**1,820**	**948**	**13,754**
Under 5	32,170	12,653	14,371	1,328	483	1,153	85	86	2,011
5 to 9	30,497	10,971	14,615	1,308	459	1,304	89	65	1,686
10 to 14	31,495	11,120	15,502	1,253	437	1,283	139	69	1,692
15 to 17	20,727	7,351	10,321	957	305	717	101	45	930
18 and 19	16,317	5,163	8,882	765	234	520	96	32	625
20 to 24	44,457	12,974	25,475	2,302	660	1,472	257	83	1,234
25 to 29	31,295	9,804	16,642	1,700	408	1,459	176	73	1,033
30 to 34	27,085	8,839	13,852	1,301	402	1,677	122	78	814
35 to 39	27,977	8,652	14,867	1,322	326	1,888	116	81	725
40 to 44	30,208	8,286	17,504	1,379	315	1,943	109	59	613
45 to 49	35,905	7,229	23,906	1,480	401	2,076	116	70	627
50 to 54	37,364	6,318	26,840	1,192	458	1,802	132	72	550
55 to 59	32,568	4,763	24,523	926	371	1,485	74	47	379
60 and 61	11,918	1,594	9,171	309	100	543	45	14	142
62 to 64	15,675	1,789	12,495	327	176	661	43	17	167
65 to 69	19,458	2,385	15,501	380	161	762	40	23	206
70 to 74	13,561	1,553	10,878	242	161	540	46	15	126
75 to 79	11,075	1,207	9,079	138	94	443	18	4	92
80 to 84	8,705	816	7,395	83	72	272	8	5	54
85 and Older	8,093	602	7,081	66	60	218	8	10	48
Under 18	114,889	42,095	54,809	4,846	1,684	4,457	414	265	6,319
65 and older	60,892	6,563	49,934	909	548	2,235	120	57	526
Median		**25.9**	**44.3**	**29.3**	**30.7**	**39.0**	**29.1**	**31.3**	**19.8**

Source: SANDAG, Current Estimates (2010)

Language Spoken at Home and Ability to Speak English

	Number	Percent
Total populatioin age 5 and over	**454,380**	**100%**
Speak Only English	344,884	76%
Speak Spanish:	79,718	18%
Speak English "well" or "very well"	64,021	14%
Speak English "not well" or "not at all"	15,697	3%
Speak Asian/Pacific Island language:	14,498	3%
Speak English "well" or "very well"	12,568	3%
Speak English "not well" or "not at all"	1,930	<1%
Speak other language:	15,280	3%
Speak English "well" or "very well"	14,067	3%
Speak English "not well" or "not at all"	1,213	<1%

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B16004

Educational Attainment

	Number	Percent
Total population age 25 and older	**310,887**	**100%**
Less than 9th grade	16,693	5%
9th through 12th grade, no diploma	22,031	7%
High school grad (incl. equivalency)	71,807	23%
Some college, no degree	84,053	27%
Associate degree	27,004	9%
Bachelor's degree	56,590	18%
Master's degree	22,238	7%
Professional school degree	6,495	2%
Doctorate degree	3,976	1%

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B15002

School Enrollment

	Total		Public School		Private School	
	Number	Percent	Number	Percent	Number	Percent
Total population age 3 and older	**466,874**	**100%**	---	---	---	---
Enrolled in school	126,358	27%	108,110	23%	18,248	4%
Nursery / Preschool	7,504	6%	3,840	4%	3,664	20%
Kindergarten to grade 4	30,263	24%	26,869	25%	3,394	19%
Grade 5 to grade 8	26,454	21%	23,743	22%	2,711	15%
Grade 9 to grade 12	28,864	23%	26,577	25%	2,287	13%
College, undergraduate	28,881	23%	24,731	23%	4,150	23%
Graduate or Professional school	4,392	3%	2,350	2%	2,042	11%
Not enrolled in school	340,516	73%	---	---	---	---

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B14002

Households by Type and Presence of Children Under 18

	Total		With Persons Under 18		Without Persons Under 18	
	Number	Percent	Number	Percent	Number	Percent
Total households	**159,318**	**100%**	**60,968**	**100%**	**98,350**	**100%**
Family Households:	121,833	76%	60,567	99%	61,266	62%
Married couple family	98,149	62%	46,357	76%	51,792	53%
Other family:	23,684	15%	14,210	23%	9,474	10%
Male householder, no wife	7,847	5%	4,445	7%	3,402	3%
Female householder, no husband	15,837	10%	9,765	16%	6,072	6%
Nonfamily households:	37,485	24%	401	1%	37,084	38%
Householder living alone	30,002	19%	----	----	----	----
Other nonfamily households	7,483	5%	----	----	----	----

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B11005

Housing Units by Type

	Number	Percent	Occupied	Unoccupied	Vacancy Rate	Persons per Household
Total Housing Units	**170,503**	**100%**	**159318**	**11,185**	**7%**	**2.88**
Single family (detached)	117,491	69%	111,108	6,383	5%	2.90
Single family (attached)	13,985	8%	12,222	1,763	13%	3.13
2 to 4 units	6,422	4%	5,898	524	8%	2.93
5 to 9 units	5,615	3%	5,244	371	7%	2.68
10 or more units	14,719	9%	13,906	813	6%	2.76
Mobile home and Other	12,271	7%	10,940	1,331	11%	2.60

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B25024

Housing Value

	Number	Percent
Total Owner-Occupied Units	**113,052**	**100%**
Less than $150,000	10,592	9%
$150,000 to $199,999	2,729	2%
$200,000 to $249,999	3,961	4%
$250,000 to $299,999	5,429	5%
$300,000 to $399,999	15,255	13%
$400,000 to $499,999	17,747	16%
$500,000 to $749,999	33,627	30%
$750,000 to $999,999	13,742	12%
$1,000,000 or more	9,970	9%
Median Value	**$509,116**	

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B25075

Year Structure Built

	Number	Percent
Total Housing units	**170,503**	**100%**
2005 or Later	9,223	5%
2000 to 2004	17,417	10%
1990 to 1999	23,168	14%
1980 to 1989	35,864	21%
1970 to 1979	44,337	26%
1960 to 1969	18,237	11%
1950 to 1959	13,671	8%
1940 to 1949	4,631	3%
1939 or earlier	3,955	2%

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B25034

Housing Units by Tenure and Occupants per Room

	Total		**Renter Occupied**		**Owner Occupied**	
	Number	Percent	Number	Percent	Number	Percent
Total occupied housing units	**159,318**	**100%**	**46,266**	**100%**	**113,052**	**100%**
1.00 occupant housing per room or less	154,110	97%	43,105	93%	111,005	98%
1.01 to 1.50 occupants per room	3,804	2%	2,188	5%	1,616	1%
1.51 to 2.00 occupants per room	913	1%	638	1%	275	<1%
2.01 or more occupants per room	491	<1%	335	1%	156	<1%

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B25014

Contract Rent

Renter Occupied Housing Units	Number	Percent
Total Units	**46,266**	**100%**
Less than $500	2,527	5%
$500 to $599	1,244	3%
$600 to $699	1,687	4%
$700 to $799	2,443	5%
$800 to $899	3,412	7%
$900 to $999	4,645	10%
$1,000 to $1,249	8,281	18%
$1,250 to $1,499	6,097	13%
$1,500 to $1,999	8,157	18%
$2,000 or more	4,353	9%
No cash rent	3,420	7%
Median contract rent	**$1,218**	

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B25056

Gross Rent as a Percentage of Household Income

Renter Occupied Housing Units	Number	Percent
Total Units	**46,266**	**100%**
Less than 20 percent	7,263	16%
20.0 to 24.9 percent	5,327	12%
25.0 to 29.9 percent	5,321	12%
30.0 to 34.9 percent	3,952	9%
35.0 to 39.9 percent	3,230	7%
40.0 to 49.9 percent	5,743	12%
50.0 percent or more	11,582	25%
Not computed	3,848	8%

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B25070

Vehicle Availability

Occupied Housing Units	Number	Percent
Total Availability	**159,318**	**100%**
No vehicle	5,414	3%
1 vehicle	37,262	23%
2 vehicles	64,261	40%
3 vehicles	33,051	21%
4 or more vehicles	19,330	12%

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B25044

Place of Work

Workers age 16 and older	Number	Percent
Total Workers	**230,366**	**100%**
Worked in state of residence	229,116	99%
Worked in county of residence	220,550	96%
Worked outside county of residence	8,566	4%
Worked outside state of residence	1,250	1%

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B08007

Employment Status

			Male		Female	
	Total	Percent	Number	Percent	Number	Percent
Population age 16 and older	**385,988**	**100%**	**196,065**	**51%**	**189,923**	**49%**
In labor force	248,500	64%	142,573	57%	105,927	43%
Armed forces	23,712	10%	22,429	95%	1,283	5%
Civilian (employed)	205,011	82%	109,666	53%	95,345	47%
Civilian (unemployed)	19,777	8%	10,478	53%	9,299	47%
Not in labor force	137,488	36%	53,492	39%	83,996	61%
Pct. of civilian labor force unemployed	8.8%		8.7%		8.9%	

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B23025

Means of Transportation to Work

Workers age 16 and older	Number	Percent
Total Workers	**230,366**	**100%**
Car, truck or van:	199,294	87%
Drove Alone	174,972	76%
Carpooled	24,322	11%
Public Transportation:	2,873	1%
Bus	2,446	1%
Trolley / Streetcar	91	<1%
Railroad	272	<1%
Other public transportation	64	<1%
Motorcycle	987	<1%
Bicycle	446	<1%
Walked	10,291	4%
Other means	1,392	1%
Worked at home	15,083	7%

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B08301

Travel Time to Work

Workers age 16 and older	Number	Percent
Total Workers	**230,366**	**100%**
Did not work at home	215,283	93%
Less than 10 minutes	29,904	13%
10 to 19 minutes	50,150	22%
20 to 29 minutes	45,609	20%
30 to 44 minutes	51,866	23%
45 to 59 minutes	18,851	8%
60 to 89 minutes	13,339	6%
90 minutes or more	5,564	2%
Worked at home	15,083	7%
Average time to work (minutes)	**31**	--

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B08303

Industry

Employed cilivian population age 16 and older	Number	Percent
Total employed civilian age 16+	**206,554**	**100%**
Agriculture, forestry, mining	3,571	2%
Utilities	2,243	1%
Construction	21,784	11%
Manufacturing	17,133	8%
Wholesale trade	5,943	3%
Retail trade	22,563	11%
Transportation & warehousing	6,399	3%
Information & communications	4,429	2%
Finance, insurance, & real estate	15,831	8%
Professional, scientific, management, administration	12,892	6%
Educational, social, & health services	39,033	19%
Art, entertainment, recreation, accommodations, food	19,195	9%
Other services	10,819	5%
Public administration	24,719	12%

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table C24030

Occupation

Employed cilivian population age 16 and older	Number	Percent
Total employed civilian age 16+	**206,554**	**100%**
Management, professional & related:	76,013	37%
Management (incl. farm managers)	25,203	12%
Business & financial	9,860	5%
Computer & mathematical	4,888	2%
Architecture & engineering	4,909	2%
Life, physical & social science	1,685	1%
Community & social service	2,417	1%
Legal	2,246	1%
Education, training, & library	11,501	6%
Art, entertainment, sports & media	3,844	2%
Healthcare practitioners	9,460	5%
Service:	33,973	16%
Healthcare support	3,112	2%
Protective service	6,237	3%
Food preparation & serving	8,533	4%
Building & grounds cleaning / maintenance	7,291	4%
Personal care & service	8,800	4%
Sales & office	55,865	27%
Farming, fishing & forestry	1,403	1%
Construction, extraction & maintenance	22,350	11%
Production, transport & material moving	16,950	8%

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table C24010

Household Income

	Number	Percent
Total Households	**159,318**	**100%**
Less than $15,000	10,813	7%
$15,000 to $29,999	17,720	11%
$30,000 to $44,999	20,329	13%
$45,000 to $59,999	20,215	13%
$60,000 to $74,999	16,868	11%
$75,000 to $99,999	23,379	15%
$100,000 to $124,999	16,113	10%
$125,000 to $149,999	10,651	7%
$150,000 to $199,999	11,881	7%
$200,000 or more	11,349	7%
Median Income	**$69,410**	**--**

Source: SANDAG, Current Estimates (2010)

Earnings and Income

	Number	Percent
Total households	**159,318**	**100%**
With earnings	130,229	82%
With wage and salary income	123,059	77%
With self-employment income	24,660	15%
With interest, dividend, or net rental income	46,489	29%
With Social Security income	43,347	27%
With Supplemental Security income	5,751	4%
With public assistance income	3,214	2%
With retirement income	33,229	21%
With other types of income	24,703	16%

Note: "Earnings" is the sum of households with wage and salary income and/or self-employment income. Also, a household may have more than one income. Therefore, subsets will not sum to the total.

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B19051 - B19060

Ratio of Income to Poverty Level

Population for whom poverty status is determined

	Number	Percent
Total	**463,797**	**100%**
Under .50	17,898	4%
.50 to .99	22,528	5%
1.00 to 1.24	16,827	4%
1.25 to 1.49	16,701	4%
1.50 to 1.84	23,492	5%
1.85 to 1.99	10,653	2%
2.00 and over	355,698	77%

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table C17002

Poverty Status

Population for whom poverty status is determined

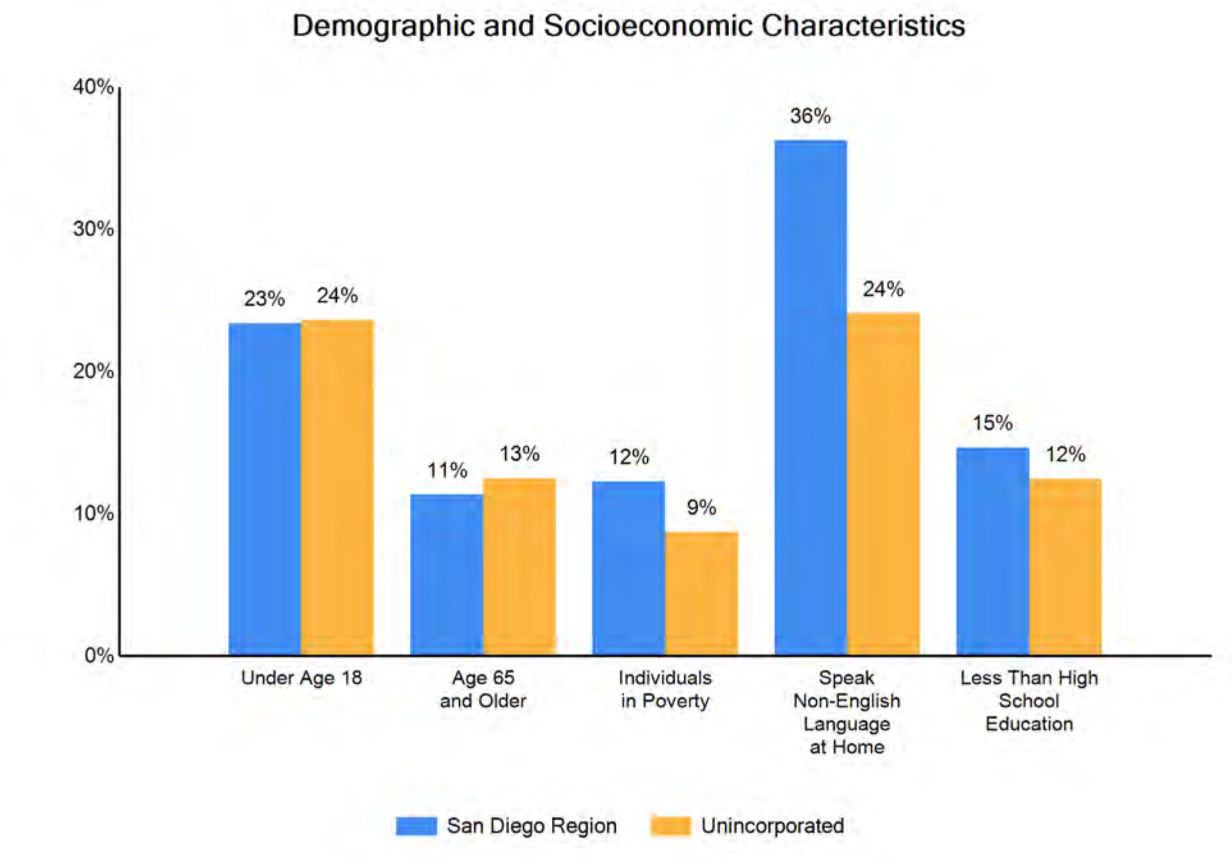
	Number	Percent
Total	**463,797**	**100%**
Above Poverty	423,371	91%
Below Poverty	40,426	9%

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B17010

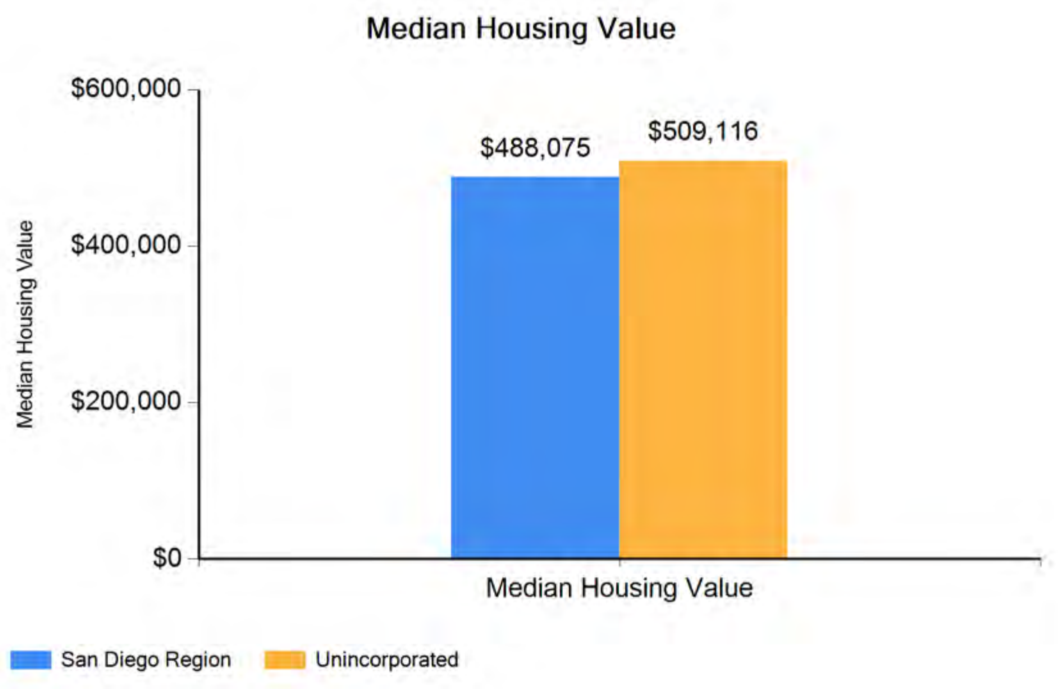
Poverty Status of Families by Family Type and Presence of Related Children Under 18

	Total Families			**Above Poverty**			**Below Povery**		
	Total	With Children	No Children	Total	With Children	No Children	Total	With Children	No Children
Total Familes	**121,833**	**60,567**	**61,266**	**115,146**	**55,530**	**59,616**	**6,687**	**5,037**	**1,650**
Married couple family	98,149	46,357	51,792	94,686	44,014	50,672	3,463	2,343	1,120
Male householder, no wife present	7,847	4,445	3,402	7,216	3,982	3,234	631	463	168
Female householder, no husband present	15,837	9,765	6,072	13,244	7,534	5,710	2,593	2,231	362

Source: SANDAG, constructed from U.S. Census Bureau's American Community Survey 2010 5-year file, Table B17010



Source: SANDAG, Current Estimates (2010) and constructed from U.S. Census Bureau's American Community survey 2010 5 - year file



Source: SANDAG, Constructed from U.S. Census Bureau's American Community survey 2010 5 - year file, Table B25075

EXHIBIT
3

Working Paper – UCD-ITS-WP-16-02

First Look at the Plug-in Vehicle Secondary Market

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FIRST LOOK AT THE PLUG-IN VEHICLE SECONDARY MARKET

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Abstract

In most markets in the world there are very few used PEVs. California is one of the first markets to have a significant secondary market - about 5-8% of the almost 200,000 PEVs in California are being used by a second owner. Looking at the market for conventional vehicles, used vehicle sales comprise the clear majority of all transactions while the new vehicle buyers are a small share of the households, making used PEV sales potentially very significant on the market as a whole. As the number of used PEVs grows, the secondary market for PEVs will have an increasing effect as used PEV buyers join new buyers in adopting a new technology.

Can these used vehicles provide environmentally friendly choices to those who do not buy new vehicles? Is range degradation an important factor in the use and purchase of the vehicles? Do the subsidies provided by State, Federal and local authorities pass to the second owner and by how much? This report explores the used PEVs in the market and the motivations behind their purchase and use.

UCDAVIS
PLUG-IN HYBRID & ELECTRIC VEHICLE RESEARCH CENTER
of the Institute of Transportation Studies

Contents

1. Background

1.5 million zero-emission vehicles, most of them plug-in electric vehicles, are planned to be on California roadways by 2025. 1.5 million zero-emission vehicles, most of them plug-in electric vehicles, are planned to be on California roadways by 2025. This translates to 1.5 million sales of new vehicles and almost the same number of households purchasing and using a PEV between 2010 and 2025. This encompasses households that purchase a new PEV and drive it for many years as well as households who purchase or lease more than one PEV over the years. Some households will purchase their second or third new PEV while others will buy the used vehicles coming into the market, enjoying the lower price, but lacking some of the incentives available to the new vehicle buyers. In the general car market, two-thirds of all U.S. vehicle purchases are for used vehicles (Edmunds, 2013). Households that purchase their first PEV (whether it is new or used) are incorporating new technology into their life and are part of the social diffusion of the plug-in vehicles in the state. PEV owners with older vehicles, whether purchased new or used, are expected to have reduced performance and effective electric range. On the other hand, they may displace less efficient internal combustion engine (ICE) vehicles used by lower income households.

A relatively defined set of households who purchase new vehicles in California will be the engine of the ZEV deployment, leasing or buying not only the first PEVs, but a second or third PEV in the coming decade, and accelerating the used PEV market. Not every household buys or leases a new vehicle - according to the 2012 Caltrans survey and the 2009 NHTS survey, two thirds of the households surveyed did not purchase a new vehicle in the last 5 years. Some in this group did not purchase any new vehicle and others did it in longer intervals than 5 years. Based on the household current fleet we know that 7% of households purchased 2 or more new vehicles in the last 5 years, which make this group responsible for up to one-third of the new vehicles sold (Figure 1).

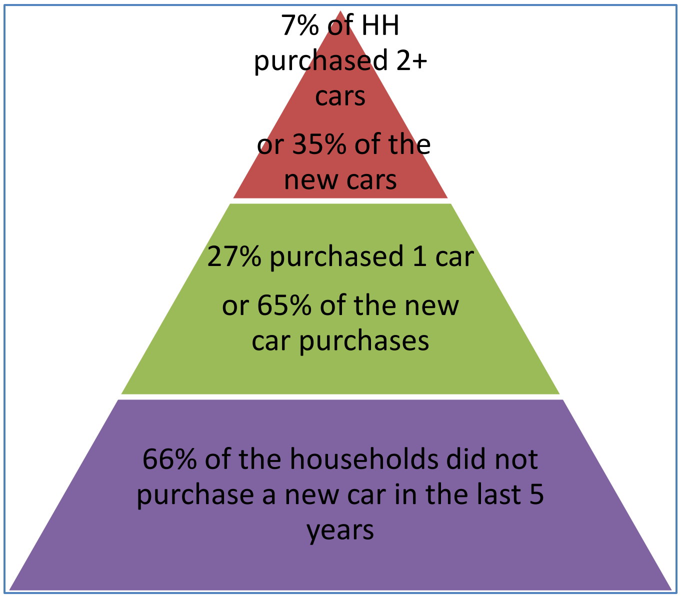

Figure 1: New-vehicle-buyers in California

In our 2015 survey that samples the first 5 years of PEV adopters in California we found that about 23% of the households who purchased a 2015 model year PEV are doing it for the second time. Of those, 12% have two PEVs now (In Figure 2, "Have 2+ PEVs") and 13% moved to the secondary market (In Figure 2, "Had a PEV").

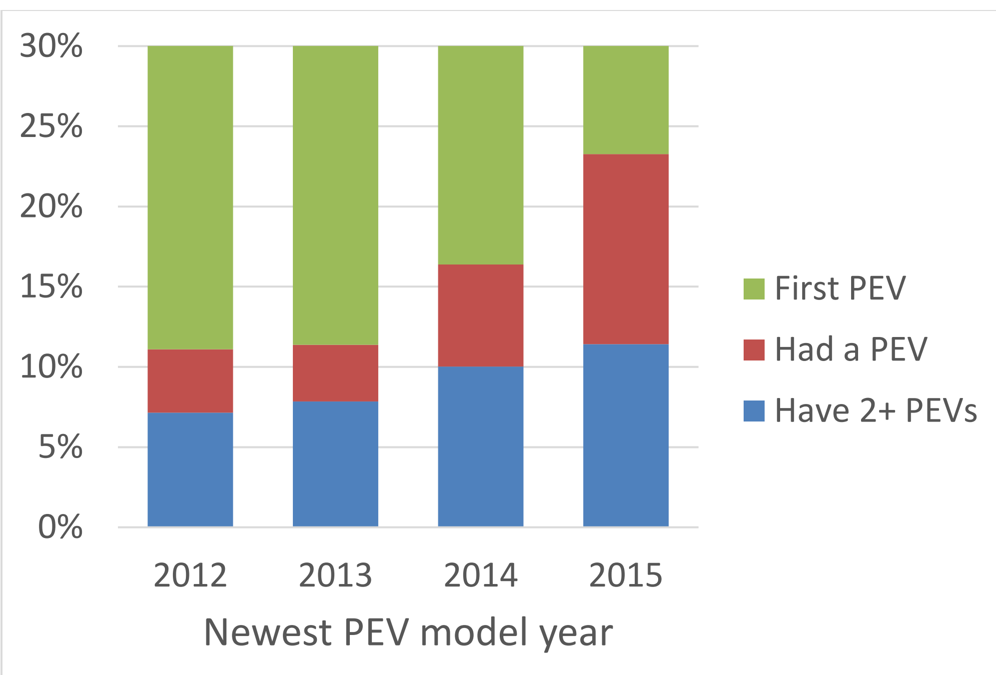

Figure 2: Current new PEV Buyers in California by model year

The multi-vehicle buyers, along with the two and three-year lease promotions, are expected to ramp up the market by purchasing a second and third plug-in vehicle and subsequently create a used market by selling their older vehicles. Using the same Californian sample of the 2009 national household travel survey, we expect that about a third of the PEVs will be sold within 5 years of purchase and more than 17% of the PEVs will be sold within 2 years of purchase to second owners.

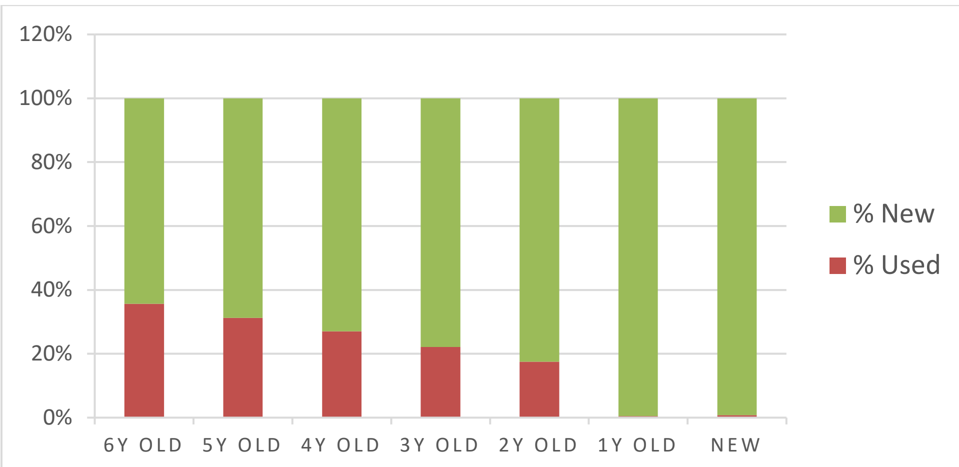

Figure 3: Ownership Status by Model Year

In the case of PEVs, we expect higher sales rates than the 2012 survey ICEs resulting from the higher income of the purchasing households PEVs. The buyers of used vehicles face different costs, incentives, and in many cases, exhibit different socioeconomic characteristics. Nevertheless, there are many households that do not purchase new vehicles and have incomes similar to new vehicle buyers as described by the blue line (66% of all households) in Figure 4.

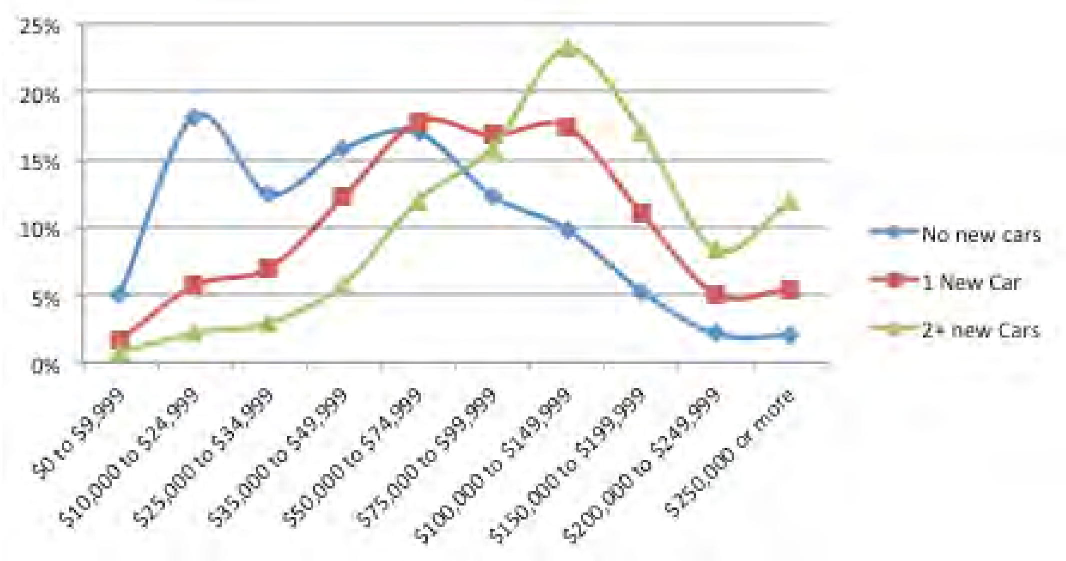

Figure 4: Income level of used PEV households by number of new vehicles purchased in the last 5 years

Based on the DMV records from the first half of 2016, we estimate that about 14,000 PEVs were already purchased by a second owner in California, not including second owners who had the vehicle for fewer than 6 months and leasers who purchased their vehicles.

2. Literature review

California had one of the first substantial plug-in electric vehicle markets in the world starting in 2011, and therefore the first substantial secondary market starting in 2015. There is no literature on the plug-in vehicle secondary market but we identified several papers that focus on the alternative fuel vehicle secondary market, mainly hybrids, that look at resale value, consumer preference, and the impact on the new market.

The residual value of plug-in cars is a function of consumer perception on reliability and durability as discussed by the national academy report (Brenna et al., 2016) and demonstrated using stated preference survey by Bühler et al. (2011). The secondary market is also heavily impacted by the subsidies and incentives for new vehicles and the impact of similar policies. Studies on the depreciation cost of hybrid vehicles show lower depreciation than regular cars in Japan (Iwata et al., 2016), as well as lower depreciation for vehicles branded as green compared to unbranded hybrid vehicles (i.e a hybrid version of a conventional vehicle) (Majid et al., 2015). Gas prices also have an impact on the secondary market as the change in gas prices in the period between the original purchase and the secondary purchase reduce the demand for fuel-efficient vehicles (Busse et al., 2013).

The residual value of the vehicles has a strong impact on the ability of the original owner to buy a second plug-in vehicle, according to Fudenberg and Tirole (1998) Furthermore, Benmelech and Bergman (2009) demonstrate the impact of the residual value on wide market when used as collateral. The secondary market influencing the OEMs depends on the durability of the product, as shown by Chen et al. (2013).

Incentives and taxes on the original owner have an impact on the residual value. They may lead to a future increase in the supply of used cars on the market and may bring reduction in prices of used cars as demonstrated by Noparumpa et al. (2016). This reduction in price can affect the economy in several ways. Owners of cars suffer damage to their “car equity,” as lower resale prices translate into erosion of collateral value. Additionally, car manufacturers may suffer as the presence of used cars affects the pricing ability and sale of future models.

3. Research Method

This report is based on an online survey designed and conducted at the UC Davis PH&EV Center. We used DMV records to identify potential used PEV owners and recruited them by mailing a letter with a link to the survey.

3.1. SURVEY TOOL

The survey includes questions on household socio-demographic factors, household fleet (Figure 5), and vehicle purchase questions including questions that will allow owners of PEVs to indicate their vehicle preferences (for example: EV range, charging speed, BEV/PHEV, size) and the willingness to pay for those characteristics.

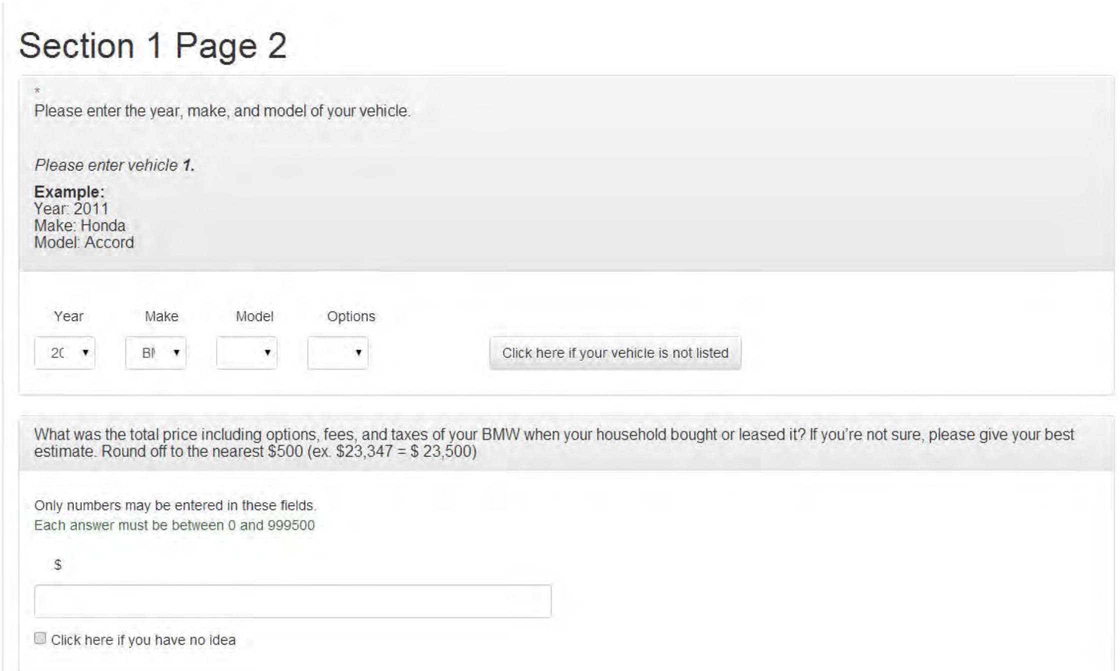

Figure 5: Vehicle Selection Survey Tool

We used a web-map survey tool (Figure 6) to collect data on travel behavior and charging activity, both actual and preferred, including the use of HOV lanes. The web-map survey allows users to indicate their origins, destinations, and preferred routes and to indicate preferred charging locations.

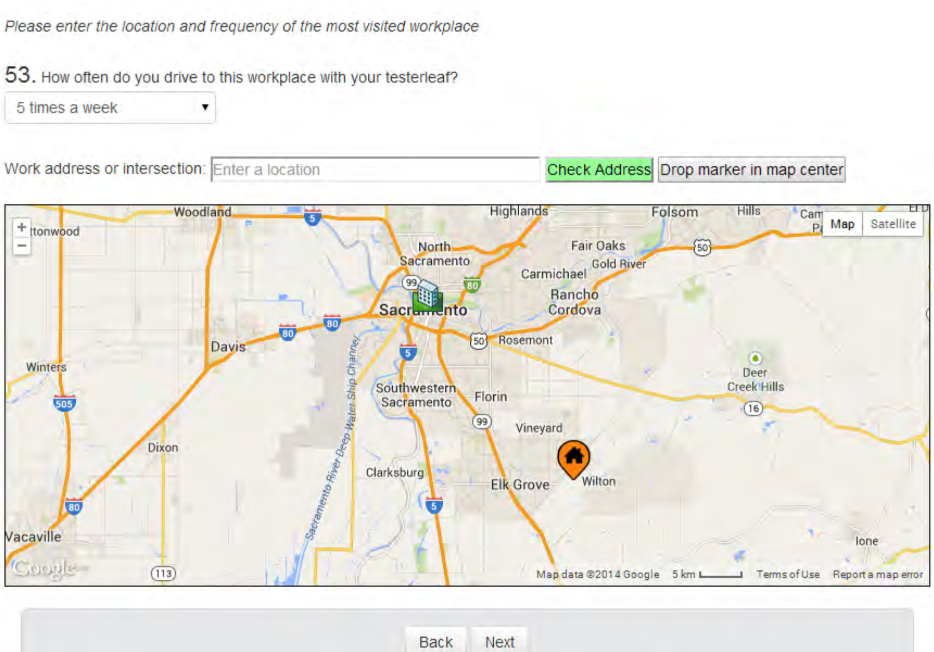

Figure 6: Web Map Survey Tool

The survey includes skip-logic to maximize the collected data with minimum survey burden. The questions are based on vehicle type, charging type and vehicle use. Questions on the vehicle purchase process are split based on private party purchase or dealer purchase and based on first time PEV buyers vs. second-time owners.

3.2. Survey Sample

Using DMV data from April 2016, the California Air Resources Board constructed a potential population of all used PEV owners in California who had registered a "used" PEV to their household. Potential used PEVs were identified if the vehicle had been transferred more than once and it had an odometer reading greater than 5,000 miles. Over 14,000 potential used PEVs were identified. We sent invitation letters to a randomly selected subsample of 4,700 households. Of those, we had 183 letters that returned because of address problems and 913 who started the survey. 27.6% of the people who started the survey indicated that they don't have a used PEV – in most cases because they purchased or leased the vehicle new and the DMV title transfer did not reflect ownership change. Based on the survey response, who indicated that they are not owners of used PEVs, we estimated that the starting population of used PEVs is about 10,130 households. Out of the valid starts, 82% completed the survey generating 602 usable surveys as described in Figure 7 and 8.

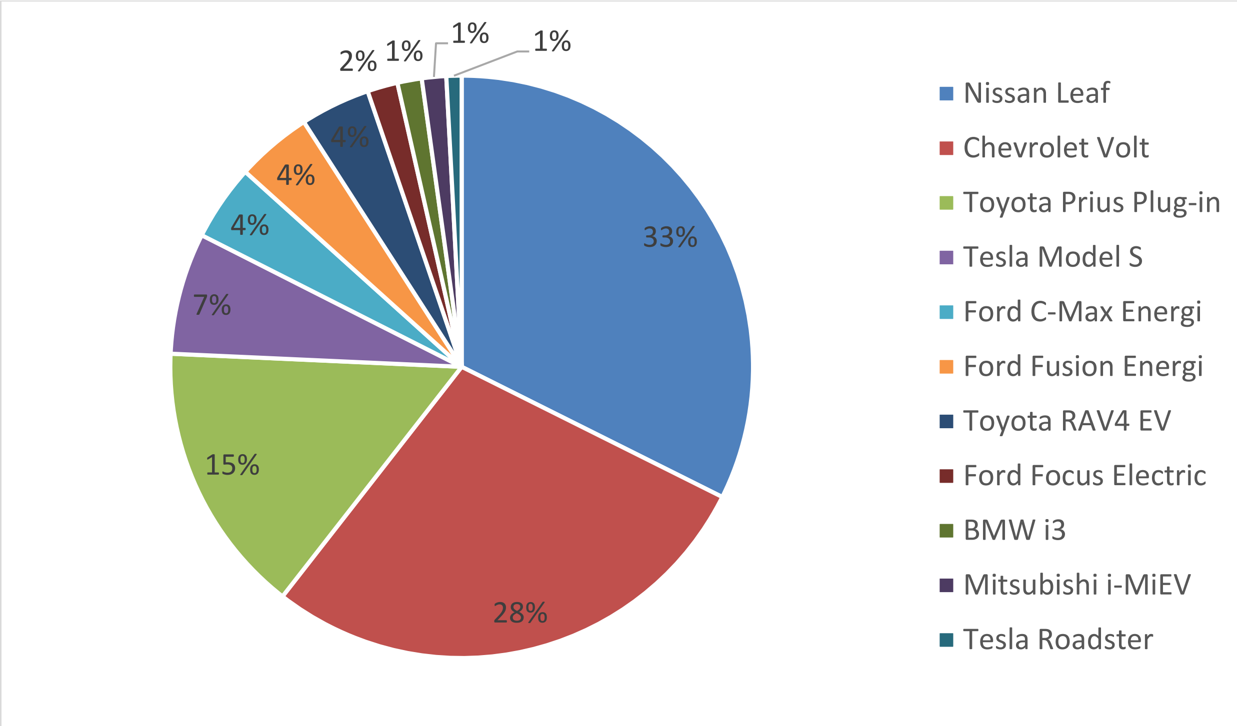

Figure 7: Used PEV surveys by vehicle model

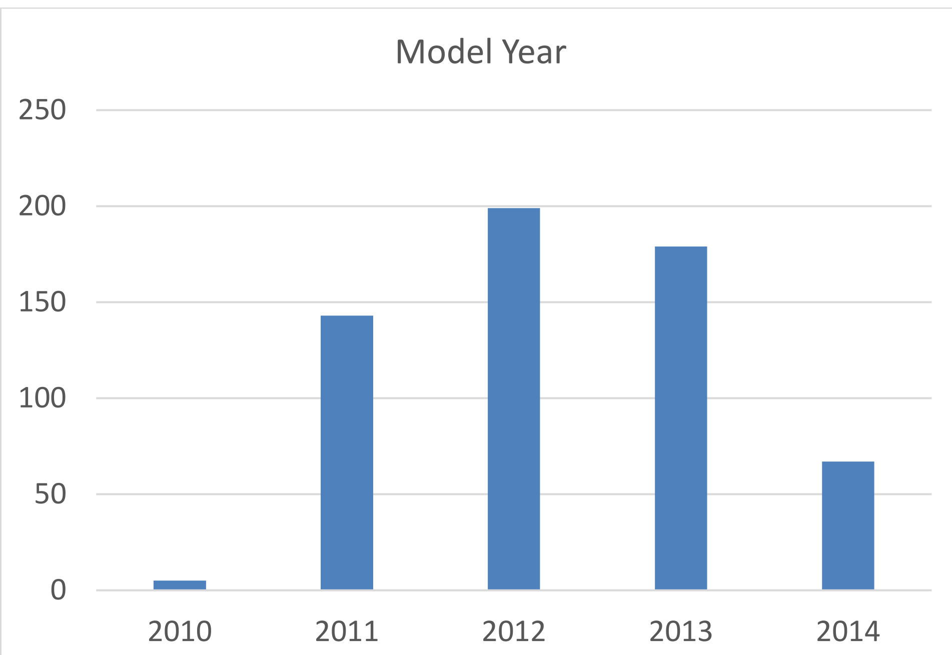

Figure 8: Used PEV surveys by model year

Most of the households in the survey owned the vehicle more than 6 months with an average of 15 months and therefore represent mostly buyers in 2015.

3.3. New PEV Comparison Sample

To estimate the price paid for the PEVs purchased new, we use 2014 and 2015 new PEV buyer surveys conducted by our PH&EV center. The surveys allow us to estimate the actual price paid for those vehicles before and after incentives including the incentives that may be paid up to a year after the vehicle purchase such as the state CVRP and the federal tax credit. We used a total of 5,227 purchased vehicles (see Table 1) to estimate both the price of the used vehicle purchased when it was new and the alternatives the used vehicle buyer had when purchasing the vehicle (i.e. what was the price of the same model but not the same year at time of purchase)

Table 1: New PEV Sample

Model and Year	New PEV sample
BMW i3_2014	175
BMW i3_2015	26
Chevrolet Volt_2011	55
Chevrolet Volt_2012	109
Chevrolet Volt_2013	451
Chevrolet Volt_2014	370
Chevrolet Volt_2015	39
Ford C-Max Energi_2013	235
Ford C-Max Energi_2014	149
Ford C-Max Energi_2015	15
Ford Focus Electric_2012	17
Ford Focus Electric_2013	41
Ford Focus Electric_2014	86
Ford Fusion Energi_2013	115
Ford Fusion Energi_2014	239
Ford Fusion Energi_2015	27
Mitsubishi i-MiEV_2012	16
Nissan Leaf_2011	94
Nissan Leaf_2012	150
Nissan Leaf_2013	546
Nissan Leaf_2014	233

Nissan Leaf_2015	107
Tesla Model S_2012	81
Tesla Model S_2013	388
Tesla Model S_2014	232
Tesla Model S_2015	34
Toyota Prius Plug-in_2012	262
Toyota Prius Plug-in_2013	244
Toyota Prius Plug-in_2014	455
Toyota RAV4 EV_2012	51
Toyota RAV4 EV_2013	76
Toyota RAV4 EV_2014	109

4. Results

4.1. Used PEV Residual Value

The resale value of used PEVs is a very important factor for the success of the PEV market. OEMs, lease companies, and private owners who plan to buy the next new vehicle strive for high resale value while potential buyers of the used PEVs compare the price to new subsidized PEVs or lower priced ICEs and constantly look for lower prices. Figure 9 describes the up to 6 different price points for the same model and year, in this case a Chevrolet Volt. The first bar is the full price paid for the vehicle based on the average price reported on the new buyers' survey. The second bar represents the MSRP as reported by the OEM and the third is the final price based on the average original price paid minus the reported incentives. The blue bars are based on the used buyer survey based on the purchasing year and reflect the vehicle's age at purchase and other factors such as the limited supply of vehicles purchased used in early years.

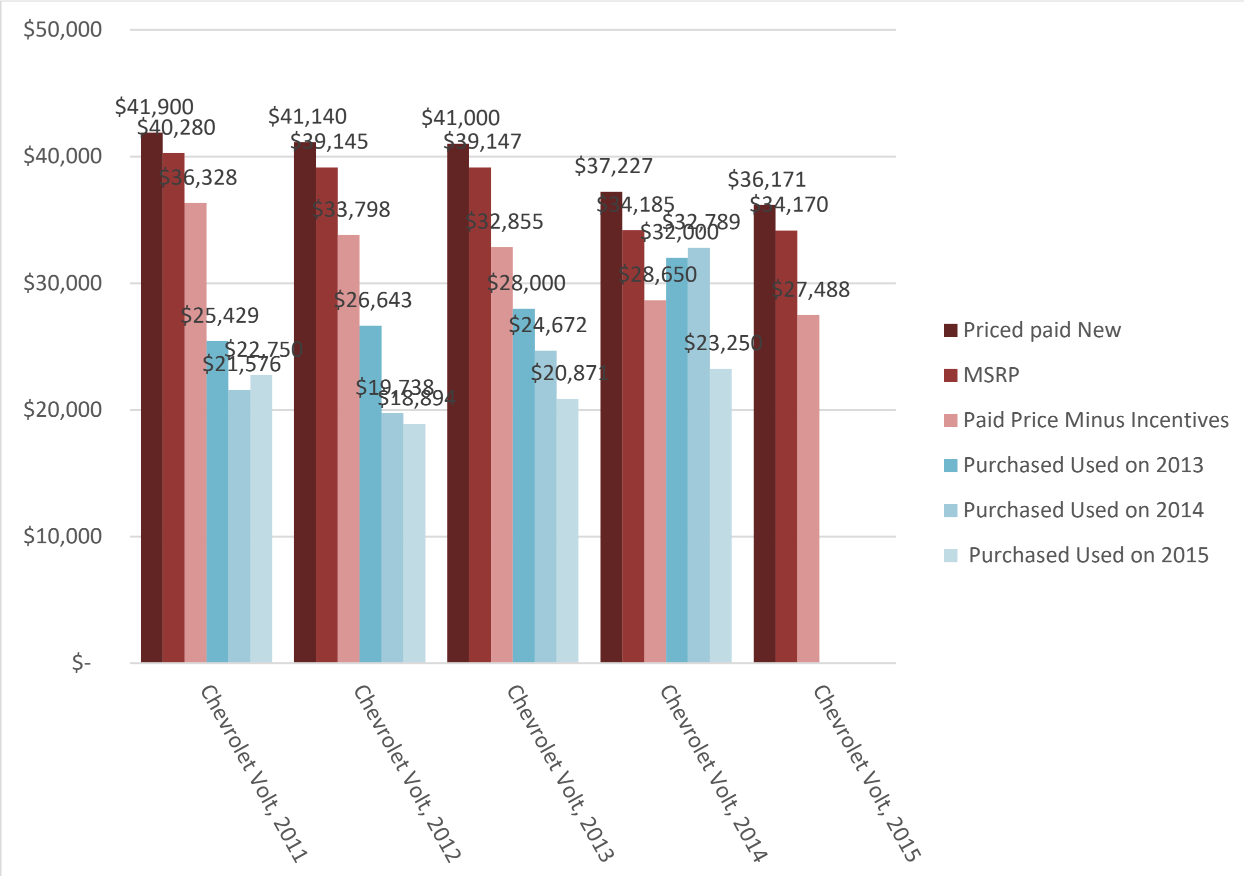

Figure 9: Chevrolet Volt price as new and used

Having up to six price points for each vehicle allows us to calculate the average residual value for the sale year based on the original values and the price of a similar vehicle at the time of purchasing the used vehicle. The residual value of a 2012 Volt sold in 2015 from the original seller's perspective (leasing companies, OEM or similar) is based on the resale price in 2015 ($18,894) divided by the original MSRP ($39,145) or 48.2%. The first owner of the vehicle has a different residual value, paying $33,798 on average for the vehicle and selling it for $18,894 or 55.9% of the price paid. The second buyer, has a different perspective when buying the vehicle in 2015. Based on the second buyer's knowledge of incentives, the alternative price for a new 2015 Volt is $27,448 (or up to $34,170 if the buyer assumes zero incentives). In case of full knowledge on the incentives, the price paid for the used vehicle ($18,894) over buying a new one for $27,448 reflects a residual value of 68.8%. Table 2 represents the residual price of 2011 to 2014 model year PEVs sold in 2015 and how these prices compare to the price paid by the original owners of similar vehicles. We only show the prices of vehicles with sample size higher than 24. Overall the lowest value calculated is 34% for a 2011 LEAF compared to MSRP or 50% of the price of new LEAF in 2015. A one year old Plug-in Prius was sold for 80% of the average prices paid by the original owner or 98% of a 2015 vehicle, which reflect the low availability of 2015 Plug-in Prius in the market and the low availability of HOV lane access stickers at that time.

Table 2: *Used price over new prices*

	MSRP	Full Price	Price Minus Incentives	Used Price in 2014	Used Price in 2015	price minus incentives of a 2015 model	2015 price over MSRP	2015 price over Paid as New	2015 price over new car price
Nissan Leaf, 2011	$33,572	$ 34,990	$ 26,815	$ 15,497	$11,463	$ 22,779	**34%**	**43%**	**50%**
Nissan Leaf, 2012	$36,882	$ 35,852	$ 26,564		$12,508	$ 22,779	**34%**	**47%**	**55%**
Nissan Leaf, 2013	$31,517	$ 33,488	$ 24,380		$13,912	$ 22,779	**44%**	**57%**	**61%**
Tesla Model S, 2013	$87,217	$ 96,732	$ 87,974		$67,338	$ 105,998	**77%**	**77%**	**64%**
Ford Fusion Energy, 2013	$39,235	$ 41,243	$ 35,936		$25,288	$ 36,214	**64%**	**70%**	**70%**
Chevrolet Volt, 2012	$39,145	$ 41,140	$ 33,798	$ 24,672	$20,871	$ 27,488	**53%**	**62%**	**76%**
Chevrolet Volt, 2013	$39,174	$ 41,000	$ 32,855	$ 24,672	$20,871	$ 27,488	**53%**	**64%**	**76%**
Ford C-Max Energy, 2013	$31,665	$ 35,014	$ 29,664		$22,875	$ 29,900	**72%**	**77%**	**77%**
Toyota Prius Plug-in, 2012	$38,195	$ 36,211	$ 32,273	$ 24,823	$22,973	$ 27,951	**60%**	**71%**	**82%**
Toyota Prius Plug-in, 2013	$38,704	$ 34,259	$ 30,394		$24,412	$ 27,951	**63%**	**80%**	**87%**
Toyota Prius Plug-in, 2014	$34,307	$ 31,726	$ 27,759		$27,525	$ 27,951	**80%**	**99%**	**98%**

A linear regression model was estimated to explore the impact of different factors on the residual price using a subset of 520 vehicles not including Tesla model S and Tesla Roadster (Table 3). We excluded those vehicles because of the different price ranges that create a biased impact on the larger market. As expected, the used PEV price is correlated positively with the original price and negatively with time on the road and mileage. We also notice that PHEV remains on average a 10.3% higher value compared to the MSRP than BEVs, and that PEVs with HOV access stickers receive $1,430 more than PEVs without an HOV sticker.

Table 3*: Parameter Estimates for price paid when purchasing used PEV*

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	6091.0037	2070.067	2.94	0.0034*
PEV Type [electric]	-1958.399	241.1654	-8.12	<.0001*
PEV age when purchased (years)	-2950.497	249.7977	-11.81	<.0001*
HOV Sticker [No]	-715.6517	252.7792	-2.83	0.0048*
Miles when purchased	-0.101106	0.016713	-6.05	<.0001*
Price paid when new	0.6887149	0.049827	13.82	<.0001*

Summary of Fit

RSquare	0.602079
RSquare Adj	0.598208
Root Mean Square Error	4642.141
Mean of Response	20814.7
Observations (or Sum Wgts)	520

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	1.6759e+10	3.3519e+9	155.5426
Error	514	1.1076e+10	21549476	Prob > F
C. Total	519	2.7836e+10		<.0001*

Lack of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	472	1.0422e+10	22080574	1.4172
Pure Error	42	654400057	15580954	Prob > F
Total Error	514	1.1076e+10		0.0819
				Max RSq
				0.9765

The model presented in Table 3 does not reflect the variation in buyer’s knowledge perspective and preference. The next section focuses on the households who purchase the vehicle trying to compare the used PEV buyers and the new PEV buyers. We do not currently have a valid comparison to new and used ICE buyers but we can compare general sociodemographic characteristics of this survey to the 2012 California travel household survey.

4.2. PEV Buyers Sociodemographic Characteristics

The survey data focuses only on buyers of used PEVs. We have no data on used ICE buyers. However, according to the 2012 CHTS, new vehicle buyers have on average higher income than used ICE buyers. Figure 11 explores the income distribution of households who purchased a vehicle in the two years prior to the survey and suggests that even though households with higher income are more likely to buy a new vehicle, the number of households who did not purchase a vehicle at all or purchased a used vehicle is much higher. The weighted income of the ICE and PEV household owner population in 2012 is $89,800 for used buyers and $119,400 for new vehicle buyers. Buyers of new PEVs between 2012 and 2014 had an average household income of

$227,000 (median response was $200,000 N=4198 not including Tesla.) Buyers of used PEVs have an average household income of $173,400 with median response of $150,000 (N=481 not including Tesla owners.) Figure 12 explores the average income differences between original owners and second owners. As expected, the income of the used PEV buyers is lower, other than the Prius and the Rav4 used buyers who have income almost as high as the original buyers reflecting the low availability of those models and the high demand for the used PEVs and HOV access stickers.

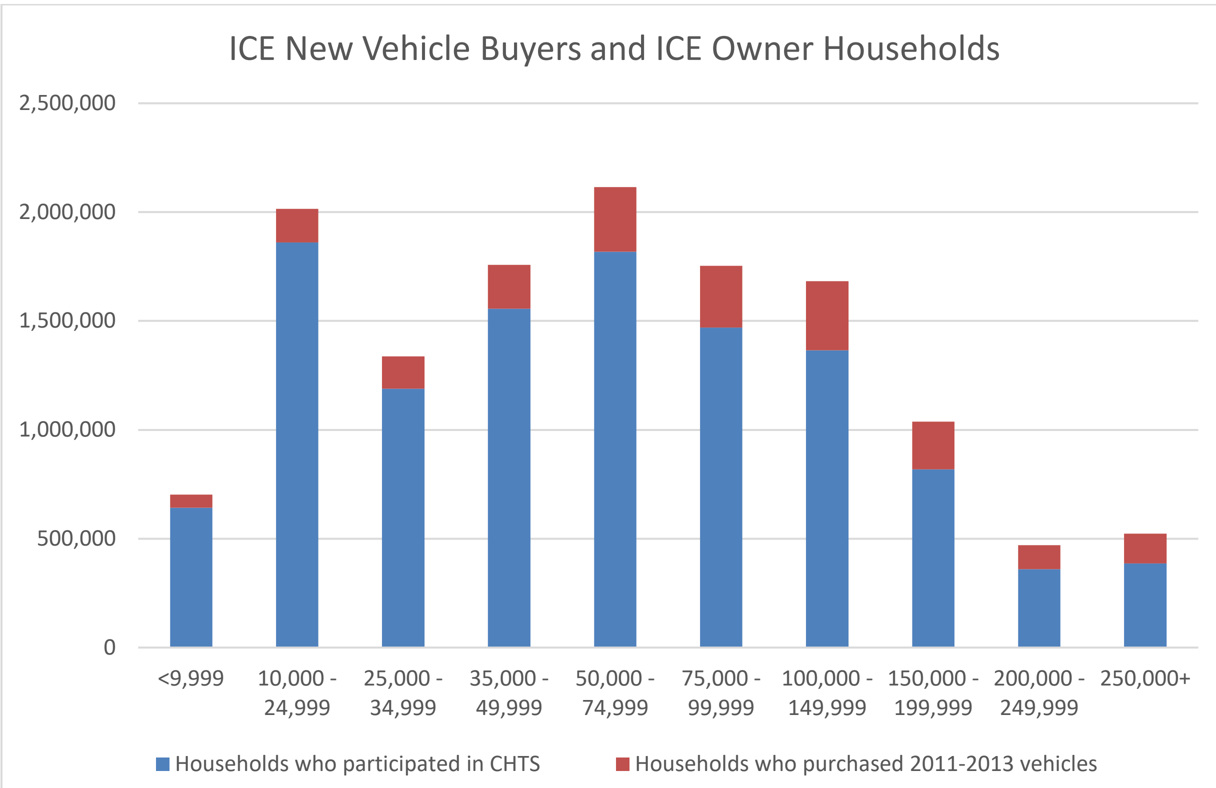

Figure 11: CHTS weighted household distribution

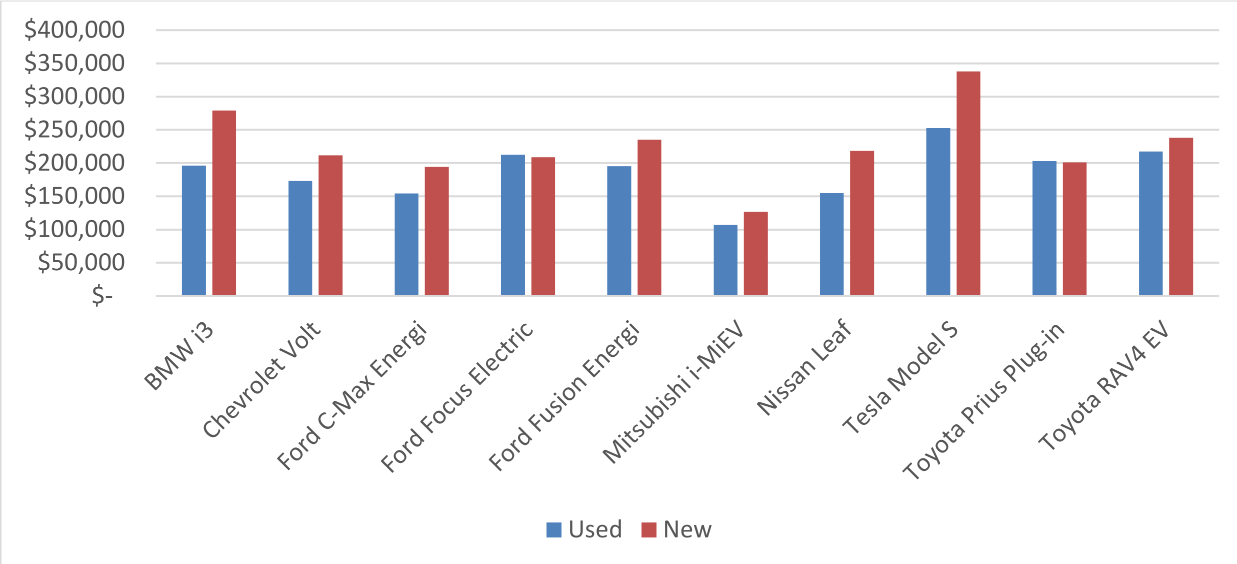

Figure 12: Household income of buyers of new and used PEVs

The differences in income may reflect the preference of lower income buyers to purchase a lower priced PEV, but may also reflect changes in preference between 2010 and 2015. We control for the change in price and preference over time by comparing the buyers of different vehicles in the same year. Figure 13 reflects the change over time, as 2013 buyers of new or used Volts had similar income but the average income of Volt buyers, for example in 2014 and 2015, drop faster than that of the new buyers.

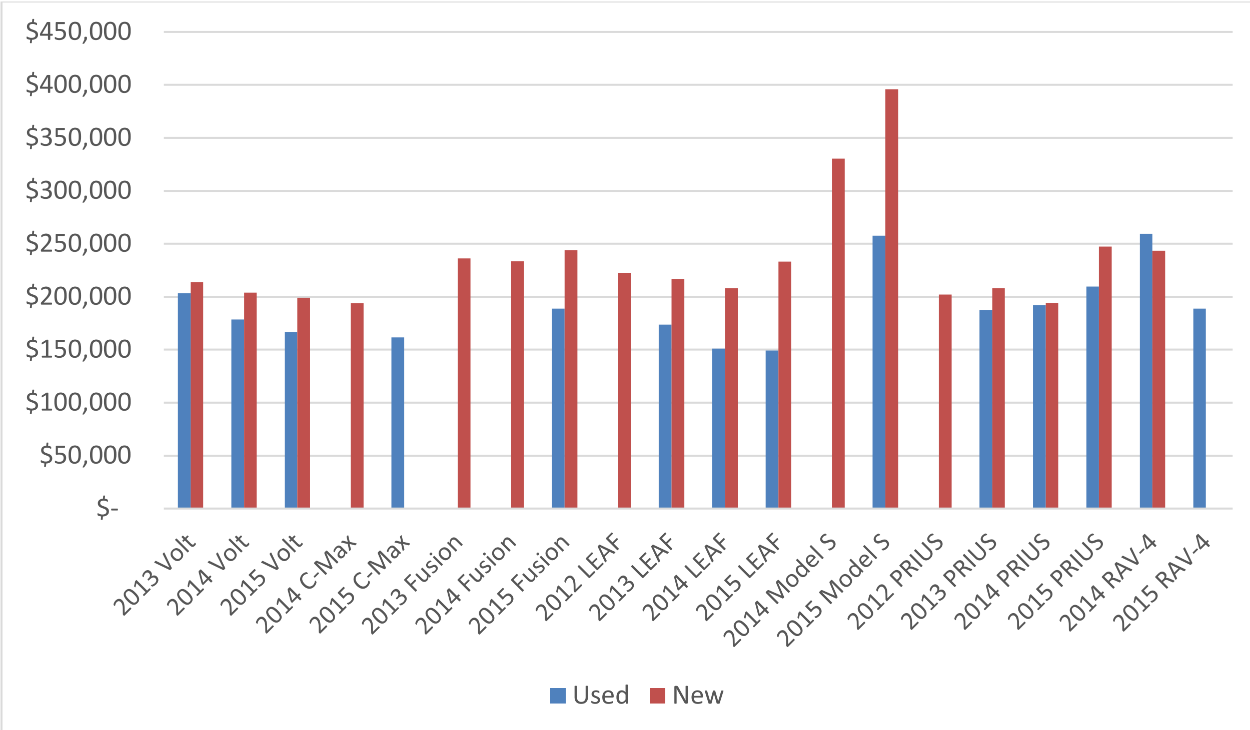

Figure 13: Household income of buyers of new and used PEV by vehicle model and purchase year

4.3. PEV buyer household fleet and vehicle preference

In order to better understand the household decision to buy a used PEV, we start with exploring the other vehicles in the household. Overall 49% had only used vehicles in their household fleet. 12% had only one used vehicle, and 38% had more than one vehicle all purchased used. On the other hand, 51% purchased new ICE vehicles in the past but elected to buy a used PEV (Figure 14). For almost 8% of the mix of new and used buyers, the used PEV is the second PEV while the first PEV was purchased new. This may reflect a change in habit, buying a new vehicle and not used as no used PEVs were available.

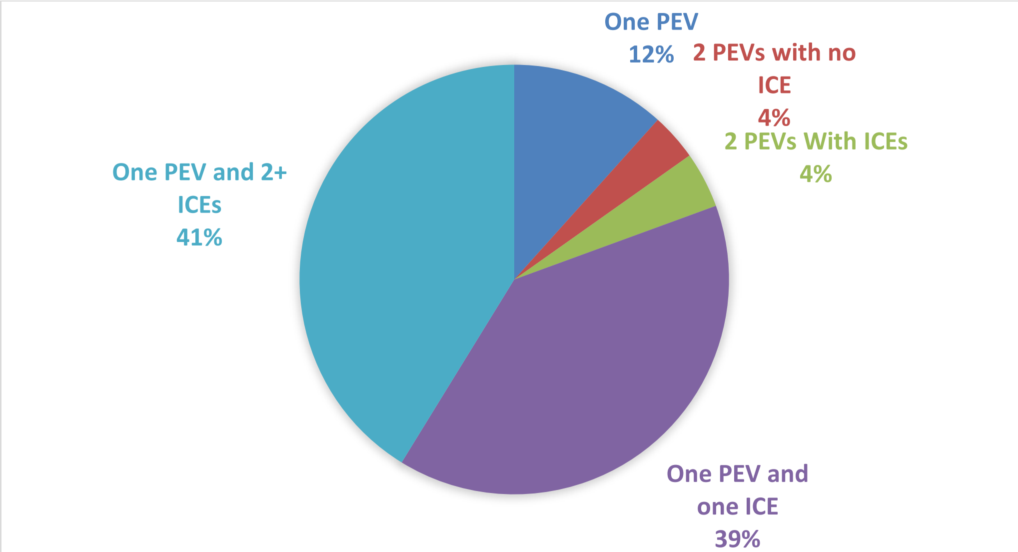

Figure 14: Survey Household Vehicles - ICEs and PEVs

4.4. Purchase preference

The buyers of used PEVs are early adopters, similar to the buyers of new PEVs. We asked the buyers for their interest in acquiring a PEV when they started the search for a vehicle to purchase and 28% answered that they were only interested in the specific make and model they ended up purchasing, while 33% answered that they were only interested in PEVs and not in ICEs. Only 11% started the search for the new vehicle with only some interest in PEVs and 4% started shopping for an ICE, but converted to a PEV in the shopping process. Asking a similar question on a continuous scale (Figure 15) shows similar patterns.

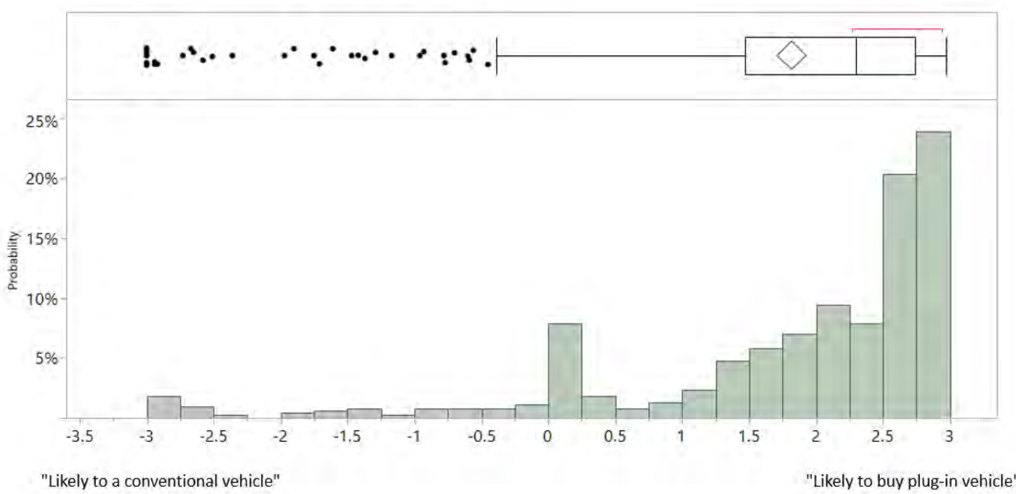

Figure 15: Likely to buy ICE or PEV

When asked about the probability of buying a used vehicle or a new vehicle, 67% of the respondents answered that they were more likely to buy a used vehicle while only 15% take into equal consideration buying a new or used vehicle, though 18% are more likely to buy new.

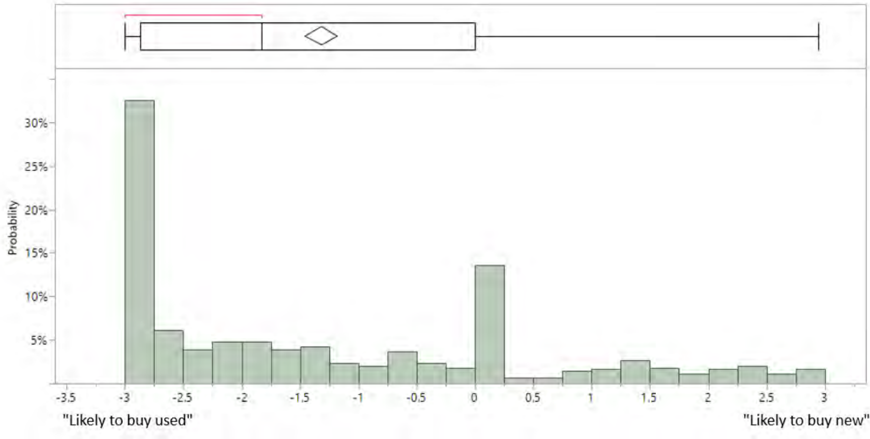

Figure 16: Likely to buy new or used

When combining the two questions together we find no linear correlation between the two questions as most buyers are in the used PEV group, but we do notice that our sample does not include potential buyers of new ICEs who end up buying used PEVs (Figure 17).

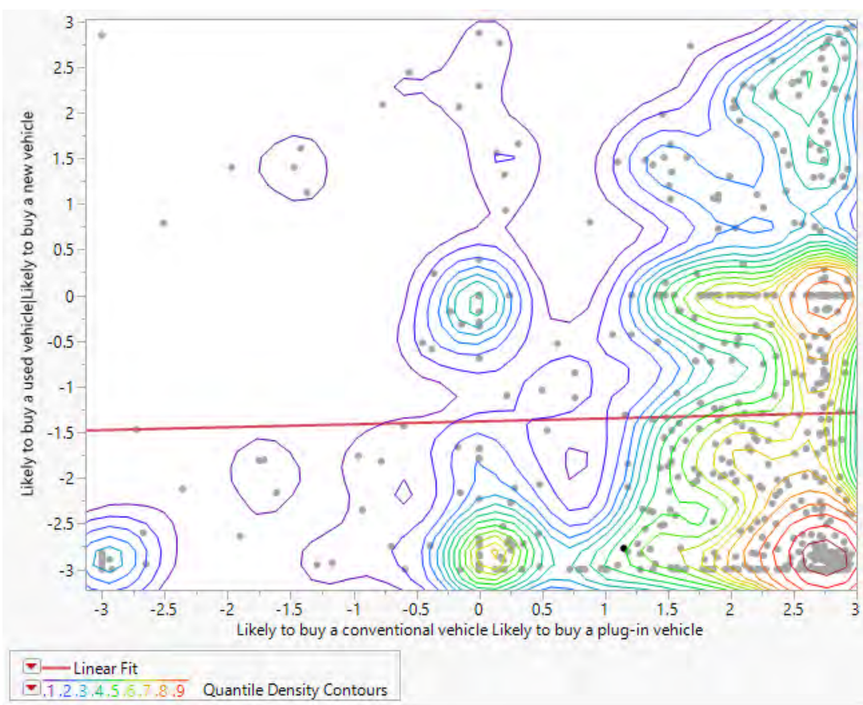

Figure 17: Density map of likely to buy new or used over likely to buy ICE or PEV

Overall, early adopters of used PEVs were in the market for a used PEV and in more than 28% of the cases, for a specific PEV. Only 3.9% started the purchase process not interested in PEVs (Figure 18)

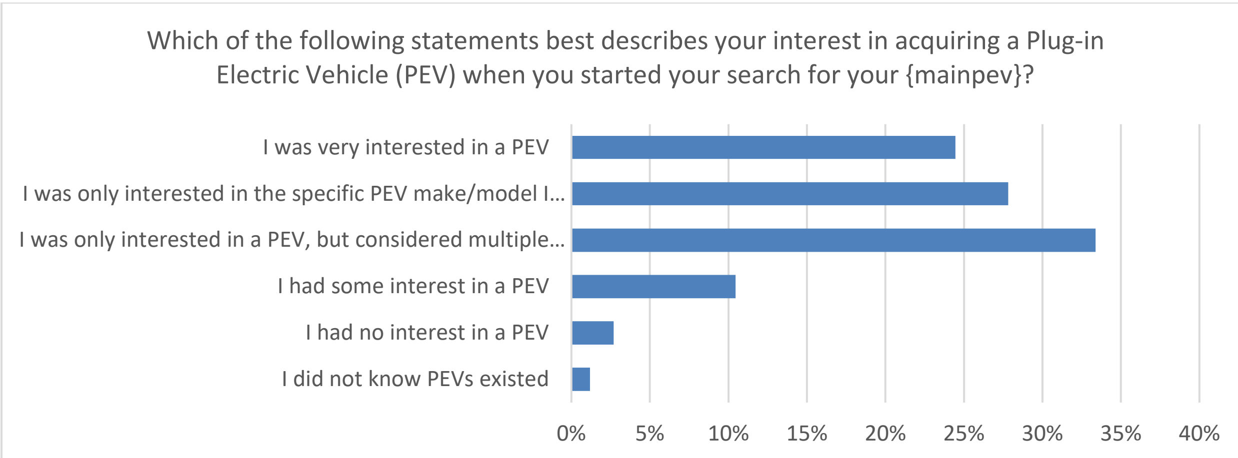

Figure 18: Interest in PEV when starting the purchase process

As presented in section 3.1, the price paid for a used PEV varied as a factor of the vehicle characteristics and the purchase timing. Next, we will explore the potential impact of the buyer attributes. We compared the price of a used PEV to that of a similar new vehicle at the time of purchase after subtracting purchase incentives and subsidies, but not all buyers were informed about the price difference between the MSRP and the actual price of a new PEV as those incentives are not available for used PEV buyers. 40.5% of the used PEV buyers had no knowledge about the federal tax credit for the purchase of a PEV with higher awareness rates for the PEVs eligible for the maximum $7,500 (Figure 19)

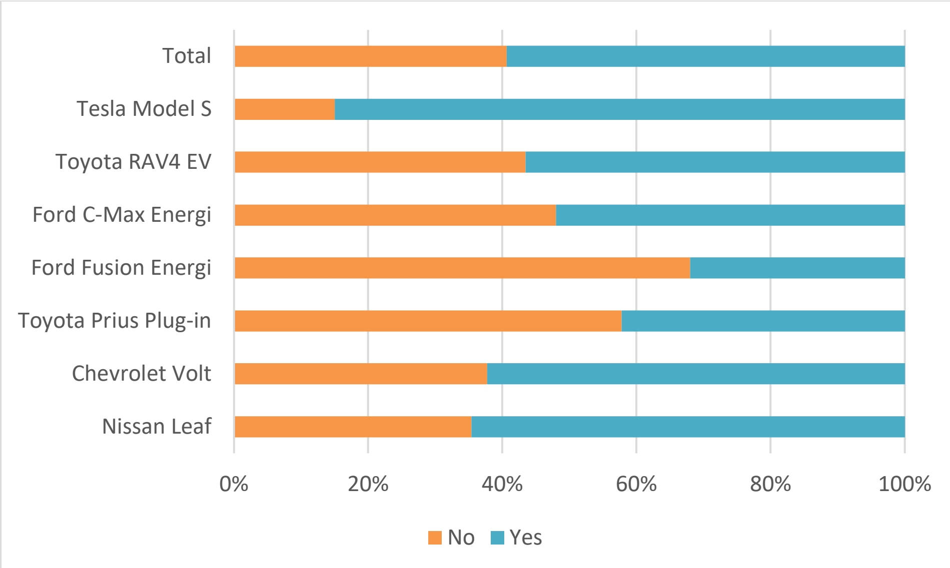

Figure 19: Knowledge about the potential federal incentive

The knowledge about the federal incentives was higher for purchasers in 2013 when most used PEVs were purchased after only a year or two on the road and lower in 2014-2015 (Figure 20)

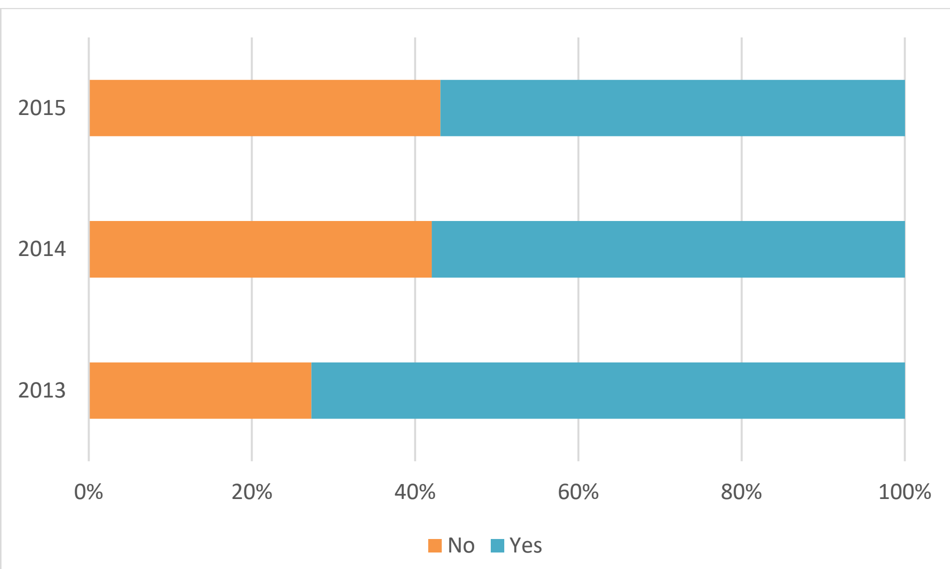

Figure 20: Knowledge of the Federal Tax credit by purchase year

We found that vehicle dealerships, even those that sell the same brand as new PEVs, were not improving the probability of knowing about the federal tax credit (Figure 21).

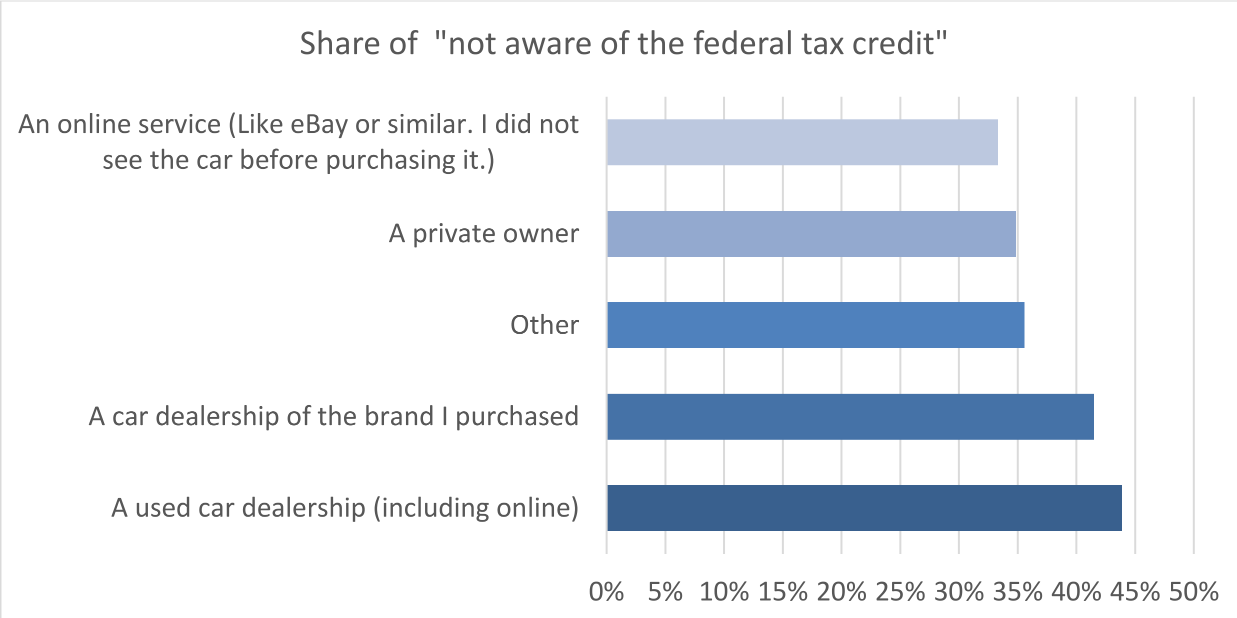

Figure 21: Knowledge of the Federal Tax credit by purchase location

The knowledge about the California PEV Clean Vehicle Rebate is lower than the knowledge about the federal tax credit which reflects the lower value of the state incentive. Only 45% of the used PEV buyers knew that if they bought a new vehicle they could receive a $1,500 to $2,500 rebate from California. Figure 20 shows a very low knowledge level for the shorter-range PHEV, perhaps because of the lower value and purchasing motivation that may be focused on HOV access and better MPG, not the plug-in capabilities.

Used PEV buyers had a long list of concerns ranking range, price and charging infrastructure as the top three (Figure 22).

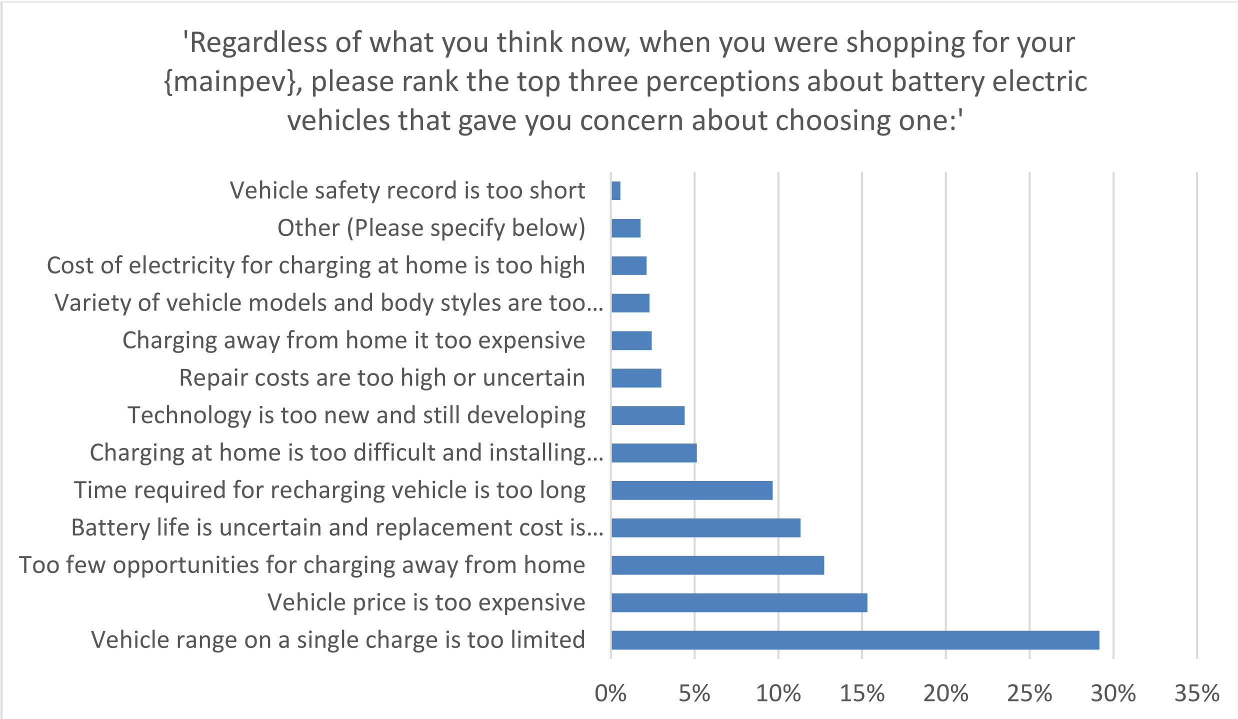

Figure 22: Initial perspectives on PEVs

Regardless of the initial perspectives, 77% of used PEV buyers would repeat their purchase if they needed to do it again and only 3% would not buy a PEV after their experience with one. 9% would buy a new vehicle if they needed to do it again, maybe as result of the additional knowledge on potential incentives (Figure 23).

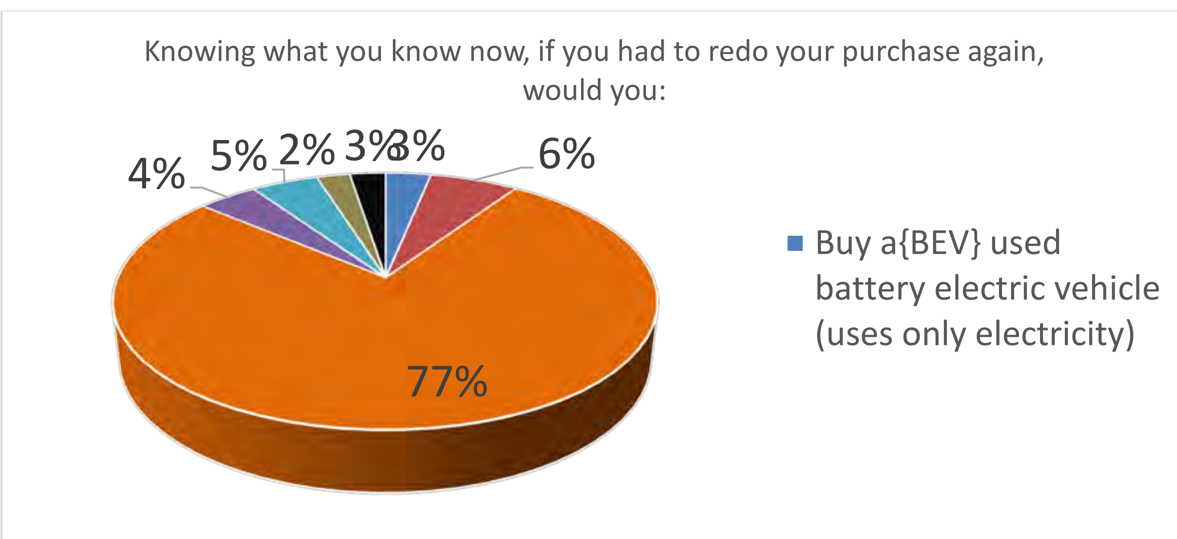

Figure 23: Would you purchase the PEV again?

The average odometer reading of used PEVs at the time of purchase was 23,400 miles. As described above, most of these vehicles entered the used PEV market after 2-3 years of usage by the original owner. The median odometer reading was 21,500 miles, with 90% of the vehicles having less than 40,000 miles as shown in the CDF plot (Figure 24).

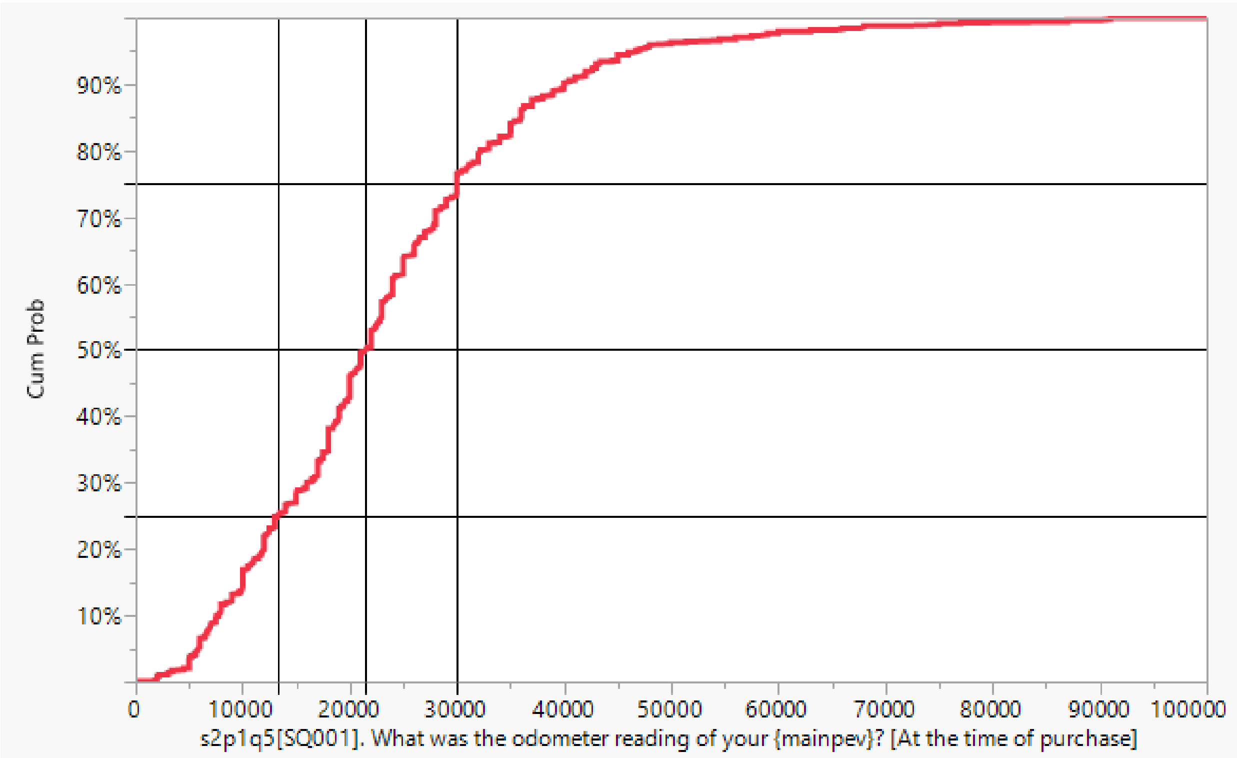

Figure 24: Odometer reading at purchase

The vehicles being relatively new and having low mileage is reflected in awareness about the battery condition as only 15% report a capacity lower than 90% of the original (Figure 25), and most buyers did not check the battery condition other than asking the seller (Figure 26).

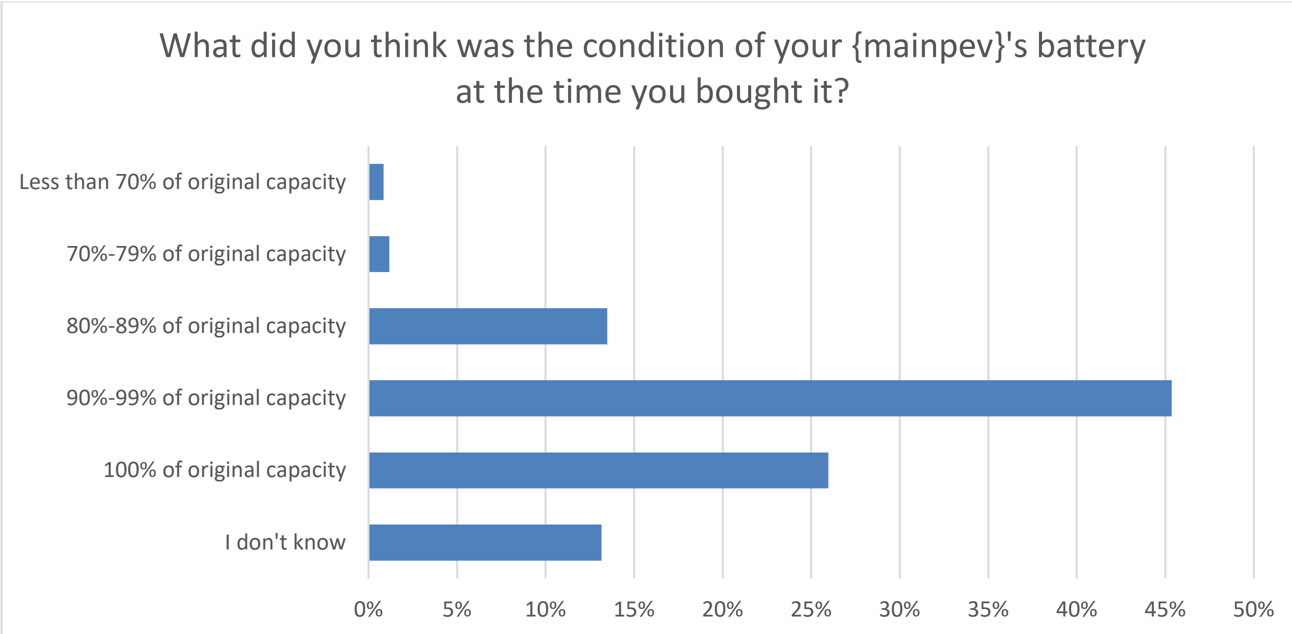

Figure 25: Battery condition at purchase

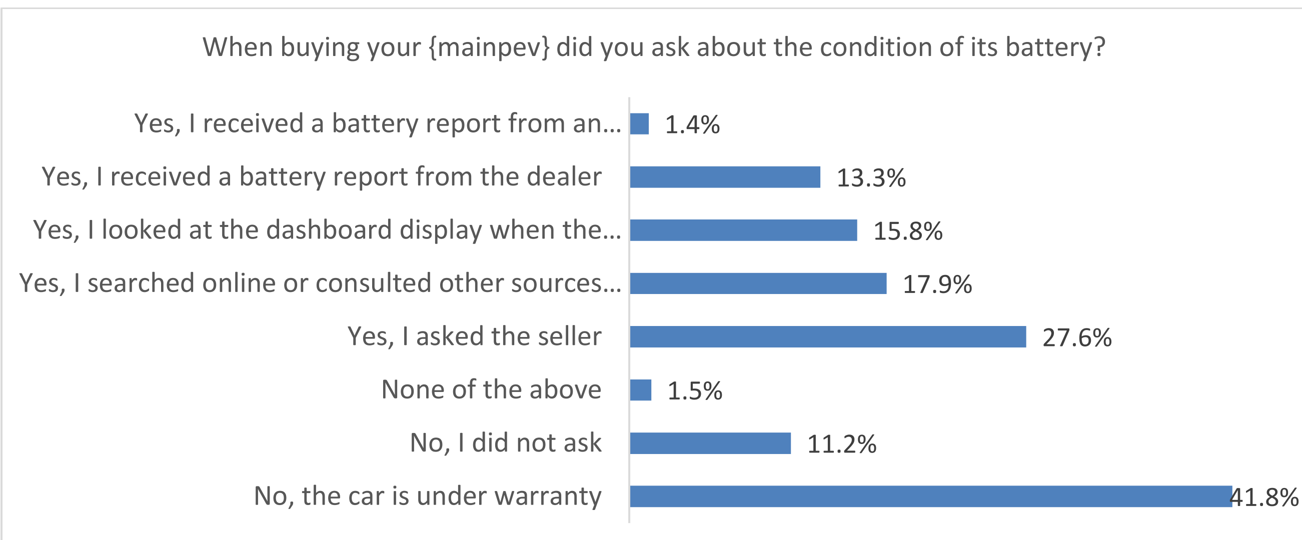

Figure 26: Asked about battery condition

4.5. Vehicle Usage

We estimated the vehicle usage based on the reported odometer reading at the time of vehicle purchase, the time of survey, and the number of months of reported ownership. We excluded outliers with less than 1,000 or over 50,000 miles per year and owners who report lower accuracy than 3,000 on their odometer report. The results, in Table 4, suggest high usage of the used PHEVs with the median higher than 15,000 for the Ford Fusion.

Table 4: Used PEV Annual miles

PEV	N	Mean	Std Dev	Median	New PEV Median
Ford Fusion Energi	25	17839	9336	15692	12600
Toyota Prius Plug-in	89	15584	9376	13678	12700
Ford C-Max Energi	24	14412	7696	12621	10800
Tesla Model S	38	14403	9490	12798	11200
Chevrolet Volt	167	13611	7126	12000	10800
Toyota RAV4 EV	23	9929	7323	8075	10500
Nissan Leaf	188	8649	6233	7836	9400

When comparing usage of the used and new PEVs (data from UCD eVMT survey data) in the last two columns of Table 4, one can see that used PHEVs are driven more than their new PHEV counterparts, but used BEVs (other than the long-range Tesla) are driven less. When comparing charging behavior (Figure 27) we see that many of those high usage PHEVs are being used as hybrid vehicles only or being plugged in less than 5 times per month. As expected, the Prius with the short-range battery has the greatest percentage of respondents that are not plugging in regularly (more than 30%), with 18% not plugging in at all.

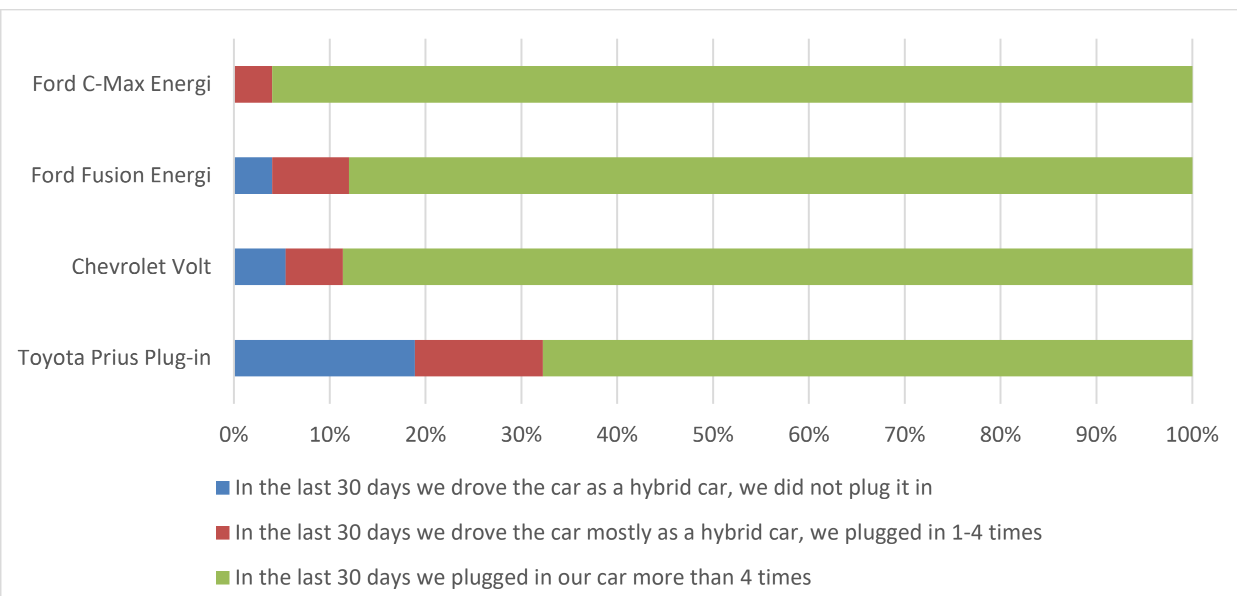

Figure 27: Not plugging in at all or less than 4 times a month

Additionally, it helps to compare the used PEV consumers to the original owners. In the eVMT project recruitment survey, we used a similar question and as shown in Figure 28 the original owners are more likely to plug in their car, even in 2016 with low gas prices.

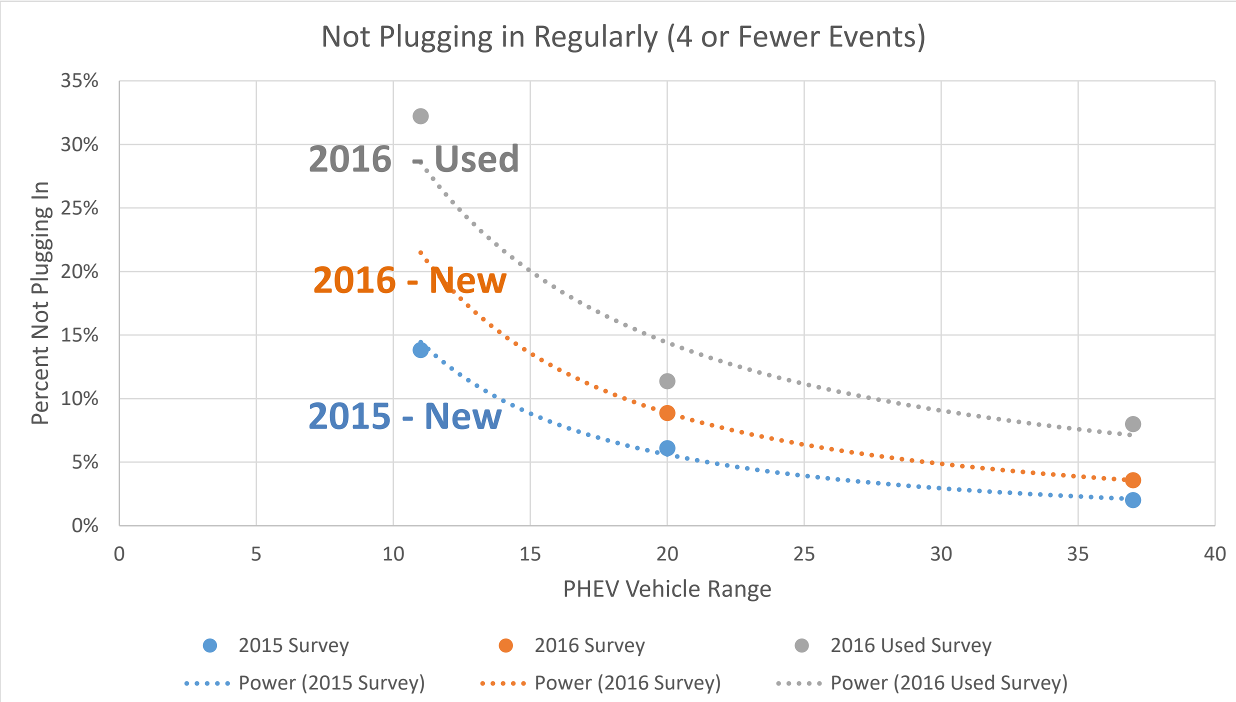

Figure 28: Percent of survey respondents rarely plugging in as a function of PHEV electric range

As the benefit of plugging in is limited by vehicle range and battery capacity, some users don't bother plugging in. We show results from 3 different surveys. The results are consistent with the premise that increasing vehicle electric range in PHEVs increases the likelihood of plugging in. Also, the plugging in of PHEVs with short ranges is vulnerable to gasoline prices and second owner user engagement.

44% of our sample plugged in only at home. Over 50% of the shorter-range PHEV drivers (of those who plugged in) plugged in only at home. We saw more public (out of home) charging for the BEVs and the longer-range Volt. Fewer than 10% of all households charge away from home only, while most the vehicles that are used as plug-in vehicles are being charged both at home and out of home (Figure 29).

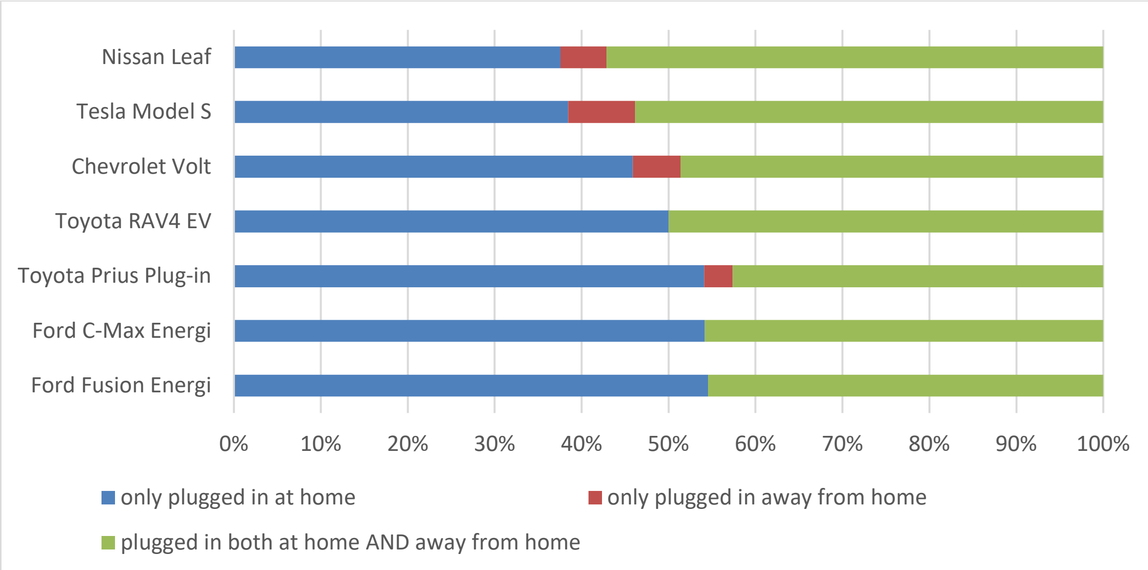

Figure 29: Charging location in the last 30 days

Figure 30 and Figure 31 show that second owners have similar levels of level 2 EVSEs at home despite a lower level of installation support. Some of the original owners received the EVSEs as part of the Federal EV project, from the OEMs or government subsidies. We see a few more converted L2 chargers with the seconed owners but a statistically similar total number of L1 use. All households who did not charge at all in the last 30 days report having L1 availability at home.

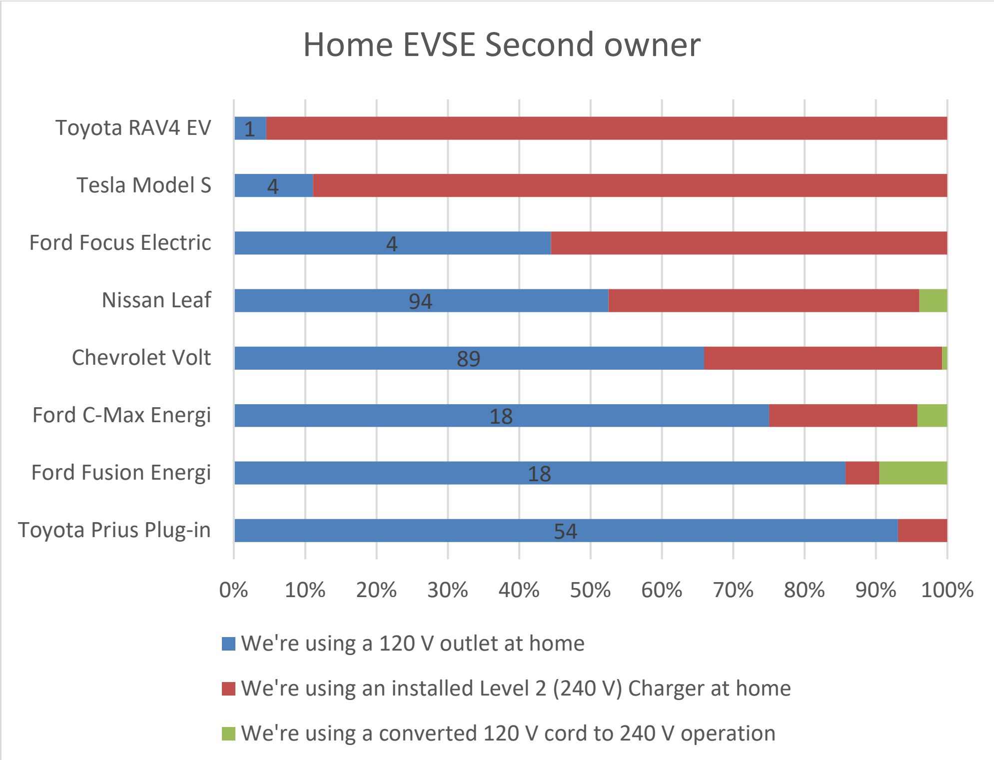

Figure 30: Second Owner- Charging at home

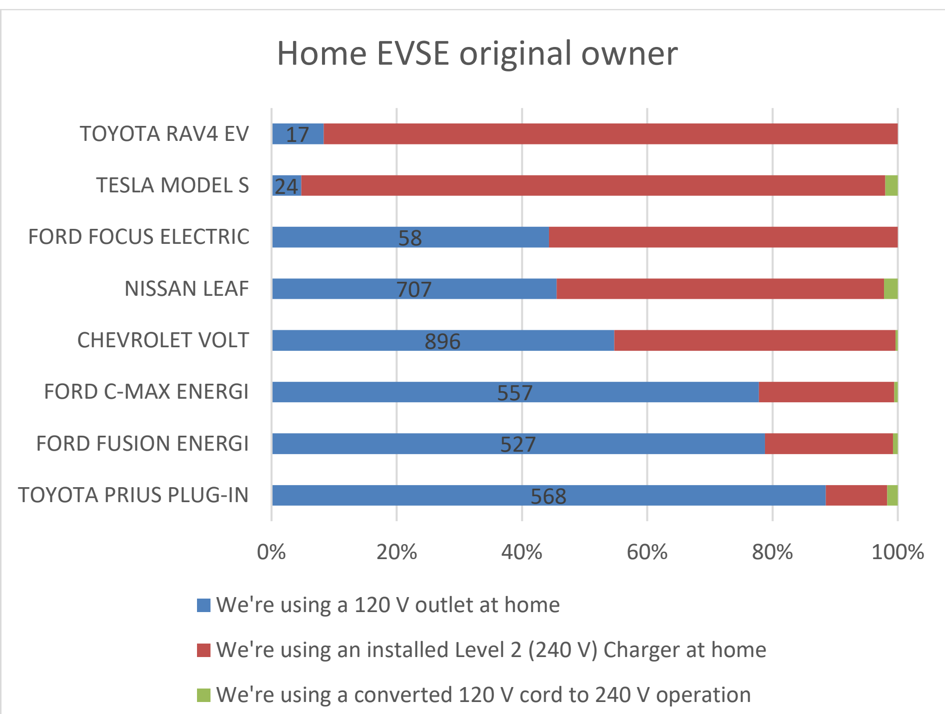

Figure 31: First Owner - Charging at Home

In Figure 32 we present the primary reason people did not install a charging station at home. Most PHEV owners reported that it is not necessary. We see 7% who reported that they are not authorized to install and 11% who report that it is too expensive. A policy that subsidizes EVSEs for second owers would benefit up to half of the buyers.

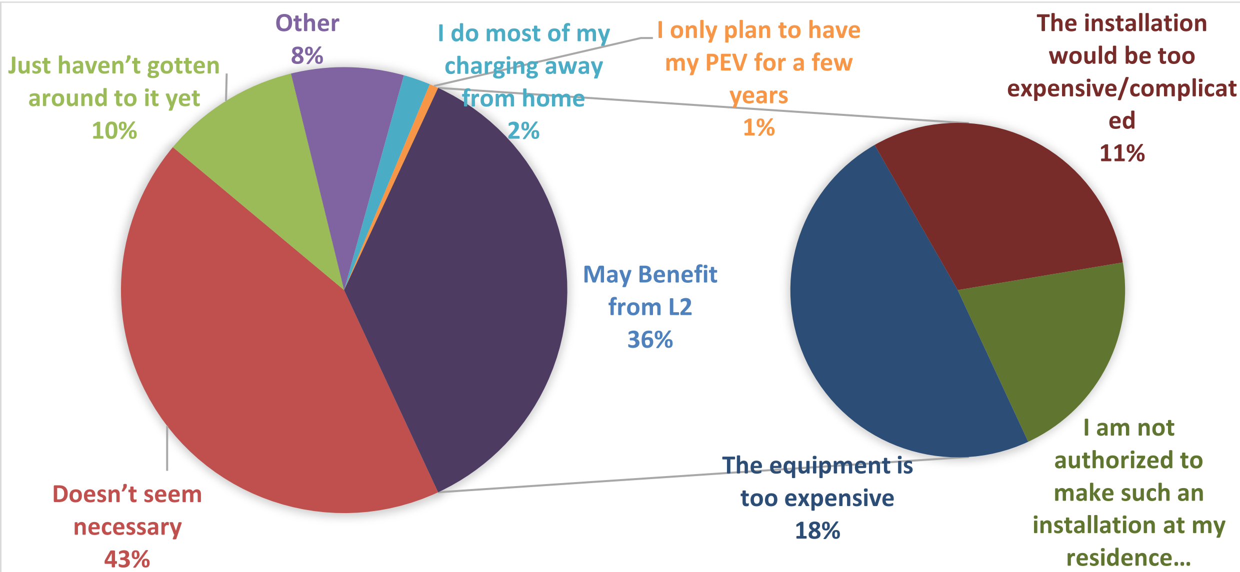

Figure 32: Reasons not to install charging station at home

5. Conclusion

Overall, buyers of used PEVs purchased a vehicle they had planned to buy and had learned about that was relatively new with low mileage, and in most cases under warranty, for a relatively low price. This may not be the case in the future, when the PEV market will contain more and older vehicles with high mileage that are over the battery and powertrain warranty limit. Used PEV buyers are more utilitarian than new PEV buyers as reflected by their high driving need but they may be less committed to electric driving; they do not always plug in their vehicle. As shown in our price analysis, HOV stickers have a high impact on the price paid and they may be negatively co33rrelated with charging behavior.

This draft research suggests a limited analysis based on the survey results and will be followed by a full report.

6. Acknowledgment/Disclaimer

This work is funded by the California Air Resources Board (ARB) through contract 14-316. The statements and conclusions in this working paper are those of the authors and not necessarily those of the ARB. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

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EXHIBIT
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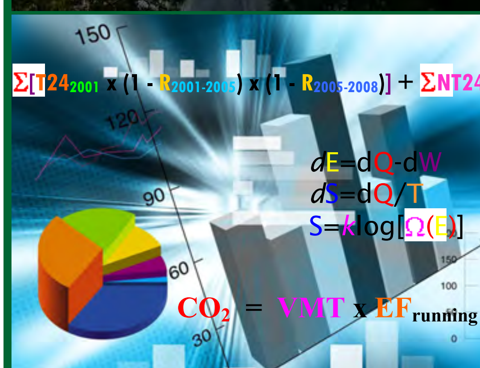

Quantifying

Greenhouse Gas Mitigation Measures

A Resource for Local Government
to Assess Emission Reductions from
Greenhouse Gas Mitigation Measures

August, 2010

Quantifying Greenhouse Gas Mitigation Measures

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California Air Pollution Control Officers Association

with

Northeast States for Coordinated Air Use Management

National Association of Clean Air Agencies

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Fehr & Peers

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Disclaimer

The California Air Pollution Control Officers Association (CAPCOA) has prepared this report on quantifying greenhouse gas emissions from select mitigation strategies to provide a common platform of information and tools to support local governments.

This paper is intended as a resource, not a guidance document. It is not intended, and should not be interpreted, to dictate the manner in which a city or county chooses to address greenhouse gas emissions in the context of projects it reviews, or in the preparation of its General Plan.

This paper has been prepared at a time when California law and regulation, as well as accepted practice regarding how climate change should be addressed in government programs, is undergoing change. There is pending litigation that may have bearing on these decisions, as well as active legislation at the federal level. In the face of this uncertainty, local governments are working to understand the new expectations, and how best to meet them. This paper is provided as a resource to local policy and decision makers to enable them to make the best decisions they can during this period of uncertainty.

Finally, in order to provide context for the quantification methodologies it describes, this report reviews requirements, discusses policy options, and highlights methods, tools, and resources available; these reviews and discussions are not intended to provide legal advice and should not be construed as such. Questions of legal interpretation, or requests for legal advice, should be directed to the jurisdiction's counsel.

Table of Contents

Executive Summary

This report on *Quantifying Greenhouse Gas Mitigation Measures: A Resource for Local Government to Assess Emission Reductions from Greenhouse Gas Mitigation Measures* was prepared by the California Air Pollution Control Officers Association with the Northeast States for Coordinated Air Use Management and the National Association of Clean Air Agencies, and with technical support from Environ and Fehr & Peers. It is primarily focused on the quantification of project-level mitigation of greenhouse gas emissions associated with land use, transportation, energy use, and other related project areas. The mitigation measures quantified in the Report generally correspond to measures previously discussed in CAPCOA's earlier reports: *CEQA and Climate Change*; and *Model Policies for Greenhouse Gases in General Plans*. The Report does not provide policy guidance or advocate any policy position related to greenhouse gas emission reduction.

The Report provides a discussion of background information on programs and other circumstances in which quantification of greenhouse gas emissions is important. This includes voluntary emission reduction efforts, project-level emission reduction efforts, reductions for regulatory compliance, and reductions for some form of credit. The information provided covers basic terms and concepts and again, does not endorse or provide guidance on any policy position.

Certain key concepts for quantification are covered in greater depth. These include baseline, business-as-usual, types of emission reductions, project scope, lifecycle analysis, accuracy and reliability, additionality, and verification.

In order to provide transparency and to enhance the understanding of underlying strengths and weaknesses, the Report includes a detailed explanation of the approaches and methods used in developing the quantification of the mitigation measures. There is a summary of baseline methods (which are discussed in greater detail in Appendix B) as well as a discussion of methods for the measures. This includes the selection process for the measures, the development of the quantification approaches, and limitations in the data used to derive the quantification.

The mitigation measures were broken into categories, and an overview is provided for each category. The overview discusses specific considerations in quantifying emissions for measures in the category, as well as project-specific data the user will need to provide. Where appropriate and where data are readily available, the user is directed to relevant data sources. In addition, some tables and other information are included in the appendices.

The mitigation measures are presented in Fact Sheets. An overview of the Fact Sheets is provided which outlines their organization and describes the layout of information. The Report also includes a step-by-step guide to using a Fact Sheet to quantify a project, and discusses the use of Fact Sheets outside of California. The Report also discusses the grouping of the measures, and outlines procedures and limitations for quantifying projects where measures are combined either within or across categories. These limitations are critical to ensure that emission reductions are appropriately quantified and are not double counted. As a general guide, approximate ranges of effectiveness are provided for each of the measures, and this is presented in tables at the end of Chapter 6. These ranges are for reference only and should not be used in lieu of the actual Fact Sheets; they do not provide accurate quantification on a project-specific basis.

The Fact Sheets themselves are presented in Chapter 7, which includes an index of the Fact Sheets and cross references each measure to measures described in CAPCOA's earlier reports: *CEQA and Climate Change*; and *Model Policies for Greenhouse Gases in General Plans*. Each Fact Sheet includes a description of the measure, assumptions and limitations in the quantification, a baseline methodology, and the quantification of the measure itself. There is also a sample project calculation, and a discussion of the data and studies used in the development of the quantification.

In the Appendices, there is a glossary of terms. The baseline methodology is fully explained, and there is additional supporting information for the transportation methods and the non-transportation methods. Finally, the Report includes select reference tables that the user may consult for select project-specific factors that are called for in some of the Fact Sheets.

Background

The California Air Pollution Control Officers Association (CAPCOA) prepared the report, *Quantifying Greenhouse Gas Mitigation Measures: A Resource for Local Government to Assess Emission Reductions from Greenhouse Gas Mitigation Measures* (Quantification Report, or Report), in collaboration with the Northeast States for Coordinated Air Use Management (NESCAUM) and the National Association of Clean Air Agencies (NACAA), and with contract support from Environ, and Fehr & Peers, who performed the technical analysis. The Report provides methods for quantifying emission reductions from a specified list of mitigation measures, primarily focused on project-level mitigation. The emissions calculations include greenhouse gases (GHGs), particulate matter (PM), carbon monoxide (CO), oxides of nitrogen (NOx), sulfur dioxide (SO2), and reactive organic gases (ROG), as well as toxic air pollutants, where information is available.

The measures included in this Report were selected because they are frequently considered as mitigation for GHG impacts, and standardized methods for quantifying emissions from these projects were not previously available. Measures were screened on the basis of the feasibility of quantifying the emissions, the availability of robust and meaningful data upon which to base the quantification, and whether the measures (alone or in combination with other measures) would result in appreciable reductions in GHG emissions. CAPCOA does not mean to suggest that other measures should not be considered, or that they might not be effective or quantifiable; on the contrary, there are many options and approaches to mitigate emissions of GHGs. CAPCOA sought to provide a high quality quantification tool to local governments with the broadest applicability possible, given the resource limitations for the project. CAPCOA encourages local governments to be bold and creative as they approach the challenge of climate change, and does not intend this Report to limit the scope of measures considered for mitigation.

The majority of the measures in the Report have been discussed in CAPCOA's previous resource documents: *CEQA and Climate Change*, and *Model Policies for Greenhouse Gases in General Plans*. The measures in this Report are cross-referenced to those prior reports. The quantification methods provided here are largely project-level in nature; they can certainly inform planning decisions, however a complete planning-level analysis of mitigation strategies will entail additional quantification.

In developing the quantification methods, CAPCOA and its contractors conducted an extensive literature review. The goal of the Report was to provide accurate and reliable quantification methods that can be used throughout California and adapted for use outside of the state as well.

Intent and Audience

This document is intended to further support the efforts of local governments to address the impacts of GHG emissions in their environmental review of projects and in their planning efforts. Project proponents and others interested in quantifying mitigation measures will also find the document useful.

The guidance provided in this Report specifically addresses appropriate procedures for applying quantification methods to achieve accurate and reliable results. The Report includes background information on programs and concepts associated with the quantification of GHG emissions. The Report does not provide policy guidance on any of these issues, nor does it dictate how any jurisdiction should address questions of policy. Policy considerations are left to individual agencies and their governing boards. Rather, this Report is intended to support the creation of a standardized approach to quantifying mitigation measures, to allow emission reductions and measure effectiveness to be considered and compared on a common basis.

Because the quantification methods in this Report were developed to meet the highest standards for accuracy and reliability, CAPCOA believes they will be generally accepted for most quantification purposes. The decision to accept any quantification method rests with the reviewing agency, however. Further, while the Report discusses the quantification of GHG emissions for a variety of purposes, including the quantification of reductions for credit, using these methods does not guarantee that credit will be awarded.

Using the Document

Chapters 2 and 3 of this Report discuss programs and concepts associated with GHG quantification. They are intended to provide background information for those interested in the context in which reductions are being made. Chapter 4 discusses the underpinnings of the quantification methods and specifically addresses limitations in the data used as well as limitations in applying the methods; it is important for anyone using this Report to review Chapter 4. Chapter 5 provides an overview of the mitigation measure categories, including key considerations in the quantification of emission reductions in those categories. Chapter 6 explains how to use the fact sheets for each measure's quantification method, and also discusses the effectiveness of the measures and how combining measures changes the effectiveness.

Once the user understands the quantification context, and the limitations of the methods, the fact sheets can be used like recipes in a cookbook . In using the fact sheets, however, CAPCOA strongly advises the reader to pay careful attention to the assumptions and limitations set forth for each individual measure, and to make sure that these are respected and appropriately considered.

The fact sheets with the actual quantification methods for each individual measure are contained in Chapter 7. The baseline methods are explained in Appendix B. It is the responsibility of the user to ensure that all data inputs are provided as called for in the methods, and that the data are of appropriate quality.

CAPCOA will not be able to provide case-by-case review or adjustments for specific projects outside of the provision for project-specific data inputs that is part of each fact sheet. Questions about individual projects may be referred to your local air district.

As a final note, the methods contained in this document include generalized information about the measures themselves. This information includes emission factors, usage rates, and other data from various sources, most commonly published data from public agencies. The data were carefully reviewed to ensure they represent the best information available for this purpose. The use of generalized information allows the quantification methods to be used across a range of circumstances, including variations in geographical location, climate, and population density, among others.

Where good quality, project-specific data is available that provides a superior characterization of a particular project, it should be used instead of the more generalized data presented here. The methods provided for baseline and mitigated emissions scenarios allow for such substitution. The local agency reviewing the project should review the project-specific data, however, to ensure that it meets standards for data quality and will not result in an inappropriate under- or overestimation of project emissions or mitigation.

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Quantification Framework

The Quantification Report has been prepared to support a range of quantification needs. It is based on the premise that quantification of GHG emissions and reductions should rest on a foundation of clear assumptions, limits, and calculations. When these elements and the methods of applying them are transparent, a common "language" is created that allows us to talk about, compare, and evaluate GHGs with confidence that we are looking at "apples to apples."

For the purpose of this report, GHGs are the six gases identified in the Kyoto Protocol: carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). GHGs are expressed in metric tons (MT) of CO_2e (carbon dioxide equivalents). Individual GHGs are converted to CO_2e by multiplying values by their global warming potential (GWP). Global warming potentials represent a ratio of a gas' heat trapping characteristics compared to CO_2, which has a global warming potential of 1.

As a general rule, the quantification methods in this report are only accurate to the degree that the project adheres to the assumptions, limitations, and other criteria specified for a given measure. Where specific data inputs are indicated for either the baseline or the project scenario calculations, those data must be provided for the calculations to be valid. Further, the quality of the data used will substantially impact the quality of the results achieved. For example, if a calculation method calls for a traffic count, the calculations can't be made without supplying a traffic count number. However, the number used could be a rough estimate, could be based on a small, one-time sample, or could be derived through a full traffic study over a representative period of time or times. Clearly, using a rough estimate for any of the data inputs will yield results that are less accurate than they would be if higher quality data inputs were provided.

This does not mean that rough estimates cannot be used. There will be times when the quantification does not need to be precise. In order to speak the common language, however, it is important to identify how precise your data inputs are. It is also important to give careful consideration to the intended use of the quantification, to make sure that the results you achieve will be sufficiently rigorous to support the conclusions you draw from them.

The quantification methods in this report rely on very specific assumptions and limitations for each mitigation measure. Unlike the discussion of data inputs, the measure assumptions and limits affect more than the precision of the calculations: they determine whether the calculation is valid at all. For example, there is a method for calculating GHG reductions for each percentage in improvement in building energy use beyond the performance standards in California's Title 24; that method states that the measure is specifically for electricity and natural gas use in residential and commercial buildings subject to Title 24. If the building is located outside of California, where Title 24 is not applicable, the method will not yield accurate results unless the baseline assumptions are adjusted to reflect the standards that actually apply. Further, the measure effectiveness is based on assumptions that certain other energy efficiency measures are also applied (such as third-party HVAC-commissioning); if those additional measures are not applied, the calculated reductions will not be accurate and will overestimate the reductions compared to what will actually be achieved.

There may be situations where you choose to apply a method even if the assumptions do not match the specific conditions of the project; while CAPCOA does not recommend this, if you do it, it is imperative that any deviations are clearly identified. While you may still be able to calculate a reduction for your measure, in many cases the error in your result will be so large that any conclusions you would draw from the analysis could be completely wrong.

Quantifying Measures for Different Purposes

There are several reasons that a person might implement measures to reduce GHG emissions. Some measures are implemented simply because it's a good thing to do. Knowing how many metric tons of GHG emissions were reduced might not be important in that case. There are other reasons for undertaking a project to reduce GHGs, however, and for some of these purposes quantification (and verification) become increasingly important, and sensitive. This chapter discusses the role of quantification, and to a lesser extent verification, in reductions undertaken for a range of reasons. These include: voluntary reductions, reductions undertaken specifically to mitigate current or future impacts, reductions for regulatory compliance, and reductions where some form of credit is being sought, including credits that may be traded on a credit exchange. The purpose for which reductions are quantified will determine the level of detail involved in the quantification, as well as the degree of verification needed to support the quantification. As stated previously, this discussion is provided for information purposes only; it should not be construed to advocate or endorse any particular policy position.

Voluntary Reductions

Voluntary reductions of GHG emissions are reductions that are not required for any reason, including a regulation, law, or other form of standard. Even when reductions are not mandatory, however, there may be reasons to quantify them. The project proponent may simply want to know how effective the project is. Examples of this would be when a project is undertaken in an educational setting, or to demonstrate the general feasibility of a concept, or promote an image of environmental responsibility. In such a case, the focus may be on implementing the project more than documenting exactly how many tons of CO_2e have been reduced, and a reasonable estimate might be sufficient. The project proponent may wish to track reductions to fulfill an organizational policy or commitment, or to establish a track record in GHG reductions. For these purposes, the quantification does not need to be precise, but it should still be based on sound principles and accepted methods.

When reductions are purely voluntary, they may be estimated using the methods contained in this document, even if all of the variables are not known, or if some of the assumptions are not fully supported by the specifics of the project. If the quantification is performed without the level of detail outlined in the method for a given measure (or specified for the baseline calculations), the results will be less accurate. The same is true if a method is used in a situation where the assumptions are not fully supported, or if the method is used outside the noted limitations. As one would expect, the greater the degree of variation from the conditions put forth in the fact sheets, the less accurate the quantification will be. Significant deviation can result in very large errors.

VOLUNTARY REPORTING of GREENHOUSE GASES

If there is any possibility that the project proponent may at some point wish to use the reductions to fulfill a future regulatory or mitigation requirement, or seek some form of credit for the reductions, the proponent should not deviate from the methods and should ensure that all necessary data are included, and all assumptions and limitations are appropriately addressed. Acceptance of the quantification methods in this Report to fulfill any requirement is solely at the discretion of the approving agency. Use of these methods does not guarantee that credit of any kind will be awarded for reductions made.

Reductions to Mitigate Current or Future Impacts

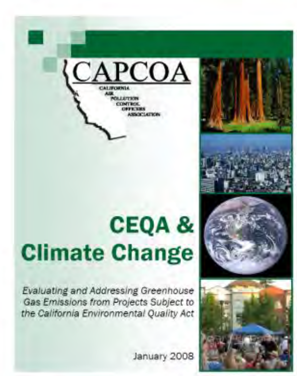
One of the most common reasons for quantifying emissions of GHG is to analyze and mitigate current or future impacts of specific actions or activities. This can include project-level impacts, such as those evaluated under the California Environmental Quality Act (CEQA), or plan-level impacts, such those resulting from the implementation of a General Plan or Climate Action Plan. Quantification of projects and mitigation under CEQA was the main focus in preparing this guidance document. Most of the measures quantified in the Report are project-level in nature. Many of these are also good examples of the kinds of policies and actions that would be included in a General Plan or a Climate Action Plan. The quantification methods provided here can be used to support conclusions about the effectiveness of different measures in a planning context; however, a full analysis of plan-level impacts will require consideration of additional factors, depending on the nature of the measure. Some of the measures have been specifically identified as General Plan measures, and a discussion is included about appropriate analysis of these measures, where study data exist to support such analysis.

Project-Level Mitigation: Existing environmental law and policy requires that environmental impacts of projects be evaluated and disclosed to the public, and where those impacts are potentially significant, that they be mitigated. At the federal level, the National Environmental Protection Act (NEPA) governs this evaluation. Many states have their own programs as well; in California, the California Environmental Quality Act, or CEQA, sets forth the requirements and the framework for the review.

The responsibility to evaluate impacts, to determine significance, and to define appropriate mitigation rests with the Lead Agency. This is typically a city or county with land-use decision-making authority, although other agencies can be Lead Agencies, depending on the nature of the project and the jurisdiction of the agency.

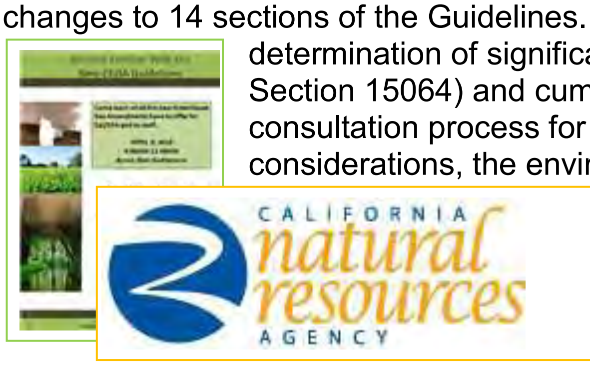
Guidance on CEQA and Climate Change: There are currently two resources for Lead Agencies on incorporating considerations of climate change into their CEQA processes. The first was prepared by CAPCOA, and the most recent is an amendment to the official CEQA Guidelines prepared by the California Natural Resources Agency (Resources Agency).

CAPCOA Guidance- In January of 2008, CAPCOA released a resource document, *"CEQA and Climate Change: Evaluating and Addressing Greenhouse Gas Emissions from Projects Subject to the California Environmental Quality Act,"* that discussed different approaches to determining whether GHG emissions from projects are significant under CEQA. It reviewed the models and other tools available at that time for conducting GHG analyses, and the document also contained a list of mitigation measures. A copy of the report is available at *http://www.capcoa.org*.



Resources Agency Guidance- Since the release of that report, the California Natural Resources Agency (Resources Agency) finalized its guidance on GHG emissions and CEQA in December of 2009. Under Senate Bill 97 (Chapter 148, Statutes of 2007), the Governor's Office of Planning and Research (OPR) was required to prepare amendments to the state's CEQA Guidelines addressing analysis and mitigation of the potential effects of GHG emissions in CEQA documents. The legislation required the Resources Agency to adopt the amended Guidelines by 2010.

The CEQA Guidelines Amendments adopted by the Resources Agency made material changes to 14 sections of the Guidelines. The changes include dealing with the determination of significance (principally in Public Resource Code Section 15064) and cumulative impacts, as well as areas such as the consultation process for the draft EIR, the statement of overriding considerations, the environmental setting, mitigation measures, and tiering and streamlining. Overall, the discussion of determining significance in



these amendments is consistent with the earlier report released by CAPCOA.

In the Final Statement of Reasons (SOR) for the adoption of the amendments to the CEQA Guidelines, the Resources Agency makes two points that are important with regard to quantification of GHG emissions from projects. First, it states that the Guidelines "appropriately focus on a project's potential incremental contribution of GHGs" and that the amendments "expressly incorporate the fair argument standard." [1] This sets the parameters for the analysis to be performed. The Resources Agency further states that the analysis for GHGs must be consistent with existing CEQA principles, which includes standards for the substantial evidence needed to support findings.

Second, the Final SOR specifically states that the amendments "interpret and make specific statutory CEQA provisions and case law … determining the significance of GHG emissions that may result from proposed projects."[2] In this context, they cite specific case law as well as CEQA Guidelines Section 15144 that require a lead agency to "meaningfully attempt to quantify the Project's potential impacts on GHG emissions and determine their significance."[3]

Complete copies of the 2009 CEQA Guidelines Amendments and the Final Statement of Reasons may be downloaded at: *http://ceres.ca.gov/ceqa/docs/*.

<u>Quantification of Projects</u>: Project level quantification, especially as it pertains to CEQA, was CAPCOA's main focus in developing this Report. The baseline conditions and quantification methods were selected to be consistent with the implementation of AB 32, as well as the Scoping Plan developed by ARB. The list of mitigation measures selected for the Report reflects the types of strategies that local governments and project proponents have shown interest in, and sought direction on quantifying. For the most part, they entail clearly delineated boundary conditions, and have been designed to be applicable across a range of circumstances.

This Quantification Report does not provide any policy guidance on what amount of GHG emissions would be significant. The determination of significance, including any thresholds, is the exclusive purview of the Lead Agency and its policy board. CAPCOA's Quantification Report provides methods to quantify emissions from specific types of mitigation projects or measures. It is based on a careful review of existing studies and determinations to develop rigorous quantification methods that meet the substantial evidence requirements of CEQA.

A project proponent or reviewer who wishes to use these methods to quantify emissions for the purpose of complying with CEQA must adhere to the assumptions and limitations

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[1] California Natural Resources Agency: "Final Statement of Reasons for Regulatory Action: Amendments to the State CEQA Guidelines Addressing and Analysis and Mitigation of Greenhouse Gas Emissions Pursuant to SB 97," December, 2009; p 12.
[2] Ibid: p. 18.
[3] Ibid: p. 18.

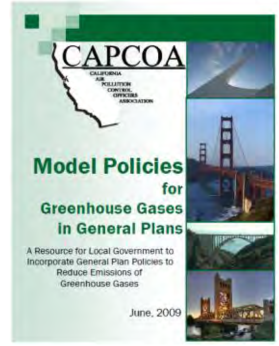
specified in the methods for each project type. If these assumptions and limitations are not followed, the quantification will not be valid. Ultimately, the Lead Agency will have the responsibility to review and decide whether to allow any requests for deviations from the method, and to determine whether those deviations have a substantive impact on the results. Lead Agencies may contact their local air district for assistance in making such a review, but CAPCOA will not be in a position to provide any case-by-case review of changes to the quantification methods in this report.

As stated previously, where good quality, project-specific data are available, they should be substituted for the more generalized data used in the baseline and mitigation emissions calculations. The quality of the data inputs can significantly affect the accuracy and reliability of the results. When quantification is performed for CEQA compliance, CAPCOA recommends that project-specific data be as robust as possible. We discourage the use of approximations or unsubstantiated numbers. In any case, CAPCOA strongly recommends that the source(s) and/or basis of all project-specific data supplied by the project proponent be clearly identified in the analysis, and the limitations of the data be discussed.

Plan-Level Mitigation: Cities and counties, as well as other entities, develop environmental planning documents. The most common are General Plans, which specify the blueprint for land-use, transportation, housing, growth, and resource management for cities, counties, and regions. These plans are periodically updated, and in recent updates, the California Attorney General has put jurisdictions on notice that their plans must consider climate change.

A stand-alone plan that considers climate change is a Climate Action Plan. Climate Action Plans can be developed for a school or company, for a city, county, region, or larger jurisdiction. A Climate Action Plan will typically identify a reduction target or commitment, and then set forth the complement of goals, policies, measures, and ordinances that will achieve the target. These policies and other strategies will typically include measures in transportation, land use, energy conservation, water conservation, and other elements.

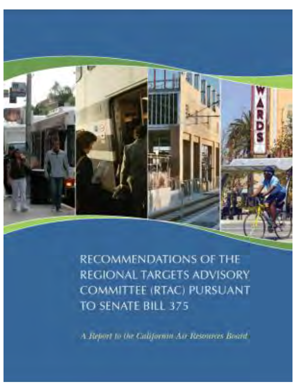
Guidance on Planning and Climate Change: CAPCOA prepared a guidance document on GHGs and General Plans for local governments. There are also several important processes under way that will have a significant impact on the planning process in the coming years. These include the early implementation of Senate Bill 375 (Steinberg, Statutes of 2008); the development of new General Plan Guidelines; and statewide planning for adaptation to the impacts of climate change. They are described below.



CAPCOA Guidance for General Plans- In June of 2009, CAPCOA released "*Model Policies for Greenhouse Gases in General Plans: A Resource for Local Government to Incorporate General Plan Policies to Reduce Emissions of Greenhouse Gases*." This document embodied a menu of GHG mitigation measures that could be included in a General Plan or a Climate Action Plan. It was structured around the elements of a General Plan, provided model language that could be taken and dropped into a plan, and also provided a worksheet for evaluating which measures to use. The CAPCOA Model Policies document focused on strategies to reduce GHG emissions; it did not address climate change adaptation, which is an important, but separate consideration.

Senate Bill 375- Senate Bill 375 is considered a landmark piece of legislation that aligns regional land use, transportation, housing, and greenhouse gas reduction planning efforts. The bill requires the ARB to set greenhouse gas emission reduction targets for light trucks and passenger vehicles for 2020 and 2035. The 18 Metropolitan Planning Organizations (MPOs) are responsible for preparing Sustainable Communities Strategies and, if needed, Alternative Planning Strategies (APS), that will include a region's respective strategy for meeting the established targets. An APS is an alternative strategy that must show how the region would, if implemented, meet the target if the SCS does not.

To develop the targets, SB 375 called for a Regional Targets Advisory Committee (RTAC), which included representatives from the MPOs, cities and counties, air districts, elected officials, the business community, nongovernmental organizations, and experts in land use and transportation. The RTAC provided recommendations on the targets to ARB in a formal report in September, 2009. The report covers a range of important considerations in target setting and implementation. Target setting topics include: the use of empirical data and modeling; key underlying assumptions; best management practices; the base year, the metric, targets for 2020 and 2035; and both statewide and regional factors affecting transportation patterns. For implementation, the report considers housing and social equity issues; local government challenges in meeting the targets; funding and other support at the state and federal level; and a variety of other important considerations. A complete copy of the report may be downloaded at: *http://www.arb.ca.gov/cc/sb375/rtac/report/092909/finalreport.pdf*.



ARB staff released draft regional targets for 2020 for the four largest MPOs in June, 2010, along with placeholder targets for 2035. Placeholder targets were also issued for both 2020 and 2035 for MPOs in the San Joaquin Valley. An alternative approach to target setting was proposed for the remaining MPOs. As required by SB 375, ARB expects to formally adopt the final targets before the end of September, 2010. Additional information about the target setting process can be found at: *http://www.arb.ca.gov/cc/sb375/sb375.htm*.

For the four largest MPOs, the draft 2020 targets are expressed as a percent reduction in emissions based on the potential reductions from land use and transportation planning scenarios provided by the MPOs, with a proposed range for the targets between 5% and 10%[4]. This reduction excludes the expected emission reductions from Pavley GHG vehicle standards and low carbon fuel standard measures. Each of the four regions has its own placeholder targets for 2035, shown in Table 2-1, below.

Table 2-1: Draft Regional Targets for 2035

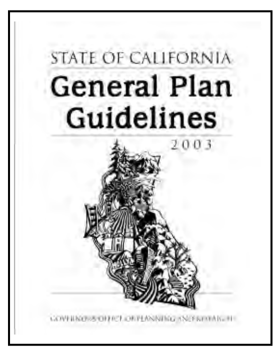
Regional MPO	Draft GHG Reduction Target
Metropolitan Planning Commission (MTC)	3-12%
Sacramento Area Council of Governments (SACOG)	13-17%
San Diego Association of Governments (SANDAG)	5-19%
Southern California Association of Governments (SCAG)	3-12%

Source: ARB: "Draft Regional Greenhouse Gas Emission Reduction Targets For Automobiles and Light Trucks Pursuant to Senate Bill 375" page 4.

The placeholder targets for the MPOs in the San Joaquin Valley range from 1-7% for both 2020 and 2035. Placeholder targets were provided in lieu of draft targets to allow the MPOs to provide additional information for ARB to consider before finalizing the targets. For the remaining six MPOs, ARB proposes to use the most current per-capita GHG emissions data, adjusted for the impacts of the recession, as the basis for setting individual regional targets in those areas.

In addition to serving on the RTAC, local districts will support the MPOs as they develop their strategies to meet their regional targets, and local cities and counties as they incorporate sustainable strategies into their own planning efforts. Two of the contractors who developed the quantification methods in this Quantification Report also served on the RTAC, and every effort has been made to ensure that work here will ultimately be compatible with, and useful in, the implementation of SB 375.

General Plan Guidelines- The Governor's Office of Planning and Research (OPR) provides technical assistance on land use planning and CEQA matters to local governments. In this effort, OPR is required to adopt and periodically revise advisory guidelines to assist local governments in the preparation of local general plans. Commonly referred to as the General Plan Guidelines, the most current edition was released in 2003.



In the 2003 edition, OPR included an overview of the General Plan statutory requirements, a review of CEQA's role in the general plan process, implementation techniques, and the General Plan's relationship to other statutory planning requirements. The 2003 Guidelines do not specifically address GHG emissions or climate change.

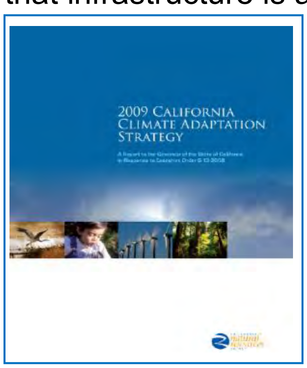
[4] ARB: "Draft Regional Greenhouse Gas Emission Reduction Targets For Automobiles and Light Trucks Pursuant to Senate Bill 375," June, 2010; page 4.

It is important to note that the General Plan Guidelines are advisory, not mandatory. Nevertheless, it is the state's only official document explaining California's legal requirements for general plans. The General Plan Guidelines are continually shaped to reflect current trends, changes in applicable laws, and incorporate additional statutory requirements. This includes anticipated effects from AB 32 and SB 375.

An update to the 2003 General Plan Guidelines has been in development and includes a Climate Change Supplement. This update is expected to be finalized by the end of 2010.

Adaptation- Adaptation has not received the same attention that has been given to steps that might prevent or mitigate the extent of climate change, however it is a topic that should not be ignored in General Plans. The overwhelming body of scientific studies point to a certain amount of change in our climate that is inevitable, even if we are aggressive and diligent in our efforts to prevent it. Many regions of the state (indeed, the nation) are projected to see substantial impacts on agriculture, climate dependant business (such as recreation and tourism), infrastructure, and habitat. Coastal areas will see a rise in sea level, currently projected to be between one and three meters by 2100. Wild fires are expected to increase in number, size, and severity. Stresses on the environment, combined with extreme weather events, are projected to increase the incidence and severity of a number of infectious diseases and other medical conditions. These and myriad other changes pose tremendous risks to people and our way of life.

For that reason, in December, 2009, a team of California state agencies released a report: "The 2009 Climate Adaptation Strategy." In it, the team states that 2.5 trillion dollars' worth of infrastructure in California is at risk from the various projected climate-related changes in our environment. The estimated cost of addressing the impacts on that infrastructure is about $3.9 billion, annually.[5] The report identifies a number of



steps to be taken in the near term to appropriately plan for and address this threat. Highlights of the actions include: the formation of a Climate Adaptation Advisory Panel; new approaches to water management; revised land-use planning to avoid construction in highly vulnerable areas; evaluation of all state infrastructure projects to avoid exacerbating threats to infrastructure; and, more specific planning by emergency response agencies, public health agencies, and others to fortify existing communities and resources, and prepare for future stressors. For more information, the full report may be downloaded at: *http://www.energy.ca.gov/2009publications/CNRA-1000-2009-027/CNRA-1000-2009-027-F.PDF*.

Quantification for Planning Purposes: Quantification of the impacts of measures for planning purposes is a different exercise than quantification for a specific project. By its

[5] California Natural Resources Agency: "2009 Climate Adaptation Strategy" Dec. 2009; p. 5.

very nature, planning involves a future set of conditions about which less is known, and indeed knowable. The art and science of planning depend upon the interpretation of present conditions and trends, and the application of that interpretation to create a picture of future conditions. This document does not address detailed planning analysis in a comprehensive manner.

The majority of the measures described and quantified here are project-level measures; only a few are plan-level measures by design. That said, many of the project level measures are good examples of the implementation of planning-level policies that were described in the CAPCOA Model Policies report. The quantification of these measures will provide important and useful information for the planner to use in the context of quantifying anticipated effects in broader planning efforts.

In a planning context, it is especially important to be mindful of the interactions of different measures. A more detailed explanation is provided in Chapter 6, but the main concern is that certain measures do interact with each other, and their effects are not independent. This means that some measures will have little effect on their own, but in combination with other measures may have significant effect. The classic example of this is the bus shelter. A clean, well-lit, and comfortable bus shelter can enhance ridership on the buses stopping at that shelter and therefore reduce vehicle trips; but without the underlying bus service, the shelter itself does not reduce vehicle trips.

There are also instances where a measure is less effective in combination with other measures than it might be by itself. There are several reasons why this can occur. In some cases this happens because of a diminishing return for consecutive efforts. For example, there may be six good methods to increase ridership on a public transit line, any one of which might increase transit ridership by 20%. But implementing all of them will not necessarily increase ridership by 120%. In fact, for each successive method applied, it is likely that a lesser effect will be observed. Another example is where the measures are in some sense competing, as in a campaign to increase ridership on a commuter rail line at the same time that a new public transit bus line is established with overlapping service areas. Although the ridership campaign might be expected to cause 5% of drivers to switch to rail, some of those potential new riders might use the new bus service instead, making the ridership campaign less effective. At the same time, the new bus line might also be expected to reduce vehicle trips by 5%, but the actual reduction may be lower in reality if some of the ridership comes from those who would have been rail passengers and not from driving. Together, the ridership campaign for the rail line and the new bus line may only reduce vehicle trips by 7%, not the 10% predicted from the estimates of their independent effectiveness.[6]

These effects become more pronounced when considered in a city-wide, county-wide, or regional context. The interplay of land use decisions and transportation infrastructure development will be better assessed with more integrated computer modeling efforts. The quantification of some of the strategies at the individual, project level will provide

[6] Please note that the effectiveness estimates provided here are only for the purposes of illustration and should not be taken as actual quantification of such measures.

insight into how useful and appropriate the strategies will be in the planning effort, however. More detailed discussion of how to quantify combinations of measures is provided in Chapter 6.

Reductions for Regulatory Compliance

There are three basic types of regulations for which emissions quantification is likely to be required: command-and-control regulations, permitting, and participation in a cap-and-trade program. A discussion of each is provided for information purposes, as is a discussion of quantification for mandatory emissions reporting regulations. The quantification methods in this document are intended primarily for use in project-level mitigation. Regulatory programs are likely to have specific requirements for monitoring, reporting, and quantification, which may or may not allow the use of the methods in this Report.

Command and Control Regulations: Some local air districts have command-and-control regulations for GHGs already on the books. These include limitations on the use of certain chemicals that are active in the atmosphere, performance requirements for landfill gas collection, and for systems that use GHGs with high Global Warming Potential, as well as efficiency standards for specific equipment or processes. Under the umbrella of the Scoping Plan, the ARB is also developing command-and-control regulations for a number of source categories. Regulations already adopted include standards for various GHGs that have a high global warming potential, such as sulfur hexafluoride (SF_6) used in the electricity sector, semiconductors, and other operations; perfluorocarbons in semiconductor manufacturing; certain refrigerants; and materials used in consumer products. There are also GHG emission limits on light-duty vehicles, rules for port drayage trucks and other heavy-duty vehicles, as well as landfill methane control requirements, and the Low Carbon Fuel Standard. Additional rulemaking is currently underway.

For these types of regulations, compliance may not rest upon quantification of emissions or emissions reductions. In many cases, installation of a specific technology, substitution of materials, or implementation of inspection and maintenance programs meets the requirements of the rule, and is presumed to have a certain effectiveness in reducing emissions from a baseline level. When a focused regulation does require quantification of emissions, it will generally specify a method for testing emissions, where appropriate, or for calculating emissions from other measured parameters.

A related, but more flexible type of regulation for emission reductions is an overall emissions cap for facilities or operations. Under this approach, sometimes referred to as a “bubble,” the regulation calls for an overall reduction in emissions from a specified baseline, but the operator has the discretion to decide how to achieve those reductions. This is different from a cap-and-trade program (see below), in that there is no trading between facilities, or purchasing of credits to offset obligations. Because energy efficiency and other conservation projects are a likely strategy to meet a facility-wide GHG emission reduction requirement, the quantification of measures in this Report may be useful for compliance with such a cap. Of course, the caveats about assumptions and data inputs are also important here. Further, demonstration of compliance with this kind of limit will also involve verification of the emissions reductions, and is likely to include ongoing compliance tracking.

The regional targets of SB 375 are a type of emissions cap. It is important to note that the quantification presented in this Report may ultimately be useful in demonstrating reductions towards those targets. Although much of the work of implementing SB 375 will involve extensive land use and transportation modeling, the project level quantification in this Report may allow cities and counties to track their contribution towards their region's goal.

Permitting Programs: In addition to land-use permitting (discussed under "Project-level Mitigation" above), there may be requirements for operations to have permits to emit GHGs because GHGs are air pollutants. Federal air permitting requirements for stationary sources will become effective on January 1, 2011 (and will apply to applications that have not been acted upon prior to that date), under several federal permit programs, including Prevention of Significant Deterioration (PSD) and Title V. These programs are implemented by the local air districts. Applicability of these programs is based on annual potential to emit GHGs, with thresholds initially set between 75,000 and 100,000 tons per year, depending on the program, and decreasing over time, with final thresholds for smaller sources of GHG to be determined by a future federal rulemaking.

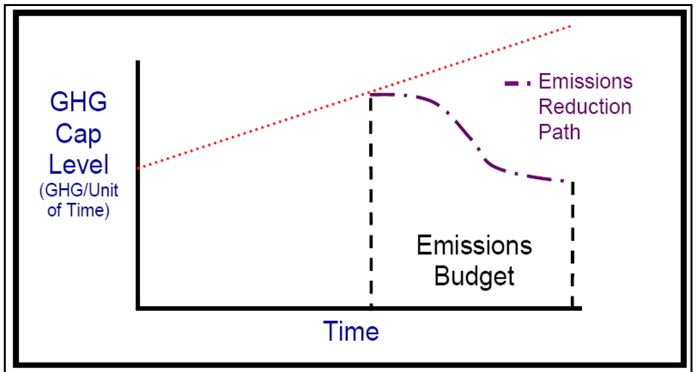
Because these permit programs are threshold-driven, quantification of emissions is an important element of compliance. At present, there is no specific federal guidance on quantifying GHG emissions pursuant to these programs, other than general guidelines for quantifying emissions of other regulated pollutants. This Quantification Report does not specifically address stationary source emissions, however some of the methods may be useful for certain elements of these programs, such as energy efficiency, water efficiency, and other associated measures of carbon use by a facility. The local air district with jurisdiction will be able to provide guidance on calculating emissions for a specific project, both for applicability and for compliance.

In addition, most permits require some form of verification, and ongoing demonstration on compliance. These obligations will be established as part of the permit.

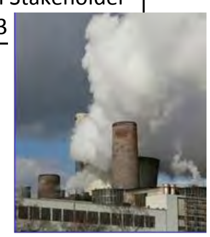
Cap-and-Trade: A cap-and-trade program is a specific type of emissions trading program. Emissions trading in general is discussed in the next section. A brief explanation of cap-and-trade programs is provided below as background information for interested readers. It is not necessary to understand cap and trade programs, or emissions trading in general, in order to use the quantification methods in this report.

Further, these quantification methods were not developed specifically for the purposes of complying with cap and trade requirements, or for emissions trading more generally.

A cap-and-trade regulation establishes "allowances" for carbon emissions, expressed as CO_2 equivalents, usually in tons, or metric tons. An emitter of carbon must hold enough allowances to cover the amount of carbon it actually emits. Allowances are obtained on a carbon exchange, or market. In some cases they may be allocated by the government to emitters. There is a "cap" placed on the amount of allowances available in the market, and the cap declines over time. Carbon emitters must either reduce their emissions or purchase allowances from someone else; this is the "trade" part of the program. In this way, the program should cause carbon to be reduced wherever the reduction costs are lowest. The ARB is developing a cap-and-trade program which they currently expect will be considered for Board approval before the end of 2010. Information about the developing ARB program can be obtained from the conceptual drafts released by staff. Legislation is also pending at the federal level that would establish cap-and-trade on a national scale, but the ultimate scope and content of the program is still unknown. The most recent ARB draft proposal may be downloaded at: *http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm*.



From ARB materials for AB 32 Program Design Technical Stakeholder Working Group Meeting, April 25, 2008, Figure 1, page 3



Although compliance with a cap-and-trade program is not likely to be a reason for quantifying GHG reductions today, it is likely to be one in the future. When that time comes, there will be several important considerations in deciding whether to use this Quantification Report in meeting those obligations.

Mandatory Reporting: The ARB currently has a Mandatory Reporting Rule for specified stationary sources with GHG emissions greater than 25,000 metric tons of CO_2e per year. This rule was established pursuant to the requirements of AB 32, and was intended to provide information to support the development of the Scoping Plan and its implementing regulations. At the time the Mandatory Reporting Rule was approved by the ARB Board, staff indicated that the Rule was not intended, nor did it include the level of detail necessary, to implement the cap-and-trade program (which, at that time, was not yet proposed). Applicable quantification protocols will be developed and approved by the ARB Board as part of its cap-and-trade regulation, as will a revised Mandatory Reporting Rule. More information about the ARB's Mandatory Reporting Rule may be obtained at *http://www.arb.ca.gov/cc/reporting/ghg-rep/ghg-rep.htm*.

The U.S. EPA also has a Mandatory Reporting Rule. Under this rule, suppliers of fossil fuels or greenhouse gases that are used in industrial operations, manufacturers of vehicles and engines, and facilities that emit 25,000 metric tons or more per year of GHG emissions are required to submit annual reports to EPA. The EPA rule does not currently specify quantification methods, and CAPCOA anticipates that any methods in this Report that would be applicable to affected reporters (e.g., building energy use) would be also be acceptable for use under the rule. Details on this rule can be found in 40 CFR Part 98, which was published in the Federal Register (*www.regulations.gov*) on October 30, 2009 under Docket ID No. EPA-HQ-OAR-2008-0508-2278.

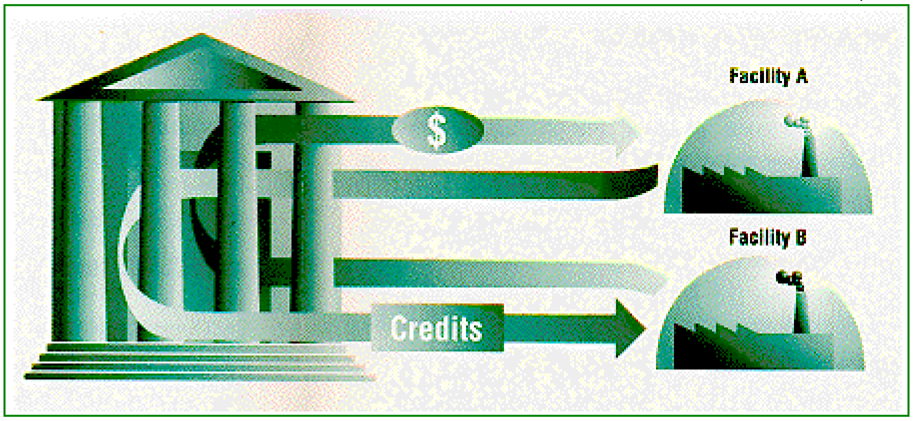
Reductions for Credit

There are several different ways to formally award credit for emission reductions. Emission reduction credits are used when the opportunity, desire, obligation, and the resources to implement reductions are not aligned. Sometimes an entity has the desire and opportunity to reduce emissions, but not the resources. Sometimes an entity is required to make reductions but has no viable project opportunities. Or funds may be available to implement project, but willing participants are needed. Systems are used to match up projects, proponents, funding, and, in some cases, compliance obligations, and the basis of the systems is emission reduction credits.

Concurrent Offsite Mitigation Projects: The simplest form of credit for emission reductions occurs when someone needs to reduce emissions to mitigate impacts (for example, under CEQA), but does not have a good opportunity within his or her own operation or project; but if a good opportunity is available at another operation the person who needs the reductions can fund that project in exchange for being able to take credit for the reduction. A variant of this can occur when a list of emission reduction projects that could be used for mitigation is maintained, and those projects are matched with people who need to implement mitigation. The key in this arrangement is that the project is directly funded by the person who needs mitigation, at whatever the cost the mitigation project ultimately has. The emission reductions occur, but are not traded as an independent commodity. The person who needs the mitigation remains obligated to ensure that the project is implemented and the emission reductions occur.

Mitigation Funds: Instead of matching the person needing mitigation with a project that is then directly funded by that person, it is also possible to collect the funding and then create the projects. In this case, funds are paid into a mitigation fund at a pre-established rate, and the operator of the fund is then obligated to find and implement emission reduction projects. The rate is typically set at a level (for example in dollars per ton needed) that is sufficient to implement an actual project to produce the emission reductions, based on data about actual project costs. As with concurrent offsite mitigation projects, the emission reductions here are not traded as an independent commodity, however a default rate is established. Under a mitigation fund, then, the person needing mitigation is considered to have provided it (that is, given “credit” for the reductions) at the point of paying into the mitigation fund. The obligation to ensure the emission reductions occur is transferred to the fund operator.

Emissions Trading: Emissions trading is a transaction that occurs between entities that make emission reductions which they don't need, and entities that desire emissions reductions but, for whatever reason, do not choose to make them. The emissions (or, more accurately, "credits" for the emission reductions) are treated as a commodity with independent value. The transaction occurs in some form of market, much as transactions occur between the grower of produce and the consumer in a local farmers market. The transaction, or trade, happens when a consumer believes that the product is worth the price being asked for it.



The obligation to ensure the emission reductions occur generally rests with the person selling the credits, and (to the extent an independent review has occurred) with whomever grants certification to the reduction project.

As explained above, a cap-and-trade program is a type of GHG trading market, but there are other types of emissions trading markets. An open GHG credit-based trading market does not have a cap, and participation is on a voluntary basis. In a credit-based market, credits are awarded for emission reductions, and may be purchased and sold as a commodity on an exchange. The credits are sometimes referred to as offsets, and they are generally tracked as tons, or metric tons, of pollutant reduced; in the case of GHGs, this is typically in the form of CO_2e. The important distinction between an open market and a cap-and-trade system is that the creation, buying, and selling of offsets is not restricted in an open market.

The following key terms and concepts are discussed to help the interested reader understand how credits are used in a trading market, It is not necessary to understand trading markets in order to use the quantification methods in this report, and the reader may proceed directly to Chapter 3.

<u>Regulators and Exchanges</u>: Some emissions trading markets are run by the government, while others are operated by independent, non-governmental entities. In government-run markets, such as the Regional Clean Air Incentives Market (RECLAIM) developed and administered by the South Coast Air Quality Management District, and U.S. EPA's Acid Rain program, a government agency establishes and implements the trading market. These markets are typically regulatory in nature, rather than voluntary, although some voluntary participation may be allowed. The Regional Greenhouse Gas Initiative (RGGI) implemented by ten Northeast and Mid-Atlantic states, and the

European Union Emission Trading Scheme (EU ETS) are other examples of regulatory markets.

Independent exchanges, such as the California Climate Action Registry (CCAR) and the Climate Registry (TCR), were established as independent, non-governmental operations. They offer a forum for entities to have emission reductions certified for credit, and for those credits to be bought and sold. These bodies develop their own structure and rules for participation. The nature of those rules determines the quality of the credits available on the exchange. Participation in the exchange is voluntary.

Standards for Credits: In order to be acceptable for credit under the AB 32 program, GHG emission reductions must be real, permanent, quantifiable, verifiable, enforceable, and additional. Historically, the federal Clean Air Act (CAA, or Act) has required emission reduction credits to be: real, permanent, quantifiable, enforceable, and surplus[7]. In this context, surplus means the reductions are not required by any law, regulation, permit condition, or other enforceable mechanism under the Act. California continued this concept in AB 32, requiring that any regulation adopted pursuant to AB 32 ensure that GHG reductions are "real, permanent, quantifiable, verifiable, and enforceable."[8]

The term "additional" comes from the Clean Development Mechanism in the Kyoto Protocol; it is essentially the same as "surplus" except that it is not restricted to any particular statute, and means that you cannot receive credit for any reductions that you were otherwise obligated to make. AB 32 requires its implementing regulations that include market-based compliance mechanisms to ensure that reductions are "in addition to any greenhouse gas emission reduction otherwise required by law or regulation, and any other greenhouse gas emission reduction that might otherwise occur."[9]

Protocols: Transactions to purchase emission reductions depend on the confidence the purchaser has in the value of reductions being purchased. Price is part of the concept of value that we can easily understand. The other, less tangible part of the concept of value is the quality of the emission reductions themselves. This is harder to understand because, unlike the produce at the farmer's market, we can't examine the product to determine its value. Not only are emission reductions invisible, they actually *didn't happen*. So to have confidence in their value, we need a reliable and accurate picture of what *would have happened*, as well as what *actually happened*.

Protocols are the formalized procedures for accounting for credits that ensure the credits are an accurate and reliable representation of emission reductions that actually occurred. Some protocols focus only on quantification of the reductions, while others also address documentation and verification. They can be developed and adopted by regulatory bodies, by the operators of exchanges, or by subject area experts. Some markets will require participants to use a specific protocol or set of protocols. Others

[7] 40 CFR Sections 51.493 and 51.852
[8] California HS&C: Section 35862(d)(1)
[9] Ibid, Section 35862(d)(2)

will allow participants to propose a protocol for developing and quantifying reductions. Failure to follow required protocols may prevent the project from receiving credit.

Holding and Using Credits: When credits are awarded for emission reduction projects, the owner of the credits is generally given a certificate of value. In this case, "value" means the corresponding emission reductions, not the price, which is determined by the market. The credits are registered with a bank where they are kept until the owner of the credits uses or sells them.

Credit Banks: Emission credit banks are similar to savings banks where money is deposited. The bank tracks credits, credit value, credit price, and transactions. It compiles data and issues reports. Banks are subject to accounting standards and requirements for transparency. It is important to note that not all credits can be banked. Credits or allowances that have a finite life do not retain their value beyond their life term.

Credit Life: Credits may have a specified life (for example, one year), or they may be permanent. The life of the credit may be dictated either by the nature of the reductions that generated it, or by the program in which it is being used. As discussed above, in California, AB 32 requires reductions for regulatory compliance to be permanent. In other markets, such as Kyoto's Clean Development Mechanism, there are both long term and short term credits.

Discounting Credit Value: Some regulatory structures require that credits be discounted, that is, the emission reduction value of the credit (not the price) is reduced to account for certain factors, or to enhance the liquidity of the market. In some cases, a portion of the credit value is surrendered or retired in the interest of environmental policy goals.

Offset Ratios: Offset ratios are a way to ensure an adequate margin of safety when credits are provided to offset impacts. A program may require that the amount of credits provided is greater than the anticipated emissions increases. If the program requires 10% extra credits, then the offset ratio is said to be "1.1 to 1."

The above discussion of emission reduction credits and trading is provided for information only, and should not be construed as endorsement of, or recommendation for, the use of credits or trading for the purposes of meeting GHG reduction obligations. CAPCOA does not make policy recommendations regarding credits or trading in this Report. Decisions about whether to allow the use of credits rests solely with the agency with jurisdiction over a project or program.

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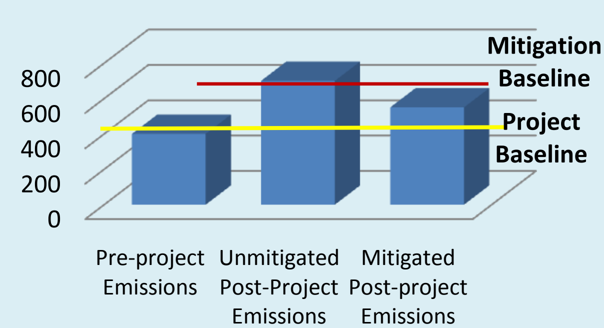
This chapter provides an overview of some key concepts that arise in considering quantification of GHG emission reduction projects. This discussion is provided so the reader understands the context in which these terms are used throughout this document. Here again, this discussion is not intended to endorse any policy position, nor does it provide any recommendations on thresholds of significance for GHG emissions. Policy decisions are left to individual agencies and their governing boards.

Baseline

An emissions baseline is the foundation of any estimate of the impacts of a project or of a mitigation measure. In its simplest form, it reflects the current level of emissions if those emissions do not vary. Usually, however, emissions do vary, typically because the activities or operations that cause the emissions change. Traffic patterns change with the time of day, ski areas are busiest in the winter, air conditioners run more in the summer, people drive less when fuel prices rise, and production of goods changes with the economy. To set a baseline, it is important to understand what factors affect the activity or operation in a way that will alter its emissions; then, the most appropriate scenario is selected and the emissions are adjusted to account for that scenario. Figure 3-1: Baseline illustrates the concept of baselines in project analysis.

Figure 3-1: Baseline



Regulatory programs that require calculation of emissions baselines generally specify the basis for the calculation. For example, a baseline scenario could be a three year average of actual emissions, or the worst case, or, as in CEQA, the program may call for an analysis to identify a representative set of conditions based on historical data.

In its proposed draft regulation for cap-and-trade, ARB defines baseline to mean “the scenario that reflects a conservative estimate of the business-as-usual performance or activities for the relevant type of activity or practice such that the baseline provides an adequate margin of safety to reasonably calculate the amount of GHG reductions in reference to such baseline.”[1]

For this Quantification Report, CAPCOA selected a baseline period to correspond to the average GHG emissions from 2002 to 2004, inclusive. This is the emissions baseline period used by ARB in its Scoping Plan[2]. The baseline conditions used to quantify the

[1] ARB: “Preliminary Draft Regulation for a California Cap-and-Trade Program,” Section 95802 (a)(2), Dec., 2009; page 5.
[2] ARB: “Climate Change Scoping Plan: a framework for change,” Dec., 2008; page 11.

effectiveness of mitigation measures for this Quantification Report reflect the conditions that formed the basis for ARB's 2007 inventory of economic activity and GHG emissions. Those conditions and the associated quantification methods are explained in Appendix B to this Report. A copy of ARB's Scoping Plan may be downloaded at: *http://www.arb.ca.gov/cc/scopingplan/document/scopingplandocument.htm*.

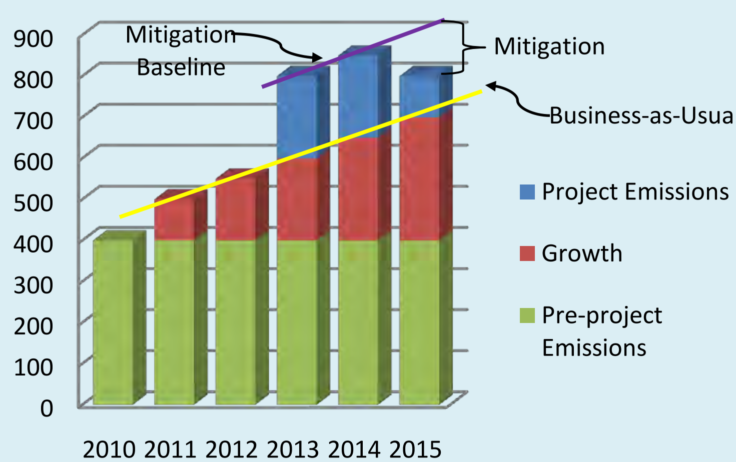
There may be circumstances in which a different set of baseline conditions is more appropriate. If a user wishes to adjust the baseline, CAPCOA recommends using the methods provided in the measure Fact Sheet, and in Appendix B, but substituting data inputs that better reflect the baseline conditions for the project under consideration. This ensures consistent methods are used so the comparison of baseline to project is an "apples-to-apples" comparison. So, for example, a user outside of California would substitute an emission factor for electricity generation that better represents the generation mix that is provided in the user's region. This alternative factor would be used in the baseline methods where electricity generation is part of the calculation, and would also be used in the quantification of emissions associated with the project.

It may also be appropriate to adjust the baseline conditions on a temporal basis if needed to account for changes over time. The ARB revises its emissions inventory information on a periodic basis. The most current inventory information was published in May of 2010, and covers the time period from 2000 to 2008. The information is available by category, with trends analysis, and with full documentation of data sources and methods. The updated emissions inventory information is available at: *http://www.arb.ca.gov/cc/inventory/data/data.htm*.

Business-as-Usual Scenario

Not all baseline conditions occur in the present. In some cases, the baseline is a forecast of the conditions that are expected to exist at some time in the future, in the absence of interventions to change those future conditions. The forecasted baseline conditions are referred to as "business-as-usual" and are intended to reflect normal operation. For example, a town might currently have 20,000 residents, and be on a course to to add another 5,000 residents in low-density, planned development at the perimeter of its existing footprint over the next 10 years. The town could add an urban growth boundary that would change that anticipated development. In order to quantify the effect of adding the urban growth boundary, the business-as-usual growth scenario must first be calculated; that will form

Figure 3-2: Business-as-Usual



the baseline to compare to the growth scenario with the adopted boundary. Figure 3-2 illustrates the application of the "business-as-usual" concept to a project.

ARB defines business-as-usual to mean, "the normal course of business or activities for an entity or a project before the imposition of greenhouse gas emission reduction requirements or incentives."[3]

Mitigation Types

There are four general ways to create emission reductions for mitigation projects: (1) the operation or activity can be avoided so that emissions are not created in the first place; (2) the operation or activity can be changed so that it creates fewer emissions; (3) emission control technology can be added to the activity or operation that prevents the release of emissions that are created; and (4) emissions that have been released can be sequestered in the environment. Each of these is discussed below.

Avoided Emissions: When someone chooses to walk to the grocery store in lieu of driving, or turn off the lights, energy isn't needed to power the car or lights, and the emissions associated with that energy don't occur. In the case of walking instead of driving, the avoided emissions include the CO_2 and other pollutants that would have come from the tailpipe of the car. These are "direct" emissions that are being avoided, and they can be readily quantified to show the benefit associated with walking. When electricity isn't needed, it isn't generated; the avoided emissions are the CO_2 and other pollutants that are not emitted by the power plant. Because the emissions are not directly emitted where the light is being used, this type of emissions are referred to as "indirect" emissions; even though they are indirect, they can still be quantified to show the benefit of turning off the lights. There can be other benefits associated with avoided emissions as well. When you consider the walking scenario in a lifecycle sense, the avoided emissions can also include the energy that would have been used to extract, refine, transport, and dispense the fuel. The same is true when you use a reusable cloth bag instead of a disposable plastic bag to carry your purchases; energy is needed to extract and refine the petroleum that goes into the bag, to make and transport the bag, and then to dispose of the bag after it is used. These kinds of avoided emissions are much more difficult to fully quantify, however, and will not be included in the quantification approaches in this document. Even if we aren't quantifying the benefits, however, it is important to understand that avoided emissions can have positive effects both upstream and downstream, creating a ripple effect of further avoided emissions.

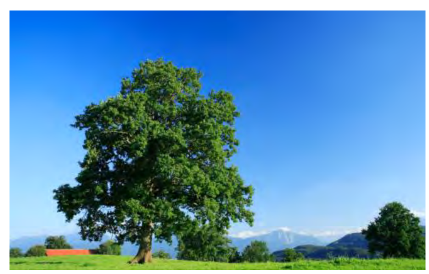
[3] ARB: "Preliminary Draft Regulation for a California Cap-and-Trade Program," Section 95802 (a)(18), Dec., 2009; page 7.

Fewer Created Emissions: If the activity or operation can't be avoided, sometimes it can be accomplished in a way that creates fewer emissions. This is usually associated with increased efficiency. So, for example, if walking to the store isn't an option, someone could choose to drive there in a more efficient vehicle, like a gas-electric hybrid powered car. The engine in the hybrid is able to drive more miles with less fuel consumed. Less fuel consumed equates to fewer emissions at the tailpipe. In the lighting example, using a more efficient light bulb is one way to reduce the indirect emissions, but a more efficient power plant would also do this.

Controlled Emissions: Once emissions are created, they are either released to the environment, or they are controlled with technology that captures and stores or destroys them. In the car example, the addition of a catalytic converter allows the tailpipe emissions to be collected after they are created, and destroyed before they are released. Note that the efficiency of the engine (discussed above), and the control of emissions after they leave it, are two distinct ways to reduce emissions. There are also emissions control technologies for power plants.

Sequestration of Emissions: Carbon emissions are "sequestered" by embedding the carbon in structure that will hold the emissions and keep them out of the atmosphere. Sequestration happens through biological, chemical, or physical processes.

Biological Sequestration: Trees and other vegetation biologically absorb carbon from the atmosphere and incorporate it into their biomass; the carbon becomes the solid form of the growing tree or plant. Many sequestration projects involve the planting of trees or vegetation to improve the uptake of carbon from the atmosphere. Enhanced farming practices may also achieve some sequestration through the use of CO_2 absorbing cover crops, improved grazing practices, and restoration of depleted land. Increased peat production in peat bogs is also method to biologically sequester carbon.



Chemical Sequestration: Oceans absorb CO_2, and it causes the oceans to become more acidic (which is detrimental to coral reefs and other sea life). Other chemical processes include reacting CO_2 through a process called mineral carbonation to form stable carbonate minerals that are normally found in the earth's crust.

Physical Sequestration: CO_2 can also be physically contained in a way that prevents its release to the atmosphere. This can involve injecting it deep into the ground, for example into depleted oil and gas reservoirs. It can also be injected into oil wells to push up the oil. Another approach is to embed it in cement through a newly developed process that causes cement to absorb CO_2 from the atmosphere while it is curing.

Measure or Project Scope

Just as good quantification requires careful and transparent consideration of the baseline or business-as-usual scenario, it also requires a complete and detailed characterization of the measure or project being undertaken. This is important because considerations of what is included in, and what is excluded from, the analysis can have a significant impact on results of the quantification.

Determining the appropriate scope for the analysis of a project or measure is not always as simple as it might appear. Take for example the installation of solar panels in a remote desert region that receives a lot of sun. The panels generate electricity without releasing GHG emissions, which offset more traditional generation of electricity that does emit GHGs. But the desert region may be prone to dust or sand storms, which would quickly obscure the glass panels and decrease their effectiveness. This decrease could be minimized if the panels were cleaned regularly. But the cleaning will require vehicles to come to the site, which takes energy and releases GHGs, and the cleaning activity itself may do so as well. If the site is truly remote, the emissions from those vehicle trips could be large. But what if there is another installation nearby: can the trip-related emissions be considered only in addition to those for the other site? Do you have to know if the cleaning for both sites can be accomplished in one trip? And what about the energy and materials needed to make the solar panels?

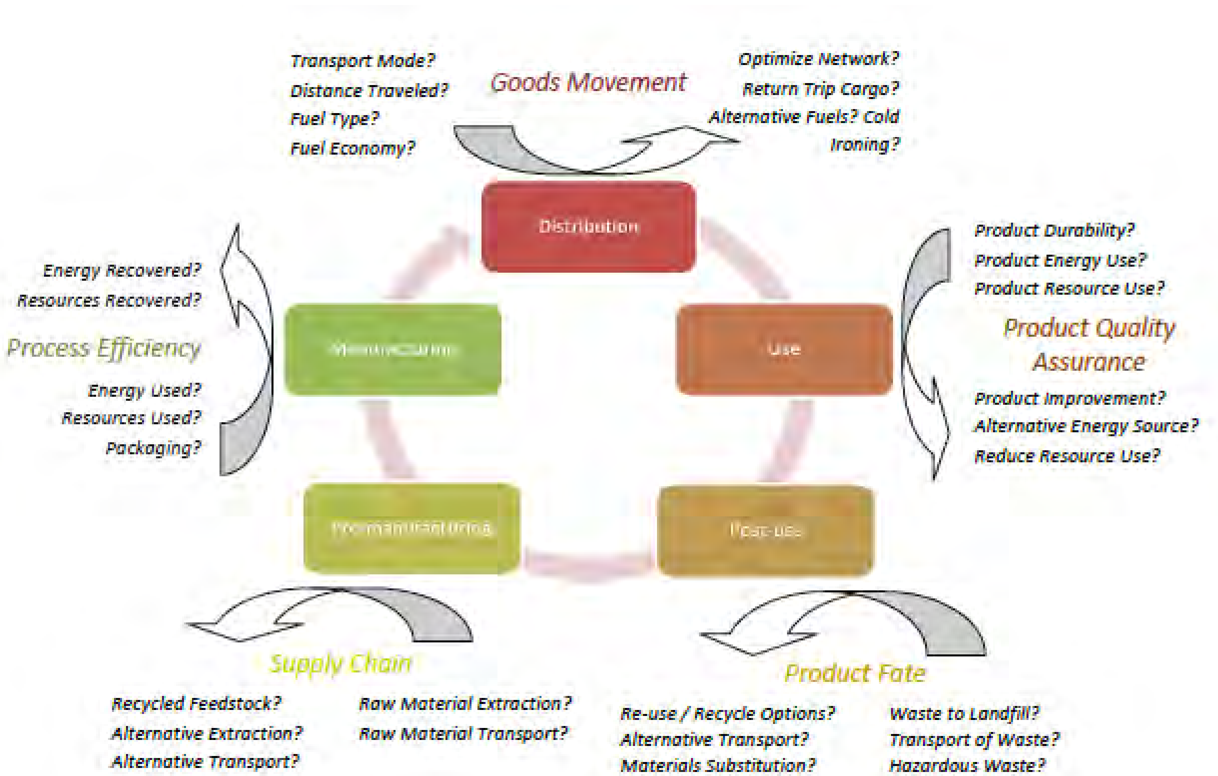
The methods in this Report generally include those reductions over which a project proponent can exercise direct control, as well as indirect emissions associated with electrical generation and the use of natural gas. CAPCOA does not include analysis of full lifecycle emissions in this Report, because of the complexity of the analysis involved and the lack of general standards for incorporating such considerations.

Lifecycle Analysis

Energy and materials are involved in the creation, processing, transport, and disposal of all of the products we use, from the tomatoes on our salads, to the computers we work with, the vehicles we drive (even if they are zero-emission vehicles), and the roadways we travel over. A lifecycle analysis attempts to identify and quantify the GHG emissions associated the energy and materials used at all stages of the product's life, from the gathering of raw materials, through the growing or fabrication, distribution, use, and the ultimate disposal at the end of the product's useful life.

This is a difficult and complicated undertaking; it is challenging to identify all of the inputs that are both necessary and meaningful for this sort of analysis. Even if the inputs can be identified, good data are not readily available to quantify emissions in most cases. Further, there is not yet agreement on methodological approaches to lifecycle analysis for most sectors (Figure 3-3: Lifecycle Analysis shows a basic schematic of some of these considerations.). For these reasons, as stated under the discussion of scope, above, CAPCOA does not include lifecycle analysis in this Report.

Figure 3-3: Lifecycle Analysis



Unfortunately, there are important mitigation projects or measures that cannot be quantified without a lifecycle analysis, and some of them are measures that are highly desirable or commonly encouraged. One example is the recycling and reuse of construction materials; it is intuitively obvious that recycling and reuse avoids both the embedded energy costs in the new material, as well as the energy and emissions associated with disposal. Another example is the push for reusable cloth grocery bags instead of disposable plastic ones, or reusable water bottles filled with tap water instead of disposable bottled water. For some of these measures, it is possible to do a limited lifecycle analysis, if the project scope is well defined and if the data are available. The Report provides a discussion of how to pursue an analysis in such cases, but otherwise identifies these kinds of measures as Best Management Practices.

It is important to note that Appendix F to the CEQA Guidelines Amendments approved in December of 2009 specifically state that a lead agency is not required to perform a project-level energy life-cycle analysis[4]. Because direct GHG emissions from electrical generation, and GHG emissions from electricity associated with water use (as well as other direct emissions associated with water treatment) are well defined and can be

[4] California Natural Resources Agency: Adopted Text of the CEQA Guidelines Amendments (Adopted December 30, 2009, Effective March 18, 2010), Appendix F.

accurately quantified, they are not considered to "lifecycle emissions" for the purposes of this Report, and they are included in these quantification methods.

Accuracy and Reliability

In an effort to standardize the creation of GHG inventories, and improve the quality of the information, the IPCC defines "good practice" for GHG emissions quantifications as those that "contain neither over- nor under-estimates so far as can be judged, and in which uncertainties are reduced as far as practicable."[5]

Part of the challenge in developing methods that meet this standard of good practice is assuring the accuracy of the methods. CAPCOA uses accuracy to mean the closeness of the agreement between the result of a measurement or calculation, and the true value, or a generally accepted reference value. When a method is accurate, it will, for a particular case, produce a quantification of emissions that is as close to the actual emissions as can practicably be done with information that is reasonably available.

To meet the good practice standard, the quantification methods must also be reliable, which is different from being accurate. A reliable method will yield accurate results across a range of different cases, not only in one particular case.

To some extent, the accuracy of the quantification is sacrificed to achieve reliability. This is because a method that can be applied across a range of scenarios must be generalized to some extent. So, for example, the transportation analyses do not, for the most part, differentiate between peak and off-peak vehicle trips, even though off-peak trips will have a lower emission impact because of the effects of congestion on travel time and engine performance. In order to fully address all of the factors that impact the emissions associated with vehicle trips in a specific project, a far more detailed and costly analysis would be needed, and it would not be readily applied to other situations. The methods contained in this Report have been developed to provide the best balance between accuracy and reliability, bearing in mind that ease of use is also important.

In order to ensure both the accuracy and the reliability of the quantification methods in this Report, each method is accompanied by a discussion of the assumptions and limitations of the method. Where either the assumptions are not met, or the limitations are exceeded, the method will not be accurate, and the error can be very large. Further, if the conditions of the project differ from the assumptions and limitations of the method, the quantification may no longer be applicable. It is possible to look at the underlying assumptions and calculation and make adjustments to the method so that it better reflects the conditions of a specific project. Doing this may preserve the accuracy to some extent, but the user is responsible for determining how best to accomplish this, and the reviewing agency will decide whether the results are still acceptable.

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[5] IPCC 2006, "2006 IPCC Guidelines for National Greenhouse Gas Inventories," Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds).Published: IGES, Japan. Page 1.6.

Additionality

In order for a project or measure that reduces emissions to count as mitigation of impacts, the reductions have to be "additional." Greenhouse gas emission reductions that are otherwise required by law or regulation would appropriately be considered part of the existing baseline. Thus, any resulting emission reduction cannot be construed as appropriate (or additional) for purposes of mitigation under CEQA. For example, in the draft regulation for cap-and-trade, ARB specifies that in order to be eligible for offset credit, "emission reductions must be in addition to any greenhouse gas reduction, avoidance or sequestration otherwise required by law or regulation, or any greenhouse gas reduction, avoidance or sequestration that would otherwise occur."[6] What this means in practice is that if there is a rule that requires, for example, increased energy efficiency in a new building, the project proponent cannot count that increased efficiency as a mitigation or credit unless the project goes beyond what the rule requires; and in that case, only the efficiency that is in excess of what is required can be counted. It also means that if there is a rule that requires a boiler to be replaced with one that releases fewer smog-forming pollutants, and the new boiler is more efficient and also releases less CO_2, the reduced CO_2 can't be counted as mitigation or credit, because the reductions were going to happen anyway. But if the boiler were replaced with a solar-powered water heater, the difference in emissions between a typical new boiler and the solar water heater could be counted.

From a practical standpoint, any reductions that are *not* additional have to be either included in the baseline or subtracted from the project, whichever is more appropriate. In preparing this Report, CAPCOA made determinations about requirements to include in or exclude from the baseline. A more complete discussion of those determinations is included in Appendix B.

Verification

Verification is the process by which we demonstrate that the emission reductions we have quantified for a project actually occurred. While not important for purely voluntary projects, verification in some form is a necessary step in most other circumstances. Verification is an important component in establishing the value of reductions that are made. It allows others to have confidence in the quality of the reductions. If the reductions are being made to satisfy an obligation to mitigate impacts, the agency with jurisdiction should be consulted to determine what standard of verification is needed. In some cases, independent, third-party verification is required. Not all regulatory programs specify third-party verification, however. For example, the U.S. EPA's Mandatory Reporting Rule relies instead on routine compliance verification through a permit system.

[6] ARB: "Preliminary Draft Regulation for a California Cap-and-Trade Program," Section 95802 (a)(4), Dec., 2009; page 6.

This chapter of the Report provides an explanation of how the quantification methods were developed, and the limitations of the sources used. There is also an overview of the presentation of the quantification methods in the Report. Finally this section discusses the limitations of the methods themselves, and how these limitations should be considered when applying the methods to actual mitigation projects.

General Emission Quantification Approach

The emission quantification methods in this Report are designed to provide GHG estimates using readily available, user-specified information for a source or activity. In general, GHG emissions associated with a given source or activity are estimated using data for a physical quantity or metric, on the underlying assumption that CO_2 emissions are directly proportional to that metric. For example, emissions related to vehicles are estimated using vehicle trips and mileage data. For sources of indirect emissions such as buildings, swimming pools, municipal lighting and water distribution, the metric is energy use as electricity or natural gas[1]. When site-specific energy use data are not available, energy use can be estimated using a physical metric such as the volume of water supplied, the size of building, and the number of lamps.

For each source metric there are emission factors that quantify the amount of emissions released as a result of the source or activity. These emission factors have been developed by various governmental agencies, public utilities and other entities though data analysis and numerical models. The factors are based on certain assumptions that define the typical or "baseline" emissions scenario. For example, emission factors for vehicles assume a particular type of fuel and driving speed, and emission factors for electricity use assume a certain mix of electricity generating methods. .

Individual GHGs are converted to carbon dioxide equivalent units by multiplying values by their global warming potential (GWP). The GWP values used in this report are based on the IPCC Second Assessment Report (SAR, 1996), even though more recent (and slightly different) GWP values were developed in the IPCC's Third Assessment Report (TAR, 2001) and Fourth Assessment Report (FAR, 2007). The values in the SAR were used in this Report because they are still used by international convention.

The general equation for emissions quantification is shown below for each GHG:

$$\text{GHG Emissions} = [\text{source metric}] \times [\text{emission factor}] \times [\text{GWP}]$$

Then, all GHGs are summed from an individual source.

$$\text{GHG Emissions}_{total} = \sum_{n=1}^{i} [\text{GHG Emissions}]_n$$

[1] Note that emissions from natural gas use are not always indirect in nature. For more discussion of direct and indirect emissions and types of mitigation, please see Chapter 3.

Where "source metric" and "emission factor" are defined as follows:

Source Metric: The "source metric" is the unit of measure of the source of the emissions. For example, for transportation sources, the metric is vehicle miles traveled; for building energy use, it is "energy intensity", that is, the energy demand per square foot of building space. Mitigation measures that involve source reduction are measures that reduce the source metric. This can include for example, reducing the miles traveled by a vehicle because the reduction in miles traveled will reduce the emissions generated from vehicle travel. Similarly, a reduction in dwelling unit electricity use by installing energy efficient appliances and lighting will reduce the emissions associated with total electricity assigned to dwelling units.

Emissions associated with source reduction measures are generally avoided emissions. As discussed in Chapter 3, there are often additional benefits to these kinds of reductions. Source reduction promotes efficient use and management of resources and utilities, in addition to avoiding emissions. Thus, source reduction can also result in a decreased need for downstream emissions control. From a quantification standpoint, for this type of measure, it is the "source metric" in the basic emissions equation (above) that changes.

Emission Factor: The "emission factor" is the rate at which emissions are generated per unit of source metric (see above). Reductions in the emission factor happen when fewer emissions are generated per unit of source metric, for example, a decrease in the amount emissions that are released per kilowatt hour, per gallon of water, etc. Such a decrease may apply if a carbon-neutral electricity source (e.g. from photovoltaics) is used in place of grid electricity, which has higher associated emissions; or if electricity is used instead of combustion fuel, such as with electric cars. Reductions can also occur if a fuel with lower GHG emissions is used in the place of one with higher GHG emissions. From a quantification standpoint, for this type of measure, it is the "emission factor" in the equation that changes.

For both kinds of measures, mitigated emissions are calculated using the same general equation, but the emissions will change based on whether the values change for the source metric or the emission factor. Several mitigation measures may apply to the same source, changing both the source metric and the emission factor, and the estimation of the overall impact of simultaneous measures must be carefully evaluated. In some cases the reductions are additive, but in others they must be evaluated sequentially. Other sets of mitigation measures may require additional analysis to avoid double-counting. Furthermore, not all types of mitigation measures will be feasible in all situations. Chapter 6 provides a detailed discussion of considerations in quantifying the combination of mitigation measures, as well as a set of rules to guard against over-estimation of reductions.

Quantification of Baseline Emissions

In order to ensure that similar assumptions and methodologies are being used to quantify both the baseline and project emissions, a consistent set of methodologies for determining the GHG emission baseline emissions was defined. This was the first step in establishing quantitative methods for assessing GHG mitigation reductions. The results of this effort are contained in Appendix B and should be utilized or considered when establishing baseline emission levels. This same set of methodologies was used to develop the quantification methods for each mitigation measure.

Quantification of Emission Reductions for Mitigation Measures

There is a wide array of mitigation measures that could reduce direct or indirect GHG emissions for a project; however, not all of them can be readily quantified with the information and tools currently available. Other measures may be individually quantifiable, but the quantification cannot be reliably extrapolated to other similar projects. The goal in developing this Quantification Report was to provide accurate and reliable methods that can be easily applied across a range of projects and settings. This section explains how the list of measures included in this guidance was developed, and how the measures are presented.

Screening of Mitigation Measures: An initial list of candidate measures was developed with about 75 types of greenhouse gas mitigation measures related to site design, land use, building components, parking measures, energy, solid waste management, etc. These were identified because they were commonly seen in land use permit applications or were measures that air districts have been frequently asked for guidance on. A literature review was done to identify potential additional measures.

Measures from this compiled list were screened based on the following criteria:

- Relevance to project-level CEQA analysis;
- Availability of empirical evidence or reliable research to credibly establish baselines and level of effectiveness; and
- Non-negligible level of effectiveness determined by credible research.

Measures or grouped measures that did not meet all three of these criteria were evaluated for the possibility of grouping measures with synergistic effects or describing as a Best Management Practice (BMP). Where measures were determined to be BMPs, the Report describes the relevant literature and, where applicable, provides methods that could be used if substantial evidence is available to support the reduction effectiveness. In addition some measures had substantial evidence of reductions when implemented at a general Plan (GP) level rather than a project level. These measures were retained as applicable for General Plans, only. Local Agencies may decide to provide incentives or allocate the General Plan level reductions to specific projects by weighting the overall effect by the number of projects to which the General Plan reduction would apply.

Information Sources and Their Limitations: The quantified effect that different mitigation measures have on source quantities or emission intensities must be based on substantial evidence and should be enforceable (to ensure that the commitments are adhered to) and verifiable (to confirm that the mitigation measures were implemented).

Examples of credible sources for supporting evidence include government agency-sponsored studies, peer-reviewed scientific literature, case studies, government-approved modeling software and widely adopted protocols. In order for the supporting evidence or data for a given mitigation measure to be deemed applicable, it must be based on similar or scalable assumptions and conditions in terms of period of study, physical scale, site-specific parameters, operating conditions, technology, population type, etc.

There are uncertainties associated with any type of estimation method. Some of these methods attempt to predict future behavior with respect to water and energy use using historical data and trends, which may not accurately reflect changes in behavior due to increasing awareness of resource conservation. Despite these uncertainties, the methods presented in Chapter 7 provide the best available estimations of GHG emissions and are therefore suitable for the project-level inventories.

Enforceable Reductions: As discussed in Chapter 2, emission reductions (whether as mitigation under CEQA, for regulatory purposes, or for trading) have to be enforceable. For that reason, in this Report the quantity of reductions or applicability of mitigation measures is limited to elements which the project proponent can control. Additional reductions in GHG emissions may be feasible in the broader sense and may occur; however, because the project proponent does not have control over these elements, those other reductions are not considered in the quantification methods here.

For instance, in the context of a building project, source reductions that rely on individual occupant behavior are generally not enforceable by the builder. A residential dwelling, when occupied, will contain a variety of electrical appliances. An individual occupant may decide to purchase energy efficient appliances and would therefore reduce energy use. This reduction in energy use is not enforceable, however, because the project proponent can't dictate individual occupants' purchases; these types of reductions are not counted in the methods in this Report. There may be some instances, however, where the project proponent is the occupant and would have the ability to enforce behavior. In these instances additional emission reductions not quantified in this document may be feasible and enforceable.

Some reductions in emissions are not enforceable when voluntary, but become enforceable when implemented as part of a regulatory scheme. Once regulations that result in emissions reductions are enacted, the project should be reviewed to determine how the requirements affect the baseline, and the reductions that can be quantified for mitigation credit.

When the emission reductions from a project are not enforceable, and therefore not quantified under these protocols, they may still have value for mitigation purposes and a qualitative analysis should be considered. Decisions about whether such reductions will be considered, and what sort of qualitative analysis is appropriate, are the responsibility of the agency reviewing the project.

Creation of Mitigation Measure Fact Sheets: Once the list of mitigation measures was determined, detailed Fact Sheets were developed for each mitigation measure. Each fact sheet presents a summary of the measure's applicability; the required calculation inputs from the actual project; the baseline emissions method; the mitigation calculation method and associated assumptions; a discussion of the calculation and an example calculation; and finally a summary of the preferred and alternative literature sources for measure efficacy. The fact sheets begin with a measure description. This description includes two critical components: (1) specific language regarding the measure implementation (which should be consistent with the implementation method for the actual project), and (2) a discussion of key support strategies that are assumed to also be in place for the reported range of effectiveness. Chapter 6 provides a discussion of the Fact Sheets and a brief description of their intended use. The Fact Sheets themselves are included in Chapter 7.

Quantification Methods

In this Report, emissions reductions are presented in terms of percentage reductions. For mitigation measures where the source metric is reduced, reductions were generally assessed based on a ratio comparison of a common "denominator" source metric for each source category in order to assist in the quantification of strategy impacts:

- Building Energy Use will utilize natural gas and electricity use.
- Water will utilize outdoor and indoor water use.
- Solid waste will utilize waste disposed.
- Mobile sources will utilize changes in vehicle miles travelled (VMT).

For mitigation measures involving emission factor reductions, a ratio comparing the mitigated and baseline emissions factor is utilized to quantify the emission reductions.

Because a ratio comparison is utilized, in most cases the reductions quantified for GHGs will also be the same reduction assessed for criteria pollutants and toxic air contaminants provided the reduction in emission factors also occurs for the other types of pollutants. This is not always the case and in some cases a reduction for one pollutant may result in an increase for another pollutant.

There is one exception to the quantitative approach described above, for off-road and on-road vehicles that affects the quantification of the emissions of ROGs. The underlying data and methods available to quantify these emissions were limited to running emissions (that is, emissions from the tailpipe while the engine is running). There are also evaporative emissions, however, which occur when pollutants evaporate from the fuel in the fuel tank and escape to the atmosphere. The evaporative emissions of most pollutants are very small when compared to the running emissions, but evaporative emissions of ROGs are not small compared to the running emissions. Because the underlying data and methods available did not address evaporative emissions, they are not part of the emission factor ratio and must be accounted for separately. Accordingly, an estimate of the ratio of running to evaporative emissions for ROGs was determined and used to adjust the reductions for ROGs from vehicles.

Limitations to Quantification of Emission Reductions for Mitigation Measures

In order to properly apply the quantification methods in this Report, it is important to understand the limitations of the methods. The following discusses the limitations of the underlying data and methods used to develop the quantification in this Report. A discussion of the limits on applying the methods in the Report is contained in Chapter 6. Further, the Fact Sheet for each individual measure identifies specific limitations and considerations that affect the application of that particular measure.

Prediction of Future Behavior: In order to assess the emissions associated with a project that does not yet exist, it is necessary to make assumptions regarding anticipated amounts of energy use, VMT, water use, etc, that will characterize the project once it occurs. These values may be based on estimates of source metrics from surveys of current values for those metrics, or from recent historical values. When such data are used, they are typically assumed to remain constant when applied to the project unless a there is a specific action (such as the application of a mitigation measure) that would alter the value(s). Although this is a commonly accepted practice, in reality, current behavior is not likely to remain constant over time in the way it is assumed. For instance, the occupant of a building determines the set point of thermostats, the duration of showers, and the usage of air conditioning, among other things. The project proponent will have little, if any, influence over these choices made by the future occupants.

Understanding the limits of these predictions, they are still the best basis for estimating future behavior. For this Report, quantification was based on current median behavior attributes. The limitations of the predictions can be minimized, however. Information about what influences behavior in specific circumstances is often available. Where data are available to show the relationship between external factors and the source metrics used to quantify a particular measure (such as fuel prices and VMT, for example), and more specific information is available about those external factors to predict future trends, that information could be used to further refine the quantification presented here. Again, the quality of the data used will substantially affect the accuracy and reliability of the results. It is also important to be aware of, and to minimize if possible, the error that can result from combining data from different sources (see below).

Combination of Data Sources: The quantification of some of the measures in this Report required the use of multiple sources of data. Any time data are derived from different sources there may be slight discrepancies the underlying in methodologies and data set characteristics; when the information between two data sets is combined, the discrepancies may affect the ultimate quantification of emissions, either over- or underestimating them. For example, some energy efficient appliances were not directly called out in the study of primary energy use based on end use. To obtain information on specific end uses, a secondary source was consulted that quantified energy use by end uses, and the values from this study were used to provide the detail where the end use data were lacking in the first study. It is not possible to determine the precise magnitude of the error that combining these two data sets induced in the final quantification, however every effort was made to minimize potential errors through thorough review of available data and exclusion of incompatible data sets.

There may be data sets available when considering a specific project that address the particulars of the project but are not generally applicable. Such case-specific data could be substituted for the more general data used to develop the quantifications in this Report. If such a substitution is considered, it is important to understand that it can result in an error in the quantification of the mitigation measure reductions because the methods used to derive the case-specific data may contain different assumptions that are not considered in, or are not consistent with the mitigation measure as characterized in the Fact Sheet. Anyone proposing the use of alternative underlying data for source metrics or emission factors must have a good understanding of the assumptions used in estimating the metrics/factors used in the baseline methodology and measure quantification for this Report. The discussion of sources and methods in the measure Fact Sheets as well as the baseline methodology in Appendix B should provide sufficient information to make this assessment.

Understanding these caveats, use of source-specific data is generally an improvement over that of generalized data, and where good quality source-specific data are available, they should be used. CAPCOA will not be able to review case-specific changes to the methods in this Report; however, the local air district may be able to provide assistance or recommendations. The decision to allow alterations to methods, including substitution of underlying data sets, rests with the agency reviewing the project.

Projects That Involve More Than One Mitigation Measure: Each mitigation measure was quantified using a specific set of underlying data and assumptions, and will provide the most accurate and reliable results when the project precisely matches the description of the measure, with all of its assumptions and limitations. In reality, projects may differ from the described measures, or may involve the application of more than one measure. In order to ensure that the resulting quantification is appropriate and accurate, specific procedures are provided in Chapter 6 for combining mitigation measures.

Lack of Detailed Information: The quantification methods provided in this report have been developed to allow them to be applied to a range of project conditions and still yield accurate and reliable results. In order to do this, the methods require data inputs that reflect the specific conditions of the project. Because the project has not yet been completed, however, certain information about the project will not be known and must be either estimated or assumed based on standard procedures. For example, at the time of the CEQA process a project proponent might know the number of residential dwelling units that will be in the project, but not know the actual square footage individual units will have. Similarly, while the project proponent may know a general type of non-residential land uses planned, these are often generalized categories such as retail and do not reflect the true diversity and range of source category parameters that would occur between the specific types of retail that the project eventually has. Nor can a project proponent predict specific appliances that will be in buildings or frequency of use. Further, most projects rely on generalized trip rate and trip lengths information that are not specific to the project; these estimates may over or underestimate the actual trip rates and trip lengths generated by the project. In each of these cases, estimates of future conditions are made based on accepted procedures and available data. This Report does not provide, or in any way alter, guidance on the level of detail required for the review or approval of any project. For the purposes of CEQA documents, the current CEQA guidelines address the information that is needed.[2]

The lack of precise and accurate data inputs limits the quality of the quantified project baseline and mitigated emissions, however. This limitation can be minimized to the extent the project proponent is able to provide better predictive data, or establish incentives, agreements, covenants, deeds, or other means of defining and restricting future uses to allow more precise estimates of the emissions associated with them. Some of these means of refining the data may also be creditable as mitigation of the project. The approval of any such enhancements of the data, or credit as mitigation, is at the discretion of the agency reviewing the project.

Use of Case Studies: One method of enhancing the data available for a project is the use of case studies. Case studies generally have detailed information regarding a particular effect. However, there are limitations of using this information to quantify emissions in other situations since adequate controls may not have been studied to separate out combined effects. There may be features or characteristics in the case-study that do not translate to the project and therefore may over or underestimate the GHG emission reductions. For the most part, case studies were not used as the primary source in the development of the quantification methods in this report. Where case studies were used to enhance underlying data, the studies were carefully reviewed to ensure that appropriate controls were used and the data meet the quality requirements of this Report.

[2] See: California Natural Resources Agency: 2007 CEQA Guidelines – Title 14 California Code of Regulations, Sections 15125, 15126.2, 15144, and 15146.

Extent Reductions Are Demonstrated in Practice: Some of the GHG mitigation measures in this Report are open-ended with regards to the amount of reductions that are theoretically possible. There are, however, practical limitations to the amount of reductions that can actually be achieved. These limitations can include the cost to implement the measure, physical constraints (e.g., roof space for photovoltaic panels), mainstream availability of technology, regulatory constraints, and other practical considerations. In applying the quantification methods for these types of measures, it is important to evaluate the reasonableness and practicability of the assumptions regarding these parameters.

Over time, some of these limitations may change. Implementation costs decrease as advanced technology is reaches mass production scale, for example, technological innovation can address physical constraints, and regulations change. The determination of feasibility for project assumptions should therefore be reconsidered for future applications based on the best available information at the time.

Biogenic CO_2 Emissions: This document did not address biogenic CO_2 emissions. Biogenic CO_2 emissions result from materials that are derived from living cells, as opposed to CO_2 emissions derived from fossil fuels, limestone, and other materials that have been transformed by geological processes. Biogenic CO_2 contains carbon that is present in organic materials that include, but are not limited to, wood, paper, vegetable oils, animal fat, and waste from food, animals, and vegetation (such as yard or forest waste). Biogenic CO_2 emissions are excluded from these GHG emissions quantification methods because they are the result of materials in the biological/physical carbon cycle, rather than the geological carbon cycle.

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Introduction

The mitigation measures quantified for this Report fall into general categories within which the quantification methods follow a common approach. The following sections summarize the select categories and subcategories of measures and discuss the quantification methods used for each one. In general, emission reductions are quantified (1) as a percentage of the baseline emissions; or (2) by calculating mitigated emissions and determining the change in emissions relative to the baseline case. More detailed explanation of the parameters and equations used to calculate the emission reductions for each individual measure are provided in the Fact Sheets in Chapter 7.

Building Energy Use

The emissions associated with building energy use come from power generation that provides the energy used to operate the building. Power is typically generated by a remote, central electricity generating plant, or onsite generation by fuel combustion. These emissions can be reduced by lowering the amount of electricity and natural gas required for building operations. This can be achieved by designing a more energy-efficient building structure and/or installing energy-efficient appliances. Replacing high-emitting energy generation with clean energy will also reduce emissions, and that type of mitigation is discussed in “On-site Energy Generation” below.

NREL.gov

As discussed in Chapter 3, this Report does not include a lifecycle analysis for GHG emissions. However, if a project proposes mitigation in the form of improved building energy use, a limited analysis of indirect emissions will be needed to quantify the associated reductions in GHG emissions. Emissions associated with energy use to light and heat buildings are, as stated previously, well-defined and not considered to be “lifecycle emissions” for the purposes of this Report. The quantification methods in this Report that deal with building energy use provide a specific method for conducting that analysis.

Emission reductions in this category are quantified as percentage reductions in specific baseline energy end uses, such as Title 24-regulated energy or household appliance energy use. The baseline values are determined using California-specific energy end use databases such as California Commercial End-Use Survey (CEUS) and Residential Appliance Saturation Study (RASS). The percentage reduction in Title-24 regulated energy is a project-specific input, whereas the percentage reductions in energy use for energy-efficient models of various household appliances can be obtained from literature sources (for example, through the Energy Star program).

Outdoor Water Use

Energy use associated with pumping, treating and conveying water generates indirect GHG emissions. The amount of energy required depends on both the volume of water and energy intensity associated with the water source. For example, it generally takes less energy to pump and convey water from a local source than to transport water across long distances. As a result, the GHG emission factor associated with locally-sourced water will also be lower. Indirect GHG emissions associated with water use can be decreased by reducing the water demand and/or by using a less energy-intensive water source. As discussed in Chapter 3, these emissions are well-defined and are not considered to be "lifecycle emissions" for the purposes of this report.

Outdoor water use at mixed-use developments is associated with irrigation for landscaping. The volume of water required for landscaping will depend on the areal extent of landscaping; the specific watering needs for the type of vegetation; and the water efficiency of the irrigation system. A reduction in outdoor water demand can be achieved by designing water-efficient landscapes that include plants with relatively low watering needs; minimizing areas of water-intensive turf; and installing smart irrigation systems to avoid excessive water use. Emission reductions associated with water-efficient design are quantified as the difference between mitigated and baseline values, which in turn are estimated using established models from government agencies or scientific literature. Emission reductions associated with smart irrigation systems and turf minimization are quantified as percentage reductions from the baseline. The implementation of gray water systems, where allowed, and the use of recycled water can also reduce emissions; however, it is important to consider the energy used to operate the gray water or water recycling system. These percentages are either taken from literature or estimated using site-specific data. The quantification methods in this Report include estimates of electricity use for recycled water systems, but not for gray water systems, because those emissions are generally more site specific.

SoCal Water$mart

As described previously, the energy use intensity for water supply will depend on the water source and its associated treatment and conveyance requirements. The typical or baseline scenario water source for Southern California is the State Water Project; however, other less-energy intensive supplies such as locally-treated recycled wastewater may instead be used to satisfy some of the project's non-potable water demand. Energy intensity values for different water sources can be obtained from California Energy Commission reports on water-related energy use, and are provided in Appendix E (Table E-2). Emissions associated with water use are estimated by multiplying the volume of water by the energy intensity value for the water source. The associated emission reduction is quantified by calculating emissions associated with water supplied by the lower impact water source (which can include the gray water or recycled water systems mentioned above), and subtracting it from the emissions associated with the same volume of water using the typical or baseline scenario water source.

Indoor Water Use

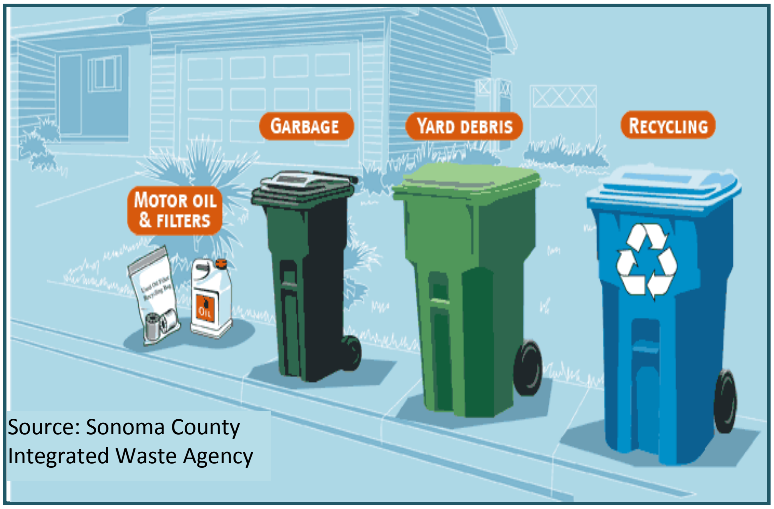
Similar to outdoor water use, indirect GHG emissions from indoor water use can be reduced by decreasing water demand or using a less energy-intensive water source. A project can reduce its indoor water demand relative to the baseline scenario by installing low-flow and high-efficiency water fixtures and appliances such as toilets, showerheads, faucets, clothes washers, and dishwashers.

Emission reductions associated with reduced water demand will be directly proportional to the decrease in demand. The total percentage reduction can be estimated by summing the reductions associated with each type of water-saving feature, which can be obtained from such sources as the California Green Building Standards Code or Energy Star standards. This total percentage would then be multiplied by the project's baseline demand, which should be available from the project's water assessment report. If the water assessment also has an estimate of mitigated water demand, which incorporates the reductions associated with water-saving features, then the reduction can be directly calculated as the difference between baseline and mitigated values.

Emission reductions associated with lower-impact water sources can be quantified as described above for outdoor water use.

Municipal Solid Waste

Solid waste generated at a site can directly produce GHG emissions via decomposition or incineration; it also generates vehicle-based emissions from trucks required to transport waste from its source to the waste handling facility. A reduction in the mass of municipal solid waste sent to landfills would lower emissions associated with its transport and treatment. This can be achieved by reducing the rate at which waste is generated, or by diverting material away from the landfill via on-site composting, reuse, or recycling operations (although direct and transport-related emissions associated with the alternate fates must be accounted for too).



Source: Sonoma County Integrated Waste Agency

Most methods to quantify municipal solid waste involve life-cycle assessments. The fact sheets describe the inventory emissions and the available tools that should be used if the Local Agency or project Applicant would like to quantify the benefits of a solid waste measure with respect to a reduction in life-cycle emissions.

Public Area and Traffic Signal Lighting

Energy use for lighting generates indirect GHG emissions. The amount of energy required for lighting depends in part on the number and energy needs of the lamps. Indirect emissions from lighting energy use can be reduced by installing energy-efficient lamps that maintain the same efficacy beyond what is required to meet any government standards. The replacement of existing, incandescent traffic signal lamps with light-emitting diode (LED) versions will reduce traffic light energy use relative to the baseline. New public lighting fixtures outfitted with energy-efficiency lamps will also use less electricity than the existing baseline energy use. However, because regulations require all new traffic lights to be LED-based, the methods in this Report do not quantify a reduction associated with LED traffic lights for new traffic intersections. Emissions reductions for lighting-based mitigation measures are quantified as percentages of the baseline emissions. The percentage reductions for energy-efficiency lighting are based on a survey of literature data.

Vegetation (including Trees)

As discussed in Chapter 3, vegetation incorporates carbon into its structure during its growth phase, and thereby can remove a finite amount of carbon from the atmosphere. The sequestration capacity of on-site vegetation is determined by the area available for vegetation, and the types of vegetation installed. A project can increase the area available for vegetation by converting previously developed land into vegetated open space. Conversions from one type of vegetated land to another may increase or decrease carbon sequestration, depending on the relative sequestration capacities of the land types. A third way to increase sequestration is by planting new trees on either developed or undeveloped land.

The increase in carbon sequestration capacity is determined by calculating the total sequestration capacity of converted land, new vegetated land and trees; and then subtracting the combined capacity of vegetated land or trees that are removed. Carbon sequestration capacities for different land types (e.g. cropland, forest land) and for different tree species classes are available from IPCC guidelines, and summarized in Table E-2, in Appendix E.

Construction Equipment

Construction equipment typically uses diesel fuel and releases emissions based on the amount of fuel combusted and emission factor of the equipment. Emissions can be reduced by using equipment that emits fewer pollutants for the same amount of work.

This is typically equipment powered through grid electricity or hybrid technology. The exclusive use of grid electricity eliminates the diesel emissions at the site but would increase indirect electricity emissions. However, grid-based emissions are typically small compared to the emissions from the diesel-fueled equipment (depending on the source of grid power). Hybrid-powered equipment would decrease but not completely eliminate fuel use. The electricity for hybrid equipment is self-generated unless the equipment has plug-in capability, so it would not increase grid-based electrical generation and the associated emissions there.

The emissions reductions in this category are determined by finding the difference between the estimated mitigation emissions and the baseline emissions for construction equipment. Emissions for the mitigated scenario may consist of direct emissions from combustion fuel use, and/or indirect emissions from grid electricity. These would be calculated using resources described previously, such as the OFFROAD database and literature-based methodologies and values.

Transportation

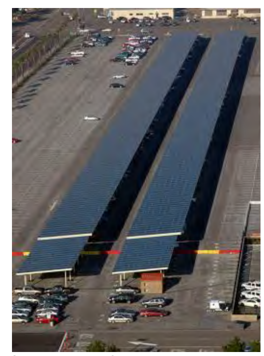
Transportation emissions can be reduced by improving the emissions profile of the vehicle fleet that travels the roads, or by reducing the vehicle miles traveled by the fleet. The majority of the measures quantified for this report focus on the reduction of VMT. This can be accomplished by optimizing the location and types of land uses in the project and its immediate vicinity, and by site enhancements to roads, and to bike and pedestrian networks to encourage the use of alternative modes of transportation. Mode shifts are also encouraged by implementing parking policies, transit system improvements, and trip reduction coordination or incentive programs.

The emission reductions in this category are determined by evaluating the elasticity of a measure relative to the amount of vehicle miles traveled that may be reduced as a result of the mitigation measure.

A few transportation measures in this Report are aimed at improving the emissions profile of the vehicle fleet. These measures promote alternative fuel, hybrid or electrical vehicles. The emission reductions in these measures are based on the improved emission factors and on changes to the assumed vehicle fleet mix.

On-Site Energy Generation

Different modes of energy generation have different GHG emission intensities. Fossil fuel-based generation emits GHG gases from combustion of the fuel, with the amount of emissions depending on the quantity and type of fuel used. Renewable energy generation, on the other hand, typically has significantly fewer emissions, and some types do not have any associated GHG emissions, such as photovoltaic systems and solar hot water heaters (excluding lifecycle emissions, as previously described in Chapter 3).


Solar Array at Coronado Naval Base

The emission reductions associated with using renewable non-emitting energy generated on-site are quantified as the emissions avoided because an equivalent amount of grid energy is not used. To calculate this, the energy generated by the on-site system(s) must be quantified, and then multiplied by the utility-specific emission factor for the type of energy (e.g. electricity, natural gas) being replaced. Energy generated on site is usually used for building operations; hence, it is generally considered a mitigation measure for building energy use.

Miscellaneous

The following miscellaneous mitigation measures are also discussed:

Loading Docks: A project applicant may elect to limit idling of engines beyond what is required by regulation at loading docks, or provide electrified loading docks. Electrified loading docks reduce the need for diesel auxiliary engines to run in order to keep refrigerated transportation units temperature controlled. The emission reduction is a comparison of the GHG emissions associated with the electricity compared to the diesel fuel combustion.

Off-site Mitigation: At the discretion of the reviewing agency, emission reductions may be created with offsite mitigation projects, as described in Chapter 2. If an off-site mitigation project is approved, the amount of emission reductions generated depends on the type of project implemented.

The numerical emission reductions would be quantified using the methods described for the different project categories above, with baseline values derived for the off-site location (instead of the project's baseline scenario). Once the numerical reductions have been estimated, they can be compared to the project's baseline emissions in order to determine the relative percentage reductions. Certain types of off-site projects may result in one-time emissions and others may result in a continuing stream of emissions reductions.

Carbon Sequestration: Emission reductions may be generated by implementing a carbon sequestration project. Carbon sequestration may be biological, chemical, or physical in nature, as described in Chapter 3. This Report does not address chemical or physical sequestration projects.

For biological sequestration, emission reductions are calculated as for vegetation projects (see above). The amount of the sequestration equals the amount of carbon removed by the vegetation.

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This chapter of the Report explains how the quantification of individual strategies is presented in Fact Sheets, how those fact sheets are designed and organized, and how to use them. This chapter also explains how and why mitigation measures have been grouped, and provides detailed discussion of how to apply the quantification methods when more than one strategy is being applied to the same project. A summary of the range of effectiveness for different measures is also provided for general information purposes, in table form, however it is very important that those generalized ranges NOT be used in place of the more specific quantification methods for the measure as detailed in the measure Fact Sheet. Finally, at the end of the Chapter there are step-by-step instructions on using the Fact Sheets, including an example.

Mitigation Strategies and Fact Sheets:

Accurate and reliable quantification depends on properly identifying the important variables that affect the emissions from an activity or source, and from changes to that activity or source. In order to provide a clear summary of those variables and usable instructions on how to find and apply the data needed, we have designed a Fact Sheet format to present each strategy or measure.

Types of Mitigation Strategies: There are three different types of mitigation strategies described in Chapter 7: Quantified measures, Best Management Practices, and General Plan strategies.

Quantified Measures: Quantified measures are fully quantified, project-level mitigation strategies. They are presented in categories where the nature of the underlying emissions sources are the same; the categories are discussed under "Organization of Fact Sheets" below. In addition, the measures may either stand alone, or be considered in connection with one or more other measures (that is, "grouped"). Groups of measures are always within a category; more detailed explanation is provided in "Grouping of Strategies" below. The majority of the strategies in this Report are fully Quantified Measures, and a strategy may be assumed to be of this type unless the Fact Sheet notes otherwise.

Best Management Practices: Several strategies are denoted as Best Management Practice (BMP). These measures are of two types. The first type of BMPs are quantifiable and describe methods that can be used to quantify the GHG mitigation reductions provided the project Applicant can provide substantial evidence supporting the values needed to quantify the reduction. These are listed as BMPs since there is not adequate literature at this time to generalize the mitigation measure reductions. However, the project Applicant may be able to provide the site specific information necessary to quantify a reduction. The second type of BMPs do not have methods for quantifying GHG mitigation reductions. These measures have preliminary evidence suggesting they will reduce GHG emissions if implemented, however, at this time adequate literature and methodologies are not available to quantify these reductions or they involve life-cycle GHG emission benefits. The measures are encouraged to be implemented nonetheless. Local Agencies may decide to provide incentives to encourage implementation of these measures.

General Plan Strategies: The measures listed under the General Plan category are measures that will have the most benefit when implemented at a General Plan level, but are not quantifiable or applicable at the project specific level. While on a project basis some of these measures may not be quantifiable, at the General Plan level they may be quantified under the assumption that this will be implemented on a widespread basis. Local Agencies may decide to provide incentives or allocate the General Plan level reductions to specific projects by weighting the overall effect by the number of projects the General Plan reduction would apply to.

Introduction to the Fact Sheets: This Report presents the quantification of each mitigation measure in a Fact Sheet format. Each Fact Sheet includes: a detailed summary of each measure's applicability; the calculation inputs for the specific project; the baseline emissions method; the mitigation calculation method and associated assumptions; a discussion of the calculation and an example calculation; and finally a summary of the preferred and alternative literature sources for measure efficacy. The Fact Sheets are found in Chapter 7.

Layout of the Fact Sheets: Each Fact Sheet describes one mitigation measure. The mitigation measure has a unique number and is provided at the bottom of each page in that measure's Fact Sheet. This will assist the end user in determining where a mitigation measure fact sheet begins and ends while still preserving consecutive page numbers in the overall Report.

At the top of each Fact Sheet, the name of the measure category appears on the left, and the subcategory on the right. Cross-references to prior CAPCOA documents appear at the top left, below the category name. Specifically, measures labeled CEQA #: are from the *CAPCOA 2008 CEQA & Climate Change*[1] and measures labeled MP#: are from the *CAPCOA 2009 Model Policies for Greenhouse Gases in General Plans*[2]. This cross-referencing is also included in the list of measures at the beginning of Chapter 7, and is intended to allow the user to move easily between the documents. The measure number is at the bottom of the page, on the right-hand side.

The fact sheets begin with a measure description. This description includes two critical components:

(1) Specific language regarding the measure implementation – which should be consistent with the implementation method suggested by the project Applicant; and

[1] Available online at http://www.capcoa.org/wp-content/uploads/downloads/2010/05/CAPCOA-White-Paper.pdf
[2] Available online at http://www.capcoa.org/wp-content/uploads/downloads/2010/05/CAPCOA-ModelPolicies-6-12-09-915am.pdf

(2) A discussion of key support strategies that are required for the reported range of effectiveness.

Appendices with additional calculations and assumptions for some of the fact sheets are provided at the end of this document. Default assumptions should be carefully reviewed for project applicability. Appendix B details the methodologies that should be used to calculate baseline GHG emissions for a project.

Organization of the Fact Sheets – Categories and Subcategories: The Fact Sheets are organized by general emission category types as follows:

- Energy
- Transportation
- Water
- Landscape Equipment
- Solid Waste
- Vegetation
- Construction
- Miscellaneous Categories
- General Plans

Several of these main categories are split into subcategories, for ease of understanding how to properly address the effects of combining the measures. Strategies are organized into categories and subcategories where they affect similar types of emissions sources. As an example, the category of “Energy” includes measures that reduce emissions associated with energy generation and use. Within that category, there are subcategories of measures that address “Building Energy Use,” “Alternative Energy,” and “Lighting,” each with one or more measures in it. The measures in the subcategory are closely related to each other.

Categories and subcategories for the measures are illustrated in Charts 6-1 and 6-2, below. Chart 6-1 shows all of the measure categories EXCEPT the Transportation category, including their subcategories; note that not all categories have subcategories. Measures in the Transportation category are shown in Chart 6-2. There are a number of subcategories associated with the Transportation category. As shown in Chart 6-2, the primary measures in each subcategory are indicated in bold type, and the measures shown in normal type are either support measures, or they are explicitly “grouped” measures.

It is important to note that subcategories are NOT the same as “grouped” measures / strategies. The grouping of strategies connotes a specific relationship, and is explained in the next section, below.

Chart 6-1: Non-Transportation Strategies Organization

Energy			Water		Area Landscaping	Solid Waste	Vegetation	Construction	Miscellaneous	General Plans
BE	AE	LE	WSW	WUW	A	SW	V	C	Misc	GP
Building Energy	**Alternative Energy**	**Lighting**	**Water Supply**	**Water Use**	**Landscaping Equipment**	**Solid Waste**	**Vegetation**	**Construction**	**Miscellaneous**	**General Plans**
Exceed Title 24	**Onsite Renewable Energy**	**Install High Efficacy Lighting**	**Adopt a Water Conservation Strategy**		**Prohibit gas Powered Landscape Equipment**	Institute or Extend Recycling & Composting Services	**Plant Urban Trees**	**Use Alternative Fuels for Construction Equipment**	**Establish Carbon Sequestration**	Fund Incentives for Energy Efficiency
			OR							
Install Energy Efficient Appliances	**Utilize Combined Heat & Power**	**Limit Outdoor Lighting**	**Use Reclaimed Water**	**Install Low-Flow Fixtures**	Implement Lawnmower Exchange Program Reduction: Grouped	Recycle Demolished Construction Material	**New Vegetated Open Space**	**Use Electric or Hybrid Construction Equipment**	**Establish Off-site Mitigation**	Establish a Local Farmer's Market
Install Programmable Thermostats Reduction: Grouped	**Establish Methane Recovery**	Replace Traffic Lights with LED Reduction: Additional	**Use Graywater**	**Design Water-Efficient Landscapes**	Electric Yard Equipment Compatibility Reduction Grouped			Limit Construction Equipment Idling	**Implement an Innovative Strategy**	Establish Community Gardens
Obtain 3rd Party Commissioning Reduction: Grouped			**Use Locally Sourced Water**	**Use Water-Efficient Irrigation**				Institute a Heavy-Duty Off-Road Vehicle Plan	Use Local and Sustainable Building Materials	Plant Urban Shade Trees
				Reduce Turf				Implement a Construction Vehicle Inventory Tracking System	Require BMP in Agriculture and Animal Operations	Implement Strategies to Reduce Urban Heat-Island Effect
				Plant Native or Drought-Resistant Vegetation					Require Environmentally Responsible Purchasing	

Note: Strategies in bold text are primary strategies with reported VMT reductions; non-bolded strategies are support or grouped strategies.

Chart 6-2: Transportation Strategies Organization

Transportation Measures (Five Subcategories) Global Maximum Reduction (all VMT):
urban = 75%; compact infill = 40%; suburban center or suburban with NEV = 20%; suburban = 15%

Global Cap for Road Pricing needs further study

Transportation Measures (Four Categories) Cross-Category Max Reduction (all VMT):
urban = 70%; compact infill = 35%; suburban center or suburban with NEV = 15%; suburban = 10%

Max Reduction = 15% overall; work VMT = 25%; school VMT = 65%;

Max Reduction = 25% (all VMT)

Land Use / Location Max Reduction: urban = 65%; compact infill = 30%; suburban center = 10%; suburban = 5%	Neighborhood / Site Enhancement Max Reduction: without NEV = 5%; with NEV = 15%	Parking Policy / Pricing Max Reduction = 20%	Transit System Improvements Max Reduction = 10%	Commute Trip Reduction (assumes mixed use) Max Reduction = 25% (work VMT)	Road Pricing Management Max Reduction = 25%	Vehicles
Density (30%)	Pedestrian Network (2%)	Parking Supply Limits (12.5%)	Network Expansion (8.2%)	CTR Program Required = 21% work VMT Voluntary = 6.2% work VMT	Cordon Pricing (22%)	Electrify Loading Docks
Design (21.3%)	Traffic Calming (1%)	Unbundled Parking Costs (13%)	Service Frequency / Speed (2.5%)	Transit Fare Subsidy (20% work VMT)	Traffic Flow Improvements (45% CO2)	Utilize Alternative Fueled Vehicles
Location Efficiency (65%)	NEV Network (14.4) <NEV Parking>	On-Street Market Pricing (5.5%)	Bus Rapid Transit (3.2%)	Employee Parking Cash-out (7.7% work VMT)	Required Contributions by Project	Utilize Electric or Hybrid Vehicles
Diversity (30%)	Car Share Program (0.7%)	Residential Area Parking Permits	Access Improvements	Workplace Parking Pricing (19.7% work VMT)		
Destination Accessibility (20%)	Bicycle Network <Lanes> <Parking> <Land Dedication for Trails>		Station Bike Parking	Alternative Work Schedules & Telecommute (5.5% work VMT)		
Transit Accessibility (25%)	Urban Non-Motorized Zones		Local Shuttles	CTR Marketing (5.5% work VMT)		
BMR Housing (1.2%)			Park & Ride Lots*	Employer-Sponsored Vanpool/Shuttle (13.4% work VMT)		
Orientation Toward Non-Auto Corridor				Ride Share Program (15% work VMT)		
Proximity to Bike Path				Bike Share Program		
				End of Trip Facilities		
				Preferential Parking Permit		
				School Pool (15.8% school VMT)		
				School Bus (6.3% school VMT)		

Note: Strategies in bold text are primary strategies with reported VMT reductions; non-bolded strategies are support or grouped strategies.

Grouping of Strategies

Strategies noted as "grouped" are separately documented in individual Fact Sheets but must be paired with other strategies within the category. When these "grouped" strategies are implemented together, the combination will result in either an enhancement to the primary strategy by improving its effectiveness or a non-negligible reduction in effectiveness that would not occur without the combination.

Rules for Combining Strategies or Measures

Mitigation measures or strategies are frequently implemented together with other measures. Often, combining measures can lead to better emission reductions than implementing a single measure by itself. Unfortunately, the effects of combining the measures are not always as straightforward as they might at first appear. When more and more measures are implemented to mitigate a particular source of emissions, the benefit of each additional measure diminishes. If it didn't, some odd results would occur. For example, if there were a series of measures that each, independently, was predicted to reduce emissions from a source by 10%, and if the effect of each measure was independent of the others, then implementing ten measures would reduce all of the emissions; and what would happen with the eleventh measure? Would the combination reduce 110% of the emissions? No. In fact, each successive measure is slightly less effective than predicted when implemented on its own.

On the other hand, some measures enhance the performance of a primary measure when they are combined. This Report includes a set of rules that govern different ways of combining measures. The rules depend on whether the measures are in the *same* category, or different categories. Remember, the categories include: Energy, Transportation, Water, Landscape Equipment, Solid Waste, Vegetation, Construction, Miscellaneous Categories, and General Plans.

Combinations <u>Between</u> Categories: The following procedures must be followed when combining mitigation measures that fall in separate categories. In order to determine the overall reduction in GHG emissions compared to the baseline emissions, the relative magnitude of emissions between the source categories needs to be considered. To do this, the user should determine the percent contribution made by each individual category to the overall baseline GHG emissions. This percent contribution by a category should be multiplied by the reduction percentages from mitigation measures in that category to determine the scaled GHG emission reductions from the measures in that category. This is done for each category to be combined. The scaled GHG emissions for each category can then be added together to give a total GHG reduction for the combined measures in all of the categories.

For example, consider a project whose total GHG emissions come from the following categories: transportation (50%), building energy use (40%), water (6%), and other (4%). This project implements a transportation mitigation measure that results in a 10% reduction in VMT. The project also implements mitigation measures that result in a 30% reduction in water usage. The overall reduction in GHG emissions is as follows:

Reduction from Transportation: 0.50 x 0.10 = 0.5 or 5%
Reduction from Water: 0.06 x 0.30 = 0.018 or 1.8%

Total Reduction: 5% + 1.8% = 6.8%

This example illustrates the importance of the magnitude of a source category and its influence on the overall GHG emission reductions.

The percent contributions from source categories will vary from project to project. In a commercial-only project it may not be unusual for transportation emissions to represent greater than 75% of all GHG emissions whereas for a residential or mixed use project, transportation emissions would be below 50%.

Combinations Within Categories: The following procedures must be followed when combining mitigation measures that fall within the same category.

Non-Transportation Combinations: When combining non-transportation subcategories, the total amount of reductions for that category should not exceed 100% except for categories that would result in additional excess capacity that can be used by others, but which the project wants to take credit for (subject to approval of the reviewing agency). This may include alternative energy generation systems tied into the grid, vegetation measures, and excess graywater or recycled water generated by the project and used by others. These excess emission reductions may be used to offset other categories of emissions, with approval of the agency reviewing the project. In these cases of excess capacity, the quantified amounts of excess emissions must be carefully verified to ensure that any credit allowed for these additional reductions is truly surplus.

Category Maximum- Each category has a maximum allowable reduction for the combination of measures in that category. It is intended to ensure that emissions are not double counted when measures within the category are combined. Effectiveness levels for multiple strategies within a subcategory (as denoted by a column in the appropriate chart, above) may be multiplied to determine a combined effectiveness level up to a maximum level. This should be done first to mitigation measures that are a source reduction followed by those that are a reduction to emission factors. Since the combination of mitigation measures and independence of mitigation measures are both complicated, this Report recommends that mitigation measure reductions within a category be multiplied unless a project applicant can provide substantial evidence indicating that emission reductions are independent of one another. This will take the following form:

GHG emission reduction for category = 1-[(1-A) x (1-B) x (1-C)]

Where:

A, B and C = Individual mitigation measure reduction percentages for the strategies to be combined in a given category.

Global Maximum- A separate maximum, referred to as a global maximum level, is also provided for a combination across subcategories. Effectiveness levels for multiple strategies across categories may also be multiplied to determine a combined effectiveness level up to global maximum level.

For example, consider a project that is combining 3 mitigation strategies from the water category. This project will install low-flow fixtures (measure WUW-1), use water-efficient irrigation (measure WUW-4, and reduce turf (measure WUW-5). Reductions from these measures will be:

• low-flow fixtures	20% or 0.20 (A)
• water efficient irrigation	10% or 0.10 (B)
• turf reductions	20% or 0.20 (C)

To combine measures within a category, the reductions would be
= 1-[(1-A) x (1-B) x (1-C)]
= 1-[(1-.20) x (1-.10) x (1-.20)]
= 1-[(0.8) x (0.9) x (.8)]
= 1-0.576 = 0.424
= 42.4%

<u>Transportation Combinations</u>: The interactions between the various categories of transportation-related mitigation measures is complex and sometimes counter-intuitive. Combining these measures can have a substantive impact on the quantification of the associated emission reductions. In order to safeguard the accuracy and reliability of the methods, while maintaining their ease of use, the following rules have been developed and should be followed when combining transportation-related mitigation measures. The rules are presented by sub-category, and reference Chart 6-2 Transportation Strategies Organization. The maximum reduction values also reflect the highest reduction levels justified by the literature. The chart indicates maximum reductions for individual mitigation measures just below the measure name.

Cross-Category Maximum- A cross-category maximum is provided for any combination of land use, neighborhood enhancements, parking, and transit strategies (columns A-D in Chart 6-1, with the maximum shown in the top row). The total project VMT reduction across these categories should be capped at these levels based on empirical evidence.[3] Caps are provided for the location/development type of the project. VMT reductions may be multiplied across the four categories up to this maximum. These include:

- Urban: 70% VMT
- Compact Infill: 35%
- Suburban Center (or Suburban with NEV): 15%
- Suburban: 10% (note that projects with this level of reduction must include a diverse land use mix, workforce housing, and project-specific transit; limited empirical evidence is available)

(See blue box, pp. 58-59.)

[3] As reported by Holtzclaw, et al for the State of California.

As used in this Report, location settings are defined as follows:

Urban: A project located within the central city and may be characterized by multi-family housing, located near office and retail. Downtown Oakland and the Nob Hill neighborhood in San Francisco are examples of the typical urban area represented in this category. The urban maximum reduction is derived from the average of the percentage difference in per capita VMT versus the California statewide average (assumed analogous to an ITE baseline) for the following locations:

Location	Percent Reduction from Statewide VMT/Capita
Central Berkeley	-48%
San Francisco	-49%
Pacific Heights (SF)	-79%
North Beach (SF)	-82%
Mission District (SF)	-75%
Nob Hill (SF)	-63%
Downtown Oakland	-61%

The average reflects a range of 48% less VMT/capita (Central Berkeley) to 82% less VMT/capita (North Beach, San Francisco) compared to the statewide average. The urban locations listed above have the following characteristics:

- Location relative to the regional core: these locations are within the CBD or less than five miles from the CBD (downtown Oakland and downtown San Francisco).
- Ratio or relationship between jobs and housing: jobs-rich (jobs/housing ratio greater than 1.5)
- Density character
    - typical building heights in stories: six stories or (much) higher
    - typical street pattern: grid
    - typical setbacks: minimal
    - parking supply: constrained on and off street
    - parking prices: high to the highest in the region
- Transit availability: high quality rail service and/or comprehensive bus service at 10 minute headways or less in peak hours

Compact infill: A project located on an existing site within the central city or inner-ring suburb with high-frequency transit service. Examples may be community redevelopment areas, reusing abandoned sites, intensification of land use at established transit stations, or converting underutilized or older industrial buildings. Albany and the Fairfax area of Los Angeles are examples of typical compact infill area as used here. The compact infill maximum reduction is derived from the average of the percentage difference in per capita VMT versus the California statewide average for the following locations:

Location	Percent Reduction from Statewide VMT/Capita
Franklin Park, Hollywood	-22%
Albany	-25%
Fairfax Area, Los Angeles	-29%
Hayward	-42%

The average reflects a range of 22% less VMT/capita (Franklin Park, Hollywood) to 42% less VMT/capita (Hayward) compared to the statewide average. The compact infill locations listed above have the following characteristics:

- Location relative to the regional core: these locations are typically 5 to 15 miles outside a regional CBD
- Ratio or relationship between jobs and housing: balanced (jobs/housing ratio ranging from 0.9 to 1.2)
- Density character
    - typical building heights in stories: two to four stories
    - typical street pattern: grid
    - typical setbacks: 0 to 20 feet
    - parking supply: constrained
    - parking prices: low to moderate
- Transit availability: rail service within two miles, or bus service at 15 minute peak headways or less

As used in this Report, additional location settings are defined as follows:

Suburban Center: A project typically involving a cluster of multi-use development within dispersed, low-density, automobile dependent land use patterns (a suburb). The center may be an historic downtown of a smaller community that has become surrounded by its region's suburban growth pattern in the latter half of the 20th Century. The suburban center serves the population of the suburb with office, retail and housing which is denser than the surrounding suburb. The suburban center maximum reduction is derived from the average of the percentage difference in per capita VMT versus the California statewide average for the following locations:

Location	Percent Reduction from Statewide VMT/Capita
Sebastopol	0%
San Rafael (Downtown)	-10%
San Mateo	-17%

The average reflects a range of 0% less VMT/capita (Sebastopol) to 17% less VMT/capita (San Mateo) compared to the statewide average. The suburban center locations listed above have the following characteristics:

- Location relative to the regional core: these locations are typically 20 miles or more from a regional CBD
- Ratio or relationship between jobs and housing: balanced
- Density character
  - typical building heights in stories: two stories
  - typical street pattern: grid
  - typical setbacks: 0 to 20 feet
  - parking supply: somewhat constrained on street; typically ample off-street
  - parking prices: low (if priced at all)
- Transit availability: bus service at 20-30 minute headways and/or a commuter rail station

While all three locations in this category reflect a suburban "downtown," San Mateo is served by regional rail (Caltrain) and the other locations are served by bus transit only. Sebastopol is located more than 50 miles from downtown San Francisco, the nearest urban center. San Rafael and San Mateo are located 20 miles from downtown San Francisco.

Suburban: A project characterized by dispersed, low-density, single-use, automobile dependent land use patterns, usually outside of the central city (a suburb). Suburbs typically have the following characteristics:

- Location relative to the regional core: these locations are typically 20 miles or more from a regional CBD
- Ratio or relationship between jobs and housing: jobs poor
- Density character
  - typical building heights in stories: one to two stories
  - typical street pattern: curvilinear (cul-de-sac based)
  - typical setbacks: parking is generally placed between the street and office or retail buildings; large-lot residential is common
  - parking supply: ample, largely surface lot-based
  - parking prices: none
- Transit availability: limited bus service, with peak headways 30 minutes or more

The maximum reduction provided for this category assumes that regardless of the measures implemented, the project's distance from transit, density, design, and lack of mixed use destinations will keep the effect of any strategies to a minimum.

Global Maximum- A global maximum is provided for any combination of land use, neighborhood enhancements, parking, transit, and commute trip reduction strategies (the first five columns in the organization chart). This excludes reductions from road-pricing measurements which are discussed separately below. The total project VMT reduction across these categories, which can be combined through multiplication, should be capped at these levels based on empirical evidence.[4] Maximums are provided for the location/development type of the project. The Global Maximum values can be found in the top row of Chart 6-2.

These include:

- Urban: 75% VMT
- Compact Infill: 40% VMT
- Suburban Center (or Suburban with NEV): 20%
- Suburban: 15% (limited empirical evidence available)

Specific Rules for Subcategories within Transportation- Because of the unique interactions of measures within the Transportation Category, each subcategory has additional rules or criteria for combining measures.

❖ Land Use/Location Strategies – Maximum Reduction Factors: Land use measures apply to a project area with a radius of ½ mile. If the project area under review is greater than this, the study area should be divided into subareas of radii of ½ mile, with subarea boundaries determined by natural "clusters" of integrated land uses within a common walkshed. If the project study area is smaller than ½ mile in radius, other land uses within a ½ mile radius of the key destination point in the study area (i.e. train station or employment center) should be included in design, density, and diversity calculations. Land use measures are capped based on empirical evidence for location setting types as follows:[5]

- Urban: 65% VMT
- Compact Infill: 30% VMT
- Suburban Center: 10% VMT
- Suburban: 5% VMT

❖ Neighborhood/Site Enhancements Strategies – Maximum Reduction Factors: The neighborhood/site enhancements category is capped at 12.7% VMT reduction (with Neighborhood Electric Vehicles (NEVs)) and 5% without NEVs based on empirical evidence (for NEVs) and the multiplied combination of the non-NEV measures.

❖ Parking Strategies – Maximum Reduction Factors: Parking strategies should be implemented in one of two combinations:

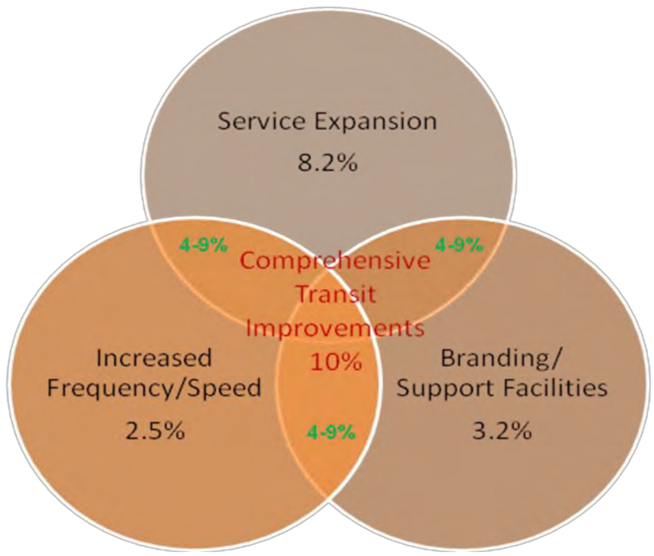
- Limited (reduced) off-street supply ratios plus residential permit parking and priced on-street parking (to limit spillover), or
- Unbundled parking plus residential permit parking and priced on-street parking (to limit spillover).

[4] As reported by Holtzclaw, et al for the State of California. Note that CTR strategies must be converted to overall VMT reductions (from work-trip VMT reductions) before being combined with strategies in other categories.

[5] As reported for California locations in Holtzclaw, et al. "Location Efficiency: Neighborhood and Socioeconomic Characteristics Determine Auto Ownership and Use – Studies in Chicago, Los Angeles, and San Francisco." *Transportation Planning and Technol*ogy, 2002, Vol. 25, pp. 1–27.

Note: The reduction maximum of 20% VMT reflects the combined (multiplied) effect of unbundled parking and priced on-street parking.

- Transit System Strategies – Maximum Reduction Factors: The 10% VMT reduction maximum for transit system improvements reflects the combined (multiplied) effect of network expansion and service frequency/speed enhancements. A comprehensive transit improvement would receive this type of reduction, as shown in the center overlap in the Venn diagram, below.



- Commuter Trip Reductions (CTR) Strategies – Maximum Reduction Factors: The most effective commute trip reduction measures combine incentives, disincentives, and mandatory monitoring, often through a transportation demand management (TDM) ordinance. Incentives encourage a particular action, for example parking cash-out, where the employee receives a monetary incentive for not driving to work, but is not punished for maintaining status quo. Disincentives establish a penalty for a status quo action. An example is workplace parking pricing, where the employee is now monetarily penalized for driving to work. The 25% maximum for work-related VMT applies to comprehensive CTR programs. TDM strategies that include only incentives, only disincentives, and/or no mandatory monitoring, should have a lower total VMT reduction than those with a comprehensive approach. Support strategies to strengthen CTR programs include guaranteed-ride-home, taxi vouchers, and message boards/marketing materials. A 25% reduction in work-related VMT is assumed equivalent to a 15% reduction in overall project VMT for the purpose of the global maximum; this can be adjusted for project-specific land use mixes.

  Two school-related VMT reduction measures are also provided in this category. The maximum reduction for these measures should be 65% of school-related VMT based on the literature.

- Road Pricing/Management Strategies – Maximum Reduction Factors: Cordon pricing is the only strategy in this category with an expected VMT reduction potential. Other forms of road pricing would be applied at a corridor or region-wide level rather than as mitigation applied to an individual development project. No domestic case studies are available for cordon pricing, but international studies suggest a VMT reduction maximum of 25%. A separate, detailed, and project-specific study should be conducted for any project where road pricing is proposed as a VMT reduction measure.

Additional Rules for Transportation Measures- There are also restrictions on the application of measures in rural applications, and application to baseline, as follows:

- Rural Application: Few empirical studies are available to suggest appropriate VMT reduction caps for strategies implemented in rural areas. Strategies likely to have the largest VMT reduction in rural areas include vanpools, telecommute or alternative work schedules, and master planned communities (with design and land use diversity to encourage intra-community travel). NEV networks may also be appropriate for larger scale developments. Because of the limited empirical data in the rural context, project-specific VMT reduction estimates should be calculated.

- Baseline Application: As discussed in previous sections of this report, VMT reductions should be applied to a baseline VMT expected for the project, based on the Institute of Transportation Engineers' 8th Edition *Trip Generation Manual* and associated typical trip distance for each land use type. Where trip generation rates and project VMT provided by the project Applicant are derived from another source, the VMT reductions must be adjusted to reflect any "discounts" already applied.

Range of Effectiveness of Mitigation Measures

The following charts provide the range of effectiveness for the quantified mitigation measures. Each chart shows one category of measures, with subcategories identified. The charts also show the basis for the quantification, and indicate applicable groupings. IMPORTANT: these ranges are approximate and should NOT be used in lieu of the specific quantification method provided in the fact sheet for each measure. Restrictions on combining measures must be observed.

Table 6-1: Energy Category

Energy						
Category	Measure Number	Strategy	BMP	Grouped With #	Range of Effectiveness	
					Percent Reduction in GHG Emissions	Basis
Building Energy Use	BE-1	Buildings exceed Title 24 Building Envelope Energy Efficiency Standards by X% (X is equal to the percentage improvement selected for the project			For a 10% improvement over 2008 Title 24: Non-Residential electricity use: 0.2-5.5%; natural gas use: 0.7-10% Residential electricity use: 0.3-2.6%; natural gas use: 7.5-9.1%	
	BE-2	Install Programmable Thermostat Timers	x		BMP	
	BE-3	Obtain Third-party HVAC Commissioning and Verification of Energy Savings	x	BE-1	BMP	
	BE-4	Install Energy Efficient Appliances			Residential building: 2-4% Grocery Stores: 17-22%	Appliance Electricity Use
	BE-5	Install Energy Efficient Boilers			1.2-18.4%	Fuel Use
Alternative Energy Generation	AE-1	Establish Onsite Renewable Energy Systems-Generic			0-100%	
	AE-2	Establish Onsite Renewable Energy Systems-Solar Power			0-100%	
	AE-3	Establish Onsite Renewable Energy Systems-Wind Power			0-100%	
	AE-4	Utilize a Combined Heat and Power System			0-46%	
	AE-5	Establish Methane Recovery in Landfills			73-77%	
	AE-6	Establish Methane Recovery in Wastewater Treatment Plants			95-97%	
Lighting	LE-1	Install Higher Efficacy Public Street and Area Lighting			16-40%	Outdoor Lighting Electricity Use
	LE-2	Limit Outdoor Lighting Requirements	x		BMP	
	LE-3	Replace Traffic Lights with LED Traffic Lights			90%	Traffic Light Electricity Use

Table 6-2: Transportation Category

Transportation						
Category	Measure Number	Strategy	BMP	Grouped With #	Range of Effectiveness	
					Percent Reduction in GHG Emissions	Basis
Land Use / Location	LUT-1	Increase Density			1.5-30.0%	VMT
	LUT-2	Increase Location Efficiency			10-65%	VMT
	LUT-3	Increase Diversity of Urban and Suburban Developments (Mixed Use)			9-30%	VMT
	LUT-4	Incr. Destination Accessibility			6.7-20%	VMT
	LUT-5	Increase Transit Accessibility			0.5-24.6%	VMT
	LUT-6	Integrate Affordable and Below Market Rate Housing			0.04-1.20%	VMT
	LUT-7	Orient Project Toward Non-Auto Corridor			NA	
	LUT-8	Locate Project near Bike Path/Bike Lane			NA	
	LUT-9	Improve Design of Development			3.0-21.3%	VMT
Neighborhood / Site Design	SDT-1	Provide Pedestrian Network Improvements			0-2%	VMT
	SDT-2	Traffic Calming Measures			0.25-1.00%	VMT
	SDT-3	Implement a Neighborhood Electric Vehicle (NEV) Network			0.5-12.7%	VMT
	SDT-4	Urban Non-Motorized Zones		SDT-1	NA	
	SDT-5	Incorporate Bike Lane Street Design (on-site)		LUT-9	NA	
	SDT-6	Provide Bike Parking in Non-Residential Projects		LUT-9	NA	
	SDT-7	Provide Bike Parking in Multi-Unit Residential Projects		LUT-9	NA	
	SDT-8	Provide EV Parking		SDT-3	NA	
	SDT-9	Dedicate Land for Bike Trails		LUT-9	NA	
Parking Policy / Pricing	PDT-1	Limit Parking Supply			5-12.5%	
	PDT-2	Unbundle Parking Costs from Property Cost			2.6-13%	
	PDT-3	Implement Market Price Public Parking (On-Street)			2.8-5.5%	
	PDT-4	Require Residential Area Parking Permits		PDT-1, 2 & 3	NA	

Transportation - continued						
Category	Measure Number	Strategy	BMP	Grouped With #	Range of Effectiveness	
					Percent Reduction in GHG Emissions	Basis
Trip Reduction Programs	TRT-1	Implement Voluntary CTR Programs			1.0-6.2%	Commute VMT
	TRT-2	Implement Mandatory CTR Programs – Required Implementation/Monitoring			4.2-21.0%	Commute VMT
	TRT-3	Provide Ride-Sharing Programs			1-15%	Commute VMT
	TRT-4	Implement Subsidized or Discounted Transit Prog.			0.3-20.0%	Commute VMT
	TRT-5	Provide End of Trip Facilities		TRT-1, 2 & 3	NA	
	TRT-6	Telecommuting and Alternative Work Schedules			0.07-5.50%	Commute VMT
	TRT-7	Implement Commute Trip Reduction Marketing			0.8-4.0%	Commute VMT
	TRT-8	Implement Preferential Parking Permit Program		TRT-1, 2 & 3	NA	
	TRT-9	Implement Car-Sharing Program			0.4-0.7%	VMT
	TRT-10	Implement School Pool Program			7.2-15.8%	School VMT
	TRT-11	Provide Employer-Sponsored Vanpool/Shuttle			0.3-13.4%	Commute VMT
	TRT-12	Implement Bike-Sharing Program		SDT-5, LUT-9	NA	
	TRT-13	Implement School Bus Program			38-63%	School VMT
	TRT-14	Price Workplace Parking			0.1-19.7%	Commute VMT
	TRT-15	Implement Employee Parking “Cash-Out”			0.6-7.7%	Commute VMT

Transportation - continued						
Category	Measure Number	Strategy	BMP	Grouped With #	Range of Effectiveness	
					Percent Reduction in GHG Emissions	Basis
Transit System Improvements	TST-1	Provide a Bus Rapid Transit System			0.02-3.2%	VMT
	TST-2	Implement Transit Access Improvements		TST-3, TST-4	NA	
	TST-3	Expand Transit Network			0.1-8.2%	VMT
	TST-4	Increase Transit Service Frequency/Speed			0.02-2.5%	VMT
	TST-5	Provide Bike Parking Near Transit		TST-3, TST-4	NA	
	TST-6	Provide Local Shuttles		TST-3, TST-4	NA	
Road Pricing / Management	RPT-1	Implement Area or Cordon Pricing			7.9-22.0%	VMT
	RPT-2	Improve Traffic Flow			0-45%	VMT
	RPT-3	Require Project Contributions to Transportation Infrastructure Improvement Projects		RPT-2, TST-1 to 6	NA	
	RPT-4	Install Park-and-Ride Lots		RPT-1, TRT-11, TRT-3, TST-1 to 6	NA	
Vehicles	VT-1	Electrify Loading Docks and/or Require Idling-Reduction Systems			26-71%	Truck Idling Time
	VT-2	Utilize Alternative Fueled Vehicles			Varies	
	VT-3	Utilize Electric or Hybrid Vehicles			0.4-20.3%	Fuel Use

Table 6-3: Water Category

Water						
Category	Measure Number	Strategy	BMP	Grouped With #	Range of Effectiveness	
					Percent Reduction in GHG Emissions	Basis
Water Supply	WSW-1	Use Reclaimed Water			up to 40% for Northern Californiaup to 81% for Southern California	Outdoor Water Use
	WSW-2	Use Gray Water			0-100%	Outdoor Water Use
	WSW-3	Use Locally-Sourced Water Supply			0-60% for Northern and Central California; 11-75% for Southern California	Indoor and Outdoor Water Use
Water Use	WUW-1	Install Low-Flow Water Fixtures.			Residential: 20% Non-Residential: 17-31%	Indoor Water Use
	WUW-2	Adopt a Water Conservation Strategy.			varies	
	WUW-3	Design Water-Efficient Landscapes			0-70%	Outdoor Water Use
	WUW-4	Use Water-Efficient Landscape Irrigation Systems			6.1%	Outdoor Water Use
	WUW-5	Reduce Turf in Landscapes and Lawns			varies	
	WUW-6	Plant Native or Drought-Resistant Trees and Vegetation			BMP	

Table 6-4: Area Landscaping

Area Landscaping						
Category	Measure Number	Strategy	BMP	Grouped With #	Range of Effectiveness	
					Percent Reduction in GHG Emissions	Basis
Area Landscaping	A-1	Prohibit Gas Powered Landscape Equipment.			LADWP: 2.5-46.5% PG&E: 64.1-80.3% SCE: 49.5-72.0% SDGE: 38.5-66.3% SMUD: 56.3-76.0%	Fuel Use
	A-2	Implement Lawnmower Exchange Program			BMP	
	A-3	Electric Yard Equipment Compatibility		A-1 or A-2	BMP	

Table 6-5: Solid Waste Category

Solid Waste						
Category	Measure Number	Strategy	BMP	Grouped With #	Range of Effectiveness	
					Percent Reduction in GHG Emissions	Basis
Solid Waste	SW-1	Institute or Extend Recycling and Composting Services			BMP	
	SW-2	Recycle Demolished Construction Material			BMP	

Table 6-6: Vegetation Category

Vegetation						
Category	Measure Number	Strategy	BMP	Grouped With #	Range of Effectiveness	
					Percent Reduction in GHG Emissions	Basis
Vegetation	V-1	Urban Tree Planting		GP-4	varies	
	V-2	Create new vegetated open space.			varies	

Table 6-7: Construction Category

Construction						
Category	Measure Number	Strategy	BMP	Grouped With #	Range of Effectiveness	
					Percent Reduction in GHG Emissions	Basis
Construction	C-1	Use Alternative Fuels for Construction Equipment			0-22%	Fuel Use
	C-2	Use Electric and Hybrid Construction Equipment			2.5-80%	Fuel Use
	C-3	Limit Construction Equipment Idling beyond Regulation Requirements			varies	
	C-4	Institute a Heavy-Duty Off-Road Vehicle Plan		Any C	BMP	
	C-5	Implement a Vehicle Inventory Tracking System		Any C	BMP	

Table 6-8: Miscellaneous Category

Miscellaneous						
Category	Measure Number	Strategy	BMP	Grouped With #	Range of Effectiveness	
					Percent Reduction in GHG Emissions	Basis
Miscellaneous	Misc-1	Establish a Carbon Sequestration Project			varies	
	Misc-2	Establish Off-Site Mitigation			varies	
	Misc-3	Use Local and Sustainable Building Materials	x		BMP	
	Misc-4	Require Best Management Practices in Agriculture and Animal Operations	x		BMP	
	Misc-5	Require Environmentally Responsible Purchasing	x		BMP	
	Misc-6	Implement an Innovative Strategy for GHG Mitigation	x		BMP	

Table 6-9: General Plans

General Plan Strategies						
Category	Measure Number	Strategy	BMP	Grouped With #	Range of Effectiveness	
					Percent Reduction in GHG Emissions	Basis
General Plans	GP-1	Fund Incentives for Energy Efficiency	x		BMP	
	GP-2	Establish a Local Farmer's Market	x		BMP	
	GP-3	Establish Community Gardens	x		BMP	
	GP-4	Plant Urban Shade Trees	x	V-1	BMP	
	GP-5	Implement Strategies to Reduce Urban Heat-Island Effect	x		BMP	

Applicability of Quantification Fact Sheets Outside of California
In order to apply the quantification methods in this Report to projects located outside of California, the assumptions and methods in the baseline methodology and in the Fact Sheets should be reviewed prior to applying them. First, evaluate the basis for use metrics and emission factors for applicability outside of California. The Report references various sources for use metrics and emission factors; if these are California-specific, the method should be evaluated to determine if these same use metrics and emission factors are applicable to the project area. If they are not applicable, factors appropriate for the project area should be substituted in the baseline and project methods. Key factors to consider are climate zone[6], precipitation, building standards, end-user behavior, and transportation environment (land use and transportation characteristics). Use metrics likely to vary outside of California include:

- Building Energy Use
- Water Use
- Vehicle Trip Lengths and Vehicle Miles Traveled
- Building Standards
- Waste Disposal Rates
- Landscape Equipment Annual Usage

Emission factors relate the use metric to carbon intensity to estimate GHG emissions. Depending on the type of emission factor, these values may or may not change based on location. For instance, the emission factor for combustion of a specific amount of fuel does not typically change; however the engine mix may change by location, and fuel use by those engines may be different. Other emission factors are regionally dependent and alternative sources should be investigated. Emission factors likely to vary outside of California include:

- Electricity associated with water and wastewater supply and treatment
- Carbon intensity of electricity supplied
- Fleet and model year distribution of vehicles which influences emission factors

The user should be able to adjust the methodologies to: (1) calculate the baseline for a given mitigation measure; and then (2) incorporate the appropriate data and assumptions into the calculations for the emission mitigation associated with the measure.

There is at least one mitigation measure that will not be applicable outside of California unless adjustments are made by substituting location-specific factors in the baseline methodology: the improvement beyond Title 24 (BE-1) is not applicable outside of California since buildings outside California would be subject to different building codes. The project Applicant may be able to estimate a baseline energy use for building envelope systems under other building standards and estimate the change in energy use for improvements to building envelope systems using building energy software or literature surveys.

[6] Climate zones are specific geographic areas of similar climatic characteristics, including temperature, weather, and other factors which affect building energy use. The California Energy Commission identified 16 Forecasting Climate Zones (FCZs) within California.

How to Use a Fact Sheet to Quantify a Project

This section provides step-by-step instructions and an example regarding how a fact sheet can be used. After choosing the appropriate fact sheet(s), follow these general steps. Steps may need to be adjusted for different types of fact sheets.

Step 1: Does this fact sheet apply?
Carefully read the measure's description and applicability to ensure that you are using the correct fact sheet.

Step 2: Is the measure "grouped"?
Check Tables 6-1 to 6-9 to see if the measure is "grouped" with other measures. If it is, then all measures in the group must be implemented together.

Step 3: Review defaults
Review the default assumptions in the fact sheet.

Step 4: Data inputs
Determine the type of data and data sources necessary. Refer to Appendix B and other suggested documents.

Step 5: Calculate baseline emissions
Calculate baseline emissions using formulas provided in the fact sheet.

Step 6: Percent reductions
If applicable, calculate the percent reduction for the specific action in the measure.

Step 7: Quantify reductions
Quantify emission reductions for a particular mitigation measure using the provided formula.

Step 8: Grouped measures
If you are using a mitigation measure that is grouped with another measure, refer to Tables 6-1 to 6-9 and complete the calculations for all measures that are grouped together for a particular mitigation strategy.

Step 9: Multiple measures
See Chapter 6 for how to combine reductions from multiple measures.

IMPORTANT: Clearly document information such as data sources, data used, and calculations.

Example:

The following is an example calculation for a building project that will use Fact Sheet 2.1.1 - *Exceed Title 24 Building Envelope Energy Efficiency Standards by X%*. In this example, a large office building is being built, and it will be designed to do 10% more than Title 24 standards for both electricity and natural gas.

- **Step 1 – Does this fact sheet apply?**
  The project and fact sheet have been reviewed, and YES, this fact sheet is appropriate to use to estimate reductions from the project.

- **Step 2 - Is the measure "grouped"?**
  NO, this is a measure that does not have to be done with other measures.

- **Step 3 – Review defaults**
  Default assumptions and emission factors have been reviewed and used, as appropriate.

- **Steps 4 – Data inputs**
  The table below shows the data needed for the example, the sample data input, and the source of the sample data. Make sure the data use the units specified in the equation. *

Data for Fact Sheet 2.1.1 Example

Data Needed	Input	Source of Data
Project type	Commercial land use = Large Office	User Input
Size	100,000 sq. ft	User Input
Climate Zone	1	From Figure BE 1.1
Electricity $Intensity_{baseline}$	8.32 kWh/SF/yr	From Fact Sheet 2.1.1
Utility Provider	PG&E	User Input
Emission $Factor_{Electricity}$	2.08E-4 MT CO_2e/kWh	Fact Sheet 2.1.1
Natural Gas $Intensity_{baseline}$	18.16 kBTU/SF/yr	From Fact Sheet 2.1.1
Emission $Factor_{NaturalGas}$	5.32E-5 MT CO_2e/therm	From Fact Sheet 2.1.1
% Reduction Commitment	10% over 2008 Title 24 Standards	User Input

- **Step 5 – Calculate baseline emissions**
  Once all necessary information has been obtained, use the equation provided to determine the baseline emissions. Round results to the nearest MT.

⇨ GHG Emissions $Baseline_{Electicity}$ = Electricity $Intensity_{Baseline}$ x Size x Emission $Factor_{Electricity}$

= 8.32 kWh/SF/yr x 100,000 SF x (2.08E-4 MT CO_2e/kWh)
= **173 MT CO_2e/yr [Baseline GHG Emissions for Electricity]**

⇨ GHG Emissions $Baseline_{Natural\ Gas}$ = Natural Gas $Intensity_{Baseline}$ x Size x Emission $Factor_{NaturalGas}$

= 18.16 kBTU/SF/yr x 100,000 SF x (5.32E-5 MT CO_2e/kBTU)
= **97 MT CO_2e/yr [Baseline GHG Emissions for Natural Gas]**

⇨ GHG $Emissions_{Baseline}$ = GHG Emissions $Baseline_{Electricity}$ + GHG Emissions $Baseline_{Natural\ Gas}$

= 173 MT CO_2e/yr + 97 MT CO_2e/yr
= 270 MT CO_2e/yr

- **Step 6 – Percent reductions**

Now calculate the percent GHG emission reduction based on the stated improvement goal. In this example the goal is a 10% reduction over Title 24 Energy Efficiency Standards. See Table BE-1.1 for data used for this step.

- $Reduction_{Electricity}$ from 1% over 2008 Title 24 Standards = 0.20%
  $Reduction_{NaturalGas}$ from 1% over 2008 Title 24 Standards = 1.00%
  From Table BE-1.1

- Multiply the Percent Factor from Table BE-1.1 by the Percent Reduction Commitment (10% for this example)

Reduction in GHG emissions from electricity generation:

= 0.20% x 10
= 2%

Reduction Percentage X 10% goal

Reduction in GHG emissions from natural gas combustion:

= 1% x 10
= 10%

Reduction Percentage X 10% goal

- **Step 7 – Quantify reductions**
  Using the percent reductions, the emission reductions can be calculated, as shown below.

- Total Building GHG emissions = GHG Emissions $Baseline_{Electricity}$ x ($Reduction_{Electricity}$) + GHG Emissions $Baseline_{NaturalGas}$ x ($Reduction_{NaturalGas}$)

= 173 MT CO_2e/yr x $\left(\frac{100\%-2\%}{100}\right)$ + 97 MT CO_2e/yr x $\left(\frac{100\%-10\%}{100}\right)$
= **257 MT CO_2e/yr**

Net reductions are the difference between the baseline emissions and the emissions calculated above for what will occur with this strategy implemented.

- Net reductions = Baseline – Total Building GHG Emissions

= 270 MT CO_2e/yr - 257 MT CO_2e/yr
= **13 MT CO_2e/yr**

This shows that a 10% improvement in energy consumption over 2008 Title 24 Standards from electricity and natural gas will result in a GHG reduction of 13 MT CO_2e/yr.

- **Step 8 – Grouped measures**
  In this example, the measure is not grouped. For grouped measures, refer to Tables 6-1 to 6-9 in Chapter 6 for how to combine reductions.

- **Step 9 – Multiple measures**
  See "Rules for Combining Strategies or Measures" section in Chapter 6 for how to add reductions from multiple measures

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1.0 Introduction

Chapter 7 is made up of a series of Fact Sheets. Each sheet summarizes the quantification methodology for a specific mitigation measure. As described in Chapter 6, the measures are grouped into Categories, and, in some cases, into subcategories. For information about the development of the Fact Sheets, please see Chapter 4. For a discussion of specific quantification issues in select measure categories or subcategories, please refer to Chapter 5. Chapter 6 provides a detailed explanation of the organization and layout of the Fact Sheets, including rules that govern the quantification of measures that have been, or will be, implemented in combination.

In order to facilitate navigation through, and the use of, the Fact Sheets, they have been color coded to reflect the Category the measure is in, and if applicable, the subcategory. The color scheme is shown in Charts 6-1 and 6-2, and also in Table 7-1 (below).

The colored bar at the top of each Fact Sheet corresponds to the Category color as shown in Charts 6-1 and 6-2, and in Table 7-1; the Category name is shown in the colored bar at the left hand margin. The second colored bar, immediately below the first one, shows the name of the subcategory, if any, and corresponds to subcategory color in those charts and tables. The subcategory name appears at the right hand margin.

At the left hand margin, below the Category name, is a cross-reference to the corresponding measure in the previous two CAPCOA reports (*CEQA and GHG*; and *Model Polices for GHG in General Plans*). The term "MP#" refers to a measure in the Model Policies document. The term CEQA# refers to a measure in the CEQA and GHG report.

At the bottom of the page is a colored bar that corresponds to the Category, and, where applicable, there is a colored box at the right hand margin, contiguous with the colored bar. This color of the box corresponds to the subcategory, where applicable. The box contains the measure number.

The layout of information in each Fact Sheet is covered in detail in Chapter 6.

Table 7-1, below, provides an index and cross-reference for the measure Fact Sheets. It is color-coded, as explained above, and may be used as a key to more quickly and easily navigate through the Fact Sheets

Table 7-1: Measure Index & Cross Reference

Section	Category	Page #	Measure #	BMP	MP #	CEQA #
2.0	**Energy**	**85**				
2.1	Building Energy Use	85				
2.1.1	Buildings Exceed Title 24 Building Envelope Energy Efficiency Standards By X%	85	BE-1		EE-2	MM-E6
2.1.2	Install Programmable Thermostat Timers	99	BE-2	x	EE-2	-
2.1.3	Obtain Third-party HVAC Commissioning and Verification of Energy Savings	101	BE-3	x	EE-2	-
2.1.4	Install Energy Efficient Appliances	103	BE-4		EE-2.1.6	MM E-19
2.1.5	Install Energy Efficient Boilers	111	BE-5		-	-
2.2	Lighting	115				
2.2.1	Install Higher Efficacy Public Street and Area Lighting	115	LE-1		EE-2.1.5	-
2.2.2	Limit Outdoor Lighting Requirements	119	LE-2	x	EE-2.3	
2.2.3	Replace Traffic Lights with LED Traffic Lights	122	LE-3		EE-2.1.5	-
2.3	Alternative Energy Generation	125				
2.3.1	Establish Onsite Renewable Energy Systems-Generic	125	AE-1		AE-2.1	MM E-5
2.3.2	Establish Onsite Renewable Energy Systems-Solar Power	128	AE-2		AE-2.1	MM E-5
2.3.3	Establish Onsite Renewable Energy Systems-Wind Power	132	AE-3		AE-2.1	MM E-5
2.3.4	Utilize a Combined Heat and Power System	135	AE-4		AE-2	-
2.3.5	Establish Methane Recovery in Landfills	143	AE-5		WRD-1	-
2.3.6	Establish Methane Recovery in Wastewater Treatment Plants	149	AE-6			
3.0	**Transportation**	**155**				
3.1	Land Use/Location	155				
3.1.1	Increase Density	155	LUT-1		LU-1.5 & LU-2.1.8	MM D-1 & D-4
3.1.2	Increase Location Efficiency	159	LUT-2		LU-3.3	-
3.1.3	Increase Diversity of Urban and Suburban Developments (Mixed Use)	162	LUT-3		LU-2	MM D-9 & D-4
3.1.4	Increase Destination Accessibility	167	LUT-4		LU-2.1.4	MM D-3
3.1.5	Increase Transit Accessibility	171	LUT-5		LU-1,LU-4	MM D-2
3.1.6	Integrate Affordable and Below Market Rate Housing	176	LUT-6		LU-2.1.8	MM D-7
3.1.7	Orient Project Toward Non-Auto Corridor	179	LUT-7		LU-4.2	LUT-3
3.1.8	Locate Project near Bike Path/Bike Lane	181	LUT-8		-	LUT-4
3.1.9	Improve Design of Development	182	LUT-9		-	-
3.2	Neighborhood/Site Enhancements	186				
3.2.1	Provide Pedestrian Network Improvements	186	SDT-1		LU-4	MM-T-6
3.2.2	Provide Traffic Calming Measures	190	SDT-2		LU-1.6	MM-T-8
3.2.3	Implement a Neighborhood Electric Vehicle (NEV) Network	194	SDT-3		TR-6	MM-D-6
3.2.4	Create Urban Non-Motorized Zones	198	SDT-4		LU-3.2.1 & 4.1.4	SDT-1
3.2.5	Incorporate Bike Lane Street Design (on-site)	200	SDT-5		TR-4.1	LUT-9
3.2.6	Provide Bike Parking in Non-Residential Projects	202	SDT-6		TR-4.1	MM T-1
3.2.7	Provide Bike Parking with Multi-Unit Residential Projects	204	SDT-7		TR-4.1.2	MM T-3
3.2.8	Provide Electric Vehicle Parking	205	SDT-8		TR-5.4	MM T-17 & E-11
3.2.9	Dedicate Land for Bike Trails	206	SDT-9		TR-4.1	LUT-9
3.3	Parking Policy/Pricing	207				
3.3.1	Limit Parking Supply	207	PDT-1		LU-1.7 & LU-2.1.1.4	-
3.3.2	Unbundle Parking Costs from Property Cost	210	PDT-2		LU-1.7	-
3.3.3	Implement Market Price Public Parking (On-Street)	213	PDT-3		-	-
3.3.4	Require Residential Area Parking Permits	217	PDT-4		-	PDT-1, PDT-2, PDT-3

2.0 Energy

2.1 Building Energy Use

To determine overall reductions, the ratio of building energy associated GHG emissions to the other project categories needs to be determined. This percent contribution to the total is multiplied by the percentage reduction.

2.1.1 Buildings Exceed Title 24 Building Envelope Energy Efficiency Standards By X%[1]

(X is equal to the percentage improvement selected by Applicant such as 5%, 10%, or 20%)

Range of Effectiveness:

For a 10% improvement beyond Title 24 the range of effectiveness is:

	Electricity	Natural Gas
Non-residential	0.2 – 5.5%	0.7 – 10%
Residential	0.3 – 2.6%	7.5 – 9.1%

This is dependent on building type and climate zones.

Measure Description:

Greenhouse gases (GHGs) are emitted as a result of activities in residential and commercial buildings when electricity and natural gas are used as energy sources. New California buildings must be designed to meet the building energy efficiency standards of Title 24, also known as the California Building Standards Code. Title 24 Part 6 regulates energy uses including space heating and cooling, hot water heating, and ventilation[2]. By committing to a percent improvement over Title 24, a development reduces its energy use and resulting GHG emissions.

[1] Compliance with Title 24 is determined from the total daily valuation (TDV) of energy use in the built-environment (on a per square foot per year basis). TDV energy use is a parameter that reflects the burden that a building imposes on an electricity supply system. In general, there is a larger electricity demand and, hence, stress on the supply system during the day (peak times) than at night (off peak). Since a TDV analysis requires significant knowledge about the actual building which is not typically available during the CEQA process, the estimate of the energy and GHG savings from an improvement over Title 24 energy use from a TDV basis is proportional to the actual energy use.

[2] Hardwired lighting is part of Title 24 part 6. However, it is not part of the building envelope energy use and therefore not considered as part of this mitigation measure.

The energy use of a building is dependent on the building type, size and climate zone it is located in.

The *California Commercial Energy Use Survey* (CEUS) and *Residential Appliance Saturation Survey* (RASS) datasets can be used for these calculations since the data is scalable size and available for several land use categories in different climate zones in California.

The Title 24 standards have been updated twice (in 2005 and 2008) since some of these data were compiled. The California Energy Commission (CEC) has published reports estimating the percentage deductions in energy use resulting from these new standards. Based on CEC's discussion on average savings for Title 24 improvements, these CEC savings percentages by end user can be used to account for reductions in electricity and natural gas use due to updates to Title 24. Since energy use for each different system type (i.e., heating, cooling, water heating, and ventilation) as well as appliances is defined, this method will also easily allow for application of mitigation measures aimed at reducing the energy use of these devices in a prescriptive manner.

Measure Applicability:

- Electricity and natural gas use in residential and commercial buildings subject to California's Title 24 building requirements.
- This measure is part of a grouped measure. To ensure the measure effectiveness, this measure also requires third-party HVAC commissioning and verification of energy savings such as including the results from an alternative compliance model indicating the energy savings.

Inputs:

The following information needs to be provided by the Project Applicant:

- Square footage of non-residential buildings
- Number of dwelling units
- Building/Housing Type
- Climate Zone[3]
- Total electricity demand (KWh) per dwelling unit or per square feet
- % reduction commitment (over 2008 Title 24 standards)

Baseline Method:

The baseline GHG emissions from electricity and natural gas usage (reflecting 2008 Title 24 standards with no energy-efficient appliances) are calculated as follows:

[3] See Figure BE-1.1.

$$\text{GHG Emissions Baseline}_{Electricity} = \text{Electricity Intensity}_{baseline} \times \text{Size} \times \text{Emission Factor}_{Electricity}$$

$$\text{GHG Emissions Baseline}_{NaturalGas} = \text{Natural Gas Intensity}_{baseline} \times \text{Size} \times \text{Emission Factor}_{NaturalGas}$$

Where:

Electricity $\text{Intensity}_{baseline}$ = Total electricity demand (kWh) per dwelling unit or per square foot; provided by applicant and adjusted for 2008 Title 24 standards (calculated based on CEUS and RASS)[4]

Natural Gas $\text{Intensity}_{baseline}$ = Total natural gas demand (kBTU or therms) per dwelling unit or per square foot; provided by applicant and adjusted for 2008 Title 24 standards (calculated based on CEUS and RASS)[5]

Emission $\text{Factor}_{Electricity}$ = Carbon intensity of local utility (CO_2e/kWh)[6]

Emission $\text{Factor}_{NaturalGas}$ = Carbon intensity of natural gas use (CO_2e/kBTU or CO_2e/therm)[7]

Size = Number of dwelling units or square footage of commercial land uses

Mitigation Method:

$$\text{GHG reduction \%}_{Mitigated\_Electricity} = \text{Reduction}_{Electricity} \times \text{Reduction Commitment}$$

$$\text{GHG reduction \%}_{Mitigated\_NaturalGas} = \text{Reduction}_{NaturalGas} \times \text{Reduction Commitment}$$

Where:

Reduction = Applicable reduction based on climate zone, building type, and energy type from Tables BE-1.1 and BE-1.2

Reduction Commitment = Project's reduction commitment beyond 2008 Title 24 standards (expressed as a whole number)

This should be done for each individual building type. If the project involves multiple building types or only a percentage of buildings will have reductions the total for all buildings needs to be determined. This percentage should be applied as follows and summed over all buildings types:

4 See Appendix B for baseline inventory calculation methodologies to assist in determining these values.
5 See Appendix B for baseline inventory calculation methodologies to assist in determining these values.
6 Ibid.
7 Ibid.

$$\sum_i (Reduction \times Commitment)\left(\frac{buildingGHG_i}{TotalGHG_i}\right)(\%BuildingType)$$

$buildingGHG_i$	=	GHG emissions for specific building type for either electricity or natural gas
$TotalGHG_i$	=	Total GHG emissions for all buildings for either electricity or natural gas
i	=	electricity or natural gas
$\%BuildingType$	=	portion of building(s) of this type

Tables BE-1.1 and BE-1.2 tabulate the percent reductions from building energy use for each land use type in the various climate zones in California. There is one table for residential land uses and another for non-residential land uses. There is a column for electricity reductions and another for natural gas reductions.

Assumptions:

See Figure BE-1.1 below for a map showing the 16 Climate Zones. Data for some Climate Zones is not presented in the CEUS and RASS studies. However, data from similar Climate Zones is representative and can be used as follows:

For non-residential building types:

Climate Zone 9 should be used for Climate Zone 11.
Climate Zone 9 should be used for Climate Zone 12.
Climate Zone 1 should be used for Climate Zone 14.
Climate Zone 10 should be used for Climate Zone 15.

For residential building types:

Climate Zone 2 should be used for Climate Zone 6.
Climate Zone 1 should be used for Climate Zone 14.
Climate Zone 10 should be used for Climate Zone 15.

Data based upon the following references:

- CEC. 2009. Residential Compliance Manual for California's 2008 Energy Efficiency Standards. Available online at: http://www.energy.ca.gov/title24/2008standards/residential_manual.html
- CEC. 2009. Nonresidential Compliance Manual for California's 2008 Energy Efficiency Standards. Available online at: http://www.energy.ca.gov/title24/2008standards/nonresidential_manual.html
- CEC. 2004. Residential Appliance Saturation Survey. Available online at: http://www.energy.ca.gov/appliances/rass/

- CEC. 2006. Commercial End-Use Survey. Available online at: http://www.energy.ca.gov/ceus/

Emission Reduction Ranges and Variables:

[Refer to Attached Tables BE-1.1 and BE-1.2 for climate zone and land use specific percentages]

This information uses 2008 Title 24 information. To adjust to 2005 Title 24, see Table BE-1.3.

Pollutant	Category Emissions Reductions
CO_2e	See Tables BE-1.1 and BE-1.2 for percentage reductions for every 1% improvement over 2008 Title 24.
PM	See Tables BE-1.1 and BE-1.2 for percentage reduction from natural gas. There is no reduction for electricity.
CO	See Tables BE-1.1 and BE-1.2 for percentage reduction from natural gas. There is no reduction for electricity.
SO_2	See Tables BE-1.1 and BE-1.2 for percentage reduction from natural gas. There is no reduction for electricity.
NOx	See Tables BE-1.1 and BE-1.2 for percentage reduction from natural gas. There is no reduction for electricity.

Discussion:

If the applicant selects to commit beyond requirements for 2008 Title 24 standards, the applicant would reduce the amount of GHG emissions associated with electricity generation and natural gas combustion.

Example:

Commercial land use = Large Office

Square footage = 100,000 sq. ft.

Climate Zone = 1

Utility Provider = PG&E

% Reduction Commitment = 10% over 2008 Title 24 Standards

Electricity $Intensity_{baseline}$ = 8.32 kWh/SF/yr (adjusted to reflect 2008 Title 24 standards)

Emission $Factor_{Electricity}$ = 2.08E-4 MT CO_2e/kWh

Electricity $Emissions_{baseline}$ = 8.32 kWh/SF/yr x 100,000 SF x (2.08E-4 MT CO_2e/kWh)
= 173 MT CO_2e/yr

Natural Gas $Intensity_{baseline}$ = 18.16 kBTU/SF/yr (adjusted to reflect 2008 Title 24 standards)

Emission $Factor_{NaturalGas}$ = 5.32E-5 MT CO_2e/therm

Natural Gas $Emissions_{baseline}$ = 18.16 kBTU/SF/yr x 100,000 SF x (5.32E-5 MT CO_2e/kBTU)
= 97 MT CO_2e/yr

GHG $emissions_{baseline}$ = 173 MT CO_2e/yr + 97 MT CO_2e/yr
= 270 MT CO_2e/yr

From Table BE-1.1:

$Reduction_{Electricity}$ from 1% over 2008 Title 24 Standards = 0.20%
$Reduction_{NaturalGas}$ from 1% over 2008 Title 24 Standards = 1.00%

Reduction in GHG emissions from electricity generation: 0.20% x 10 = 2%
Reduction in GHG emissions from natural gas combustion: 1% x 10 = 10%
Mitigated Building GHG emissions = 173 MT CO_2e/yr x (100% - 2%) + 97 MT CO_2e/yr x (100% - 10%) = 257 CO_2e/yr

Preferred Literature:

GHG reductions from a percent improvement over Title 24 can be quantified by calculating baseline energy usage using methodologies based on the California Energy Commission (CEC)'s Residential Appliance Saturation Survey (RASS) and Commercial End-Use Survey (CEUS), or an applicable Alternative Calculation Method (ACM). RASS and CEUS data are based on CEC Forecasting Climate Zones (FCZs); therefore, differences in project energy usage due to different climates are accounted for. The percent improvement is applied to Title 24 built environment energy uses, and overall GHG emissions are calculated using local utility emission factors. This methodology allows the Project Applicant flexibility in choosing which specific measures it will pursue to achieve the percent reductions (for example, installing higher quality building insulation, or installing a more efficient water heating system), while still making the mitigation commitment at the time of California Environmental Quality Act (CEQA) analysis.

Alternative Literature:

Alternatively, a Project Applicant could use the "prescriptive package" approach to demonstrate compliance with Title 24. Using this approach, the Project Applicant would commit to specific design elements above Title 24 prescriptive package requirements at the time of CEQA analysis, such as using solar water heating or improved insulation. Rather than calculating an overall percent reduction in GHG emissions based on an overall baseline value as presented above, the prescriptive approach requires the Project Applicant to break down building energy use by end-use. The Project Applicant would need to provide substantial evidence supporting the GHG reductions attributable to mitigation measures for each end-use. There are several references for quantifying GHG reductions from prescriptive measures. One example of a prescriptive measure is installing tankless or on-demand water heaters. These systems use a gas burner or electric element to heat water as needed and therefore do not use energy to store heated water. According to the U.S. Department of Energy (USDOE), typical tankless water heaters can be 24-34% more energy efficient than conventional storage tank water heaters [1]. Another example of a prescriptive measure is installing geothermal (ground-source or water-source) heat pumps. This measure takes advantage of the fact that the temperature beneath the ground surface is relatively constant. Fluid circulating through underground pipe loops is either heated or cooled and the heat is either upgraded or reduced in the heat pump depending on whether the building requires heating or cooling [2]. United States Environmental Protection Agency (USEPA) reports that ENERGY STAR - qualified geothermal heat pump systems are 30-45% more efficient than conventional heat pumps [3].

Alternative Literature References:

[1] USDOE. Energy Savers: Demand (Tankless or Instantaneous) Water Heaters. Accessed February 2010. Available online at: http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=12820

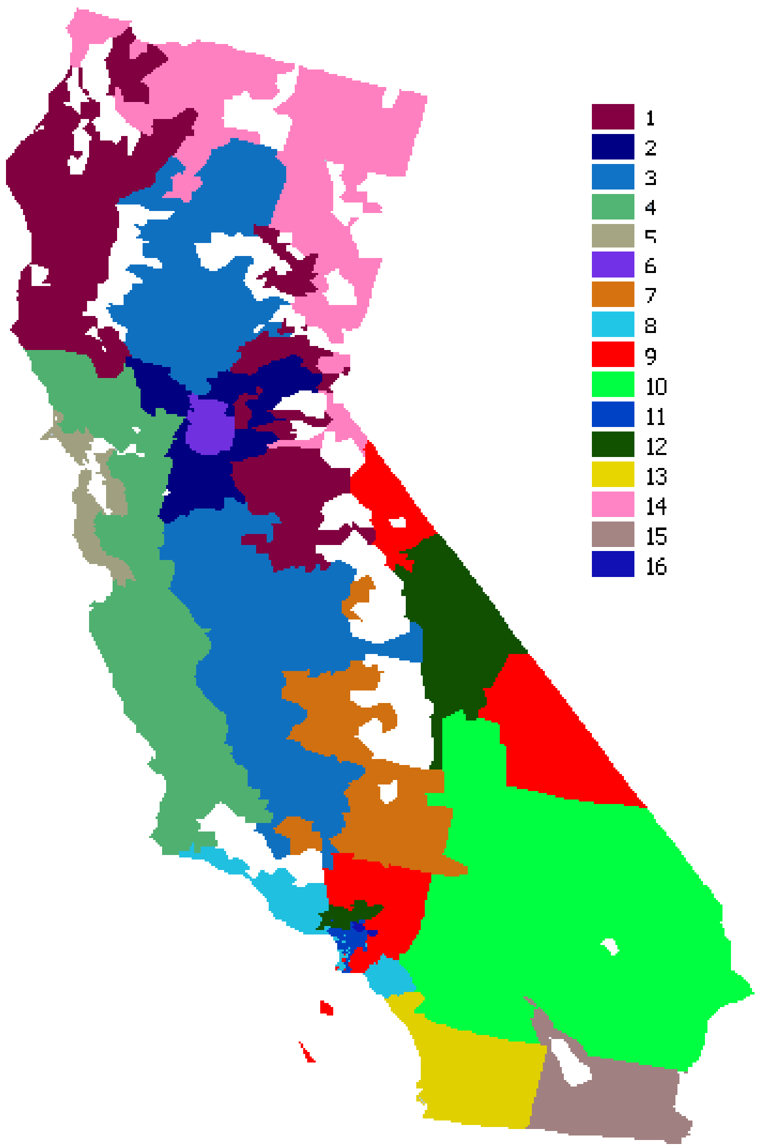
[2] CEC. Consumer Energy Center: Geothermal or Ground Source Heat Pumps. Accessed February 2010. Available online at: http://www.consumerenergycenter.org/home/heating_cooling/geothermal.html

[3] USEPA. ENERGY STAR: Heat Pumps, Geothermal. Accessed February 2010. Available online at: http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=HP

Other Literature Reviewed:

None

Figure BE-1.1
CEC Forecast Climate Zones[8,9]



[8] Adapted from Figure 2 of CEC. 2004. Residential Appliance Saturation Survey. Available online at: http://www.energy.ca.gov/appliances/rass/
[9] White spaces represent national parks and forests.

Table BE-1.1
Non-Residential
Reduction for 1% Improvement over 2008 Title 24

Climate Zone	Building Types	Reduction	
		Electricity	Natural Gas
1	All Commercial	0.22%	0.76%
	All Office	0.36%	1.00%
	All Warehouses	0.02%	0.00%
	College	0.28%	1.00%
	Grocery	0.08%	0.96%
	Health	0.33%	1.00%
	Large Office	0.20%	1.00%
	Lodging	0.30%	1.00%
	Miscellaneous	0.16%	0.91%
	Refrigerated Warehouse	0.02%	0.00%
	Restaurant	0.19%	0.25%
	Retail	0.40%	1.00%
	School	0.26%	0.94%
	Small Office	0.37%	1.00%
	Unrefrigerated Warehouse	0.00%	0.00%
2	All Commercial	0.24%	0.86%
	All Office	0.35%	0.97%
	All Warehouses	0.07%	1.00%
	College	0.45%	1.00%
	Grocery	0.17%	1.00%
	Health	0.35%	0.72%
	Large Office	0.31%	1.00%
	Lodging	0.30%	0.99%
	Miscellaneous	0.22%	1.00%
	Refrigerated Warehouse	0.02%	1.00%
	Restaurant	0.22%	0.38%
	Retail	0.36%	0.97%
	School	0.36%	0.96%
	Small Office	0.38%	0.96%
	Unrefrigerated Warehouse	0.12%	1.00%
3	All Commercial	0.26%	0.66%
	All Office	0.32%	0.98%
	All Warehouses	0.03%	0.95%
	College	0.28%	0.94%
	Grocery	0.14%	0.53%
	Health	0.43%	0.82%
	Large Office	0.34%	0.97%
	Lodging	0.55%	0.73%

Climate Zone	Building Types	Reduction	
		Electricity	Natural Gas
	Miscellaneous	0.25%	0.82%
	Refrigerated Warehouse	0.02%	1.00%
	Restaurant	0.26%	0.18%
	Retail	0.29%	0.81%
	School	0.33%	0.93%
	Small Office	0.30%	1.00%
	Unrefrigerated Warehouse	0.13%	0.94%
4	All Commercial	0.27%	0.71%
	All Office	0.38%	1.00%
	All Warehouses	0.06%	0.77%
	College	0.37%	0.87%
	Grocery	0.12%	0.75%
	Health	0.45%	0.85%
	Large Office	0.41%	1.00%
	Lodging	0.30%	0.90%
	Miscellaneous	0.20%	0.76%
	Refrigerated Warehouse	0.02%	0.20%
	Restaurant	0.18%	0.30%
	Retail	0.29%	1.00%
	School	0.32%	0.95%
	Small Office	0.30%	1.00%
	Unrefrigerated Warehouse	0.10%	0.98%
5	All Commercial	0.26%	0.72%
	All Office	0.36%	0.95%
	All Warehouses	0.06%	0.46%
	College	0.44%	0.98%
	Grocery	0.09%	0.67%
	Health	0.40%	0.84%
	Large Office	0.37%	0.94%
	Lodging	0.29%	0.81%
	Miscellaneous	0.18%	0.73%
	Refrigerated Warehouse	0.04%	0.29%
	Restaurant	0.11%	0.25%
	Retail	0.24%	0.85%
	School	0.16%	0.91%
	Small Office	0.29%	1.00%
	Unrefrigerated Warehouse	0.07%	0.85%
6	All Commercial	0.31%	0.73%
	All Office	0.38%	0.95%
	All Warehouses	0.07%	0.86%
	College	0.43%	0.99%

Climate Zone	Building Types	Reduction	
		Electricity	Natural Gas
	Grocery	0.16%	0.64%
	Health	0.46%	0.86%
	Large Office	0.39%	0.94%
	Lodging	0.40%	0.86%
	Miscellaneous	0.25%	0.66%
	Refrigerated Warehouse	0.03%	0.58%
	Restaurant	0.24%	0.35%
	Retail	0.31%	0.83%
	School	0.31%	0.96%
	Small Office	0.34%	1.00%
	Unrefrigerated Warehouse	0.09%	1.00%
7	All Commercial	0.25%	0.88%
	All Office	0.32%	0.94%
	All Warehouses	0.02%	0.64%
	College	0.25%	0.99%
	Grocery	0.12%	0.90%
	Health	0.32%	0.93%
	Large Office	0.34%	1.00%
	Lodging	0.41%	0.94%
	Miscellaneous	0.18%	0.99%
	Refrigerated Warehouse	0.02%	0.64%
	Restaurant	0.27%	0.19%
	Retail	0.34%	0.99%
	School	0.29%	0.96%
	Small Office	0.31%	0.91%
	Unrefrigerated Warehouse	0.00%	0.00%
8	All Commercial	0.30%	0.62%
	All Office	0.37%	0.94%
	All Warehouses	0.12%	0.99%
	College	0.43%	0.67%
	Grocery	0.14%	0.50%
	Health	0.45%	0.85%
	Large Office	0.38%	0.94%
	Lodging	0.34%	0.86%
	Miscellaneous	0.22%	0.68%
	Refrigerated Warehouse	0.02%	0.93%
	Restaurant	0.27%	0.31%
	Retail	0.28%	0.49%
	School	0.33%	0.92%
	Small Office	0.33%	0.96%
	Unrefrigerated Warehouse	0.16%	0.99%

Climate Zone	Building Types	Reduction	
		Electricity	Natural Gas
9	All Commercial	0.28%	0.60%
	All Office	0.39%	0.96%
	All Warehouses	0.13%	0.95%
	College	0.33%	0.98%
	Grocery	0.14%	0.46%
	Health	0.44%	0.85%
	Large Office	0.43%	0.98%
	Lodging	0.37%	0.84%
	Miscellaneous	0.23%	0.76%
	Refrigerated Warehouse	0.03%	0.91%
	Restaurant	0.21%	0.19%
	Retail	0.32%	0.71%
	School	0.32%	0.90%
	Small Office	0.31%	0.94%
	Unrefrigerated Warehouse	0.18%	0.96%
10	All Commercial	0.30%	0.61%
	All Office	0.35%	1.00%
	All Warehouses	0.11%	0.58%
	College	0.27%	1.00%
	Grocery	0.19%	0.67%
	Health	0.46%	0.92%
	Large Office	0.34%	1.00%
	Lodging	0.39%	0.92%
	Miscellaneous	0.24%	0.49%
	Refrigerated Warehouse	0.03%	0.07%
	Restaurant	0.29%	0.29%
	Retail	0.36%	0.87%
	School	0.37%	0.80%
	Small Office	0.36%	1.00%
	Unrefrigerated Warehouse	0.15%	0.98%
13	All Commercial	0.29%	0.66%
	All Office	0.38%	0.80%
	All Warehouses	0.19%	0.95%
	College	0.33%	0.86%
	Grocery	0.11%	0.40%
	Health	0.39%	0.88%
	Large Office	0.41%	0.80%
	Lodging	0.40%	0.82%
	Miscellaneous	0.17%	0.39%

Climate Zone	Building Types	Reduction	
		Electricity	Natural Gas
	Refrigerated Warehouse	0.07%	1.00%
	Restaurant	0.24%	0.21%
	Retail	0.28%	0.53%
	School	0.31%	0.92%
	Small Office	0.32%	0.76%
	Unrefrigerated Warehouse	0.26%	0.93%

Table BE-1.2
Residential
Reduction for 1% Improvement over 2008 Title 24

Climate Zone	Housing	Reduction	
		Electricity	Natural Gas
1	Multi	0.24%	0.86%
	Single	0.17%	0.87%
	Townhome	0.22%	0.87%
2	Multi	0.15%	0.89%
	Single	0.14%	0.91%
	Townhome	0.11%	0.89%
3	Multi	0.23%	0.90%
	Single	0.18%	0.91%
	Townhome	0.16%	0.90%
4	Multi	0.12%	0.88%
	Single	0.09%	0.91%
	Townhome	0.09%	0.90%
5	Multi	0.09%	0.88%
	Single	0.04%	0.91%
	Townhome	0.05%	0.90%
7	Multi	0.25%	0.87%
	Single	0.16%	0.88%
	Townhome	0.18%	0.85%
8	Multi	0.09%	0.77%
	Single	0.07%	0.82%
	Townhome	0.07%	0.80%
9	Multi	0.08%	0.77%
	Single	0.11%	0.82%
	Townhome	0.09%	0.80%
10	Multi	0.26%	0.80%
	Single	0.18%	0.83%
	Townhome	0.22%	0.81%

11	Multi	0.05%	0.77%
	Single	0.05%	0.83%
	Townhome	0.03%	0.81%
12	Multi	0.15%	0.75%
	Single	0.15%	0.83%
	Townhome	0.13%	0.80%
13	Multi	0.09%	0.79%
	Single	0.06%	0.83%
	Townhome	0.05%	0.81%

2.1.2 Install Programmable Thermostat Timers

Range of Effectiveness:

Best Management Practice influences building energy use for heating and cooling.

Measure Description:

Programmable thermostat timers allow users to easily control when the HVAC system will heat or cool a certain space, thereby saving energy. Because most commercial buildings already have timed HVAC systems, this mitigation measure focuses on residential programmable thermostats.

The DOE reports [1] that residents can save around 10% on heating and cooling bills per year by lowering the thermostat by 10-15 degrees for eight hours[10]. This can be accomplished using an automatic timer or programmable thermostat, such that the heat is reduced while the residents are at work or otherwise out of the house. The energy savings from a programmable thermostat, however, depend on the user. Some users preset the thermostat to heat the house before they come home, thereby increasing energy usage, while others use it to avoid heating the house when they are not home or asleep. Because of the large variability in individual occupant behavior and because it is unclear whether programmable thermostats systematically reduce energy use, this measure cannot be reasonably quantified. This mitigation measure should be incorporated as a Best Management Practice to allow for educated occupants to have the most efficient means at controlling their heating and cooling energy use. In order to take quantitative credit for this mitigation measure, the Project Applicant would need to provide detailed and substantial evidence supporting a reduction in energy use and associated GHG emissions.

Measure Applicability:

- Electricity use in residential dwellings.
- Best Management Practice only.

Assumptions:

Data based upon the following references:

[1] USDOE. Energy Savers: Thermostats and Control Systems. Available online at: http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12720

[10] Such a large drop in thermostat temperatures may not be applicable in parts of California; more applicable may be the raising of the thermostat for airconditioned spaces.

Emission Reduction Ranges and Variables:

This is a best management practice and therefore at this time there is no quantifiable reduction. Check with local agencies for guidance on any allowed reductions associated with implementation of best management practices.

If substantial evidence was provided, the GHG reductions would equal the percent savings in total electricity or natural gas. The total reduction would be:

GHG reduction = (% thermostat reduce heat/cool energy use) x
(% end use heat/cool of total energy use)

Preferred Literature:

The DOE reports [1] that residents can save approximately 10% on heating and cooling bills per year by lowering the thermostat by 10-15 degrees for eight hours. This can be accomplished using an automatic timer or programmable thermostat, such that the heat is reduced while the residents are at work or otherwise out of the house. The energy savings from a programmable thermostat, however, depend on the user. Some users preset the thermostat to heat the house before they come home, thereby increasing energy usage, while others use it to avoid heating the house when they are not home or asleep.

Alternative Literature:

None

Other Literature Reviewed:

Pacific Northwest National Laboratory. 2007. GridWise Demonstration Project Fast Facts. Available online at: http://gridwise.pnl.gov/docs/pnnl_gridwiseoverview.pdf.

2.1.3 Obtain Third-party HVAC Commissioning and Verification of Energy Savings

Range of Effectiveness:

Not applicable on its own. This measure enhances effectiveness of BE-1.

Measure Description:

Ensuring the proper installation and construction of energy reduction features is essential to achieving high thermal efficiency in a house. In practice, HVAC systems commonly do not operate at the designed efficiency due to errors in installation or adjustments. A Project Applicant can obtain HVAC commissioning and third-party verification of energy savings in thermal efficiency components including HVAC systems, insulation, windows, and water heating.

This measure is required to be grouped with measure “Exceed Title 24 Energy Efficiency Standards by X% (BE-1).

Measure Applicability:

- This measure is part of a grouped measure. This measure also requires third-party HVAC commissioning and verification of energy savings.
- Buildings subject to California’s Title 24 building requirements.

Preferred Literature:

While Title 24 requires that a home’s ducts be tested for leaks whenever the central air conditioner or furnace is installed or replaced, a third-party verifier such as the California Home Energy Efficiency Rating Service (CHEERS) and ENERGY STAR Home Energy Rating Service (HERS) can ensure that ducts were properly sealed [1-3]. These certified raters can also verify other energy efficiency measures, such as HVAC controls, insulation performance, and the air-tightness of the building envelope. Furthermore, these raters can analyze a home and make climate-specific recommendations for further improving the home’s energy efficiency. Since this mitigation measure ensures that the building envelope systems are properly installed and sealed, there is no quantifiable reduction for this measure. It is recommended as a Best Management Practice grouped with the Title 24 improvement mitigation measure.

Alternative Literature:

None

Literature References:

[1] California Home Energy Efficiency Rating Services. What is CHEERS? Available online at: http://www.cheers.org/Home/Overview/tabid/124/Default.aspx. Accessed March 2010.

[2] USEPA. ENERGY STAR: Features of ENERGY STAR Qualified New Homes. Available online at: http://www.energystar.gov/index.cfm?c=new_homes.nh_features. Accessed March 2010.

[3] USEPA. ENERGY STAR: Independent Inspection and Testing. Available online at: http://www.energystar.gov/ia/new_homes/features/HERSrater_062906.pdf. Accessed March 2010.

2.1.4 Install Energy Efficient Appliances

Range of Effectiveness:

Residential 2-4% GHG emissions from electricity use. Grocery Stores: 17-22% of GHG emissions from electricity use.

Measure Description:

Using energy-efficient appliances reduces a building's energy consumption as well as the associated GHG emissions from natural gas combustion and electricity production. To take credit for this mitigation measure, the Project Applicant (or contracted builder) would need to ensure that energy efficient appliances are installed. For residential dwellings, typical builder-supplied appliances include refrigerators and dishwashers. Clothes washers and ceiling fans would be applicable if the builder supplied them. For commercial land uses, energy-efficient refrigerators have been evaluated for grocery stores. See Mitigation Method section on how project applicant may quantify additional building types and appliances.

The energy use of a building is dependent on the building type, size and climate zone it is located in. The *California Commercial Energy Use Survey* (CEUS) and *Residential Appliance Saturation Survey* (RASS) datasets for this calculation since the data is scalable by size and available for several land use categories in different climate zones in California. Typical reductions for energy-efficient appliances can be found in the *Energy Star and Other Climate Protection Partnerships 2008 Annual Report* or subsequent Annual Reports. ENERGY STAR refrigerators, clothes washers, dishwashers, and ceiling fans use 15%, 25%, 40%, and 50% less electricity than standard appliances, respectively.

RASS does not specify a ceiling fan end-use; rather, electricity use from ceiling fans is accounted for in the Miscellaneous category which includes interior lighting, attic fans, and other miscellaneous plug-in loads. Since the electricity usage of ceiling fans alone is not specified, a value from the National Renewable Energy Laboratory (NREL) Building American Research Benchmark Definition (BARBD) is used. BARBD reports that the average energy use per ceiling fan is 84.1 kWh per year. In this mitigation measure, it is assumed that each multi-family, single-family, and townhome residence has one ceiling fan. The electricity savings shown here is based on installing an ENERGY STAR ceiling fan and does not account for an occupant's decreased use of cooling devices such as air conditioners. For ceiling fans, the 50% reduction was applied to 84.1 kWh of the electricity attributed to the Miscellaneous RASS category.

Measure Applicability:

- Electricity use in residential dwellings and commercial grocery stores.
- This mitigation measure applies only when appliance installation can be specified as part of the Project.

Inputs:

The following information needs to be provided by the Project Applicant:

- Number of dwelling units and/or size of grocery store
- Climate Zone
- Housing Type (if residential)
- Utility provider
- Total natural gas demand (kBTU or therms) per dwelling unit or per square foot
- Types of energy efficient appliances to be installed (refrigerator, dishwasher, or clothes washer for residential land uses and refrigerators for grocery stores)

Baseline Method:

$$\text{GHG emissions} = \text{Electricity Intensity}_{baseline} \times \text{Size} \times \text{Emission Factor}_{Electricity} + \text{Natural Gas Intensity}_{baseline} \times \text{Size} \times \text{Emission Factor}_{NaturalGas}$$

Where:

GHG emissions = MT CO_2e (reflecting 2008 Title 24 standards with no energy-efficient appliances)

Electricity $\text{Intensity}_{baseline}$ = Total electricity demand (kWh) per dwelling unit or per square foot; provided by applicant and adjusted for 2008 Title 24 standards[11]

Natural Gas $\text{Intensity}_{baseline}$ = Total natural gas demand (kBTU or therms) per dwelling unit or per square foot; provided by applicant and adjusted for 2008 Title 24 standards[12]

Emission $\text{Factor}_{Electricity}$ = Carbon intensity of local utility (CO2e/kWh)[13]

Emission $\text{Factor}_{NaturalGas}$ = Carbon intensity of natural gas use (CO_2e/kBTU or CO_2e/therm)[14]

Size = Number of dwelling units or square footage of commercial land uses

Mitigation Method:

$$\text{GHG emissions}_{mitigated} = \text{Electricity Emissions}_{baseline} \times (1-(\text{Sum of Reductions})) +$$

[11] See Appendix B for baseline inventory calculation methodologies to assist in determining these values.
[12] Ibid
[13] Ibid.
[14] Ibid.

Natural Gas $\text{Emissions}_{\text{baseline}}$

Where:

Electricity $\text{Emissions}_{\text{baseline}}$	=	Emissions due to electricity generation, adjusted for 2008 Title 24 Standards (calculated based on CEUS and RASS)
Sum of Reductions	=	Applicable reduction based on energy efficient appliances installed (expressed as a decimal)
Natural Gas $\text{Emissions}_{\text{baseline}}$	=	Emissions due to natural gas combustion, adjusted for 2008 Title 24 Standards (calculated based on CEUS and RASS)
Building GHG reduction Percentage	=	[GHG emissions mitigated/GHG emissions baseline]

Tables BE-4.1 and BE-4.2 tabulate the percent reductions from installing specific ENERGY STAR appliances for each land use type in the various climate zones in California. There is one table for residential land uses and another for non-residential land uses. This will only result in reductions associated with electricity use and does not apply to natural gas since there are no major Energy Star appliances that use natural gas. The energy efficient heating, cooling, and water heating systems that may use natural gas are included in improvements over Title 24 (see measure BE-1).

For other building types and energy efficient appliances, the reductions similar to those in the tables can be quantified as follows:

Reduction = (Appliance End Use %) x (1 – efficiency)

Where:

Appliance End Use %	=	portion of energy for this appliance compared to total electricity use
Efficiency	=	percent reduction in energy use for efficient appliance compared to standard.

Assumptions:

Data for some Climate Zones is not presented in the CEUS and RASS studies. However, data from similar Climate Zones is representative and can be used as follows:

For non-residential building types:
Climate Zone 9 should be used for Climate Zone 11.
Climate Zone 9 should be used for Climate Zone 12.

Climate Zone 1 should be used for Climate Zone 14.
Climate Zone 10 should be used for Climate Zone 15.
For residential building types:
Climate Zone 2 should be used for Climate Zone 6.
Climate Zone 1 should be used for Climate Zone 14.
Climate Zone 10 should be used for Climate Zone 15.

Data based upon the following references:

[1] USEPA. 2008. ENERGY STAR 2008 Annual Report. Available online at: http://www.epa.gov/cpd/annualreports/annualreports.htm

[2] CEC. 2004. Residential Appliance Saturation Survey. Available online at: http://www.energy.ca.gov/appliances/rass/

[3] CEC. 2006. Commercial End-Use Survey. Available online at: http://www.energy.ca.gov/ceus/

[4] NREL. 2010. Building America Research Benchmark Definition. Available online at: http://www.nrel.gov/docs/fy10osti/47246.pdf

Emission Reduction Ranges and Variables:

[Refer to Attached Tables BE-4.1 and BE-4.2 for climate zone and land use specific percentages]

If more than one type of appliance is considered the percentage for each appliance should be added together.

Pollutant	Category Emissions Reductions
CO_2e	See Tables BE-4.1 and BE-4.2 for percentage reductions.
PM	Not Quantified[15]
CO	Not Quantified
SO_2	Not Quantified
NOx	Not Quantified

Discussion:

If the applicant commits to installing energy efficient appliances, the applicant would reduce the amount of GHG emissions associated with electricity generation because

[15] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

more energy efficient appliances will require less electricity to run. This reduces GHG emissions from power plants.

Example:

Housing Type = Single Family Home

Number of Dwelling Units = 100

Climate Zone = 1

Utility Provider = PG&E

Energy efficient appliances to be installed = refrigerator and dishwasher

Electricity $Intensity_{baseline}$	=	7,196 kWh/DU/yr (adjusted to reflect 2008 Title 24 standards)
Emission $Factor_{Electricity}$	=	2.08E-4 MT /kWh
Electricity $Emissions_{baseline}$	=	7,196 kWh/DU/yr x 100 DU x (2.08E-4 MT CO_2e/kWh)
	=	150 MT CO_2e/yr
Natural Gas $Intensity_{baseline}$	=	365 therms/DU/yr (adjusted to reflect 2008 Title 24 standards)
Emission $Factor_{NaturalGas}$	=	5.32E-3 MT CO_2e/kBTU
Natural Gas $Emissions_{baseline}$	=	365 therm/DU/yr x 100 DU x (5.32E-3 MT CO_2e/therm)
	=	194 MT CO_2e/yr
GHG $emissions_{baseline}$	=	150 MT CO_2e/yr + 194 MT CO_2e/yr
	=	344 MT CO_2e/yr

Sum of Reductions associated with electricity generation from Table BE-4.2 = 2.05%
Reductions associated with natural gas combustion = 0%

GHG $emissions_{mitigated}$ = 150*(1-.0205) + 194

= 341

Building GHG reduction = 1 - 341 / 344 = 0.9%

Preferred Literature:

The USEPA ENERGY STAR Program has identified energy efficient residential and consumer appliances including air conditioners, refrigerators, freezers, clothes washers, dishwashers, fryers, steamers, and vending machines. The ENERGY STAR Annual Report presents the average percent energy savings from using an ENERGY STAR-qualified appliance instead of a standard appliance. GHG emissions reductions are calculated based on local utility emission factors and the baseline appliance energy use derived from the CEC RASS and CEUS methodologies. RASS and CEUS data are climate-specific; therefore, differences in project energy usage due to different climates are accounted for.

Alternative Literature:

None

Other Literature Reviewed:

None

Table BE-4.1
Non-Residential
Reduction for ENERGY STAR Refrigerators in Grocery Stores

Climate Zone	Electricity Reduction
1	20%
2	17%
3	18%
4	21%
5	22%
6	19%
7	18%
8	19%
9	20%
10	18%
13	21%

Table BE-4.2
Residential
Reduction for ENERGY STAR Appliances

Climate Zone	Housing	Refrigerator[1,3]	Clothes Washer[1,3]	Dishwasher[1,3]	Ceiling Fan[2,3]
		Total Electricity Reduction			
1	Multi	2.59%	0.03%	0.10%	1.01%
	Single	1.72%	0.50%	0.12%	0.58%
	Townhome	2.28%	0.28%	0.11%	0.83%
2	Multi	2.86%	0.03%	0.11%	1.12%
	Single	1.79%	0.53%	0.13%	0.61%
	Townhome	2.61%	0.32%	0.13%	0.96%
3	Multi	2.62%	0.03%	0.10%	1.02%
	Single	1.69%	0.50%	0.12%	0.58%
	Townhome	2.44%	0.30%	0.12%	0.89%
4	Multi	2.97%	0.03%	0.12%	1.16%
	Single	1.90%	0.56%	0.14%	0.65%
	Townhome	2.64%	0.33%	0.13%	0.97%
5	Multi	3.07%	0.03%	0.12%	1.20%
	Single	1.99%	0.58%	0.14%	0.68%
	Townhome	2.78%	0.35%	0.14%	1.02%
7	Multi	2.54%	0.03%	0.10%	0.99%
	Single	1.74%	0.51%	0.12%	0.59%
	Townhome	2.39%	0.30%	0.12%	0.88%
8	Multi	3.08%	0.03%	0.12%	1.20%
	Single	1.94%	0.57%	0.14%	0.66%
	Townhome	2.71%	0.34%	0.14%	0.99%
9	Multi	3.13%	0.03%	0.12%	1.22%
	Single	1.85%	0.54%	0.13%	0.63%
	Townhome	2.65%	0.33%	0.13%	0.97%
10	Multi	2.52%	0.03%	0.10%	0.98%
	Single	1.71%	0.50%	0.12%	0.58%
	Townhome	2.27%	0.28%	0.11%	0.83%
11	Multi	3.21%	0.03%	0.13%	1.25%
	Single	1.97%	0.58%	0.14%	0.67%
	Townhome	2.83%	0.35%	0.14%	1.04%
12	Multi	2.89%	0.03%	0.11%	1.13%
	Single	1.76%	0.51%	0.13%	0.60%
	Townhome	2.53%	0.32%	0.13%	0.93%
13	Multi	3.09%	0.03%	0.12%	1.21%
	Single	1.95%	0.57%	0.14%	0.66%
	Townhome	2.76%	0.34%	0.14%	1.01%

Notes:

1. Percent reductions are based on the saturation values presented in RASS. The Project Applicant may use project-specific saturation values (i.e. if 100% of homes have clothes washers, then saturation = 1).

Notes:

2. CEC's RASS does not specify a ceiling fan end-use; rather, electricity use from ceiling fans is accounted for in the Miscellaneous category, which includes interior lighting, attic fans, and other miscellaneous plug-in loads. Since the electricity usage of ceiling fans alone is not specified, a value from NREL's BARBD was used. BARBD reports that the average energy use per ceiling fan is 84.1 kWh per year. In this table, it is assumed that each multi-family, single-family, and townhome residence has one ceiling fan. The electricity savings shown here is based on installing an ENERGY STAR ceiling fan and does not account for an occupant's decreased use of cooling devices such as air conditioners.

3. Total electricity reduction is based on installing ENERGY STAR appliances instead of standard appliances. ENERGY STAR refrigerators, clothes washers, dishwashers, and ceiling fans use 15%, 25%, 40%, and 50% less electricity than standard appliances, respectively. For ceiling fans, the 50% reduction was applied to 84.1 kWh of the electricity attributed to the Miscellaneous RASS category.

Abbreviations:

BARBD - Building America Research Benchmark Definition
CEC - California Energy Commission
NREL - National Renewable Energy Laboratory
RASS - Residential Appliance Saturation Survey
USEPA - United States Environmental Protection Agency

Sources:

CEC. 2004. Residential Appliance Saturation Survey. Available online at: http://www.energy.ca.gov/appliances/rass/

NREL. 2010. Building America Research Benchmark Definition. Available online at: http://www.nrel.gov/docs/fy10osti/47246.pdf

USEPA. 2008. ENERGY STAR 2008 Annual Report. Available online at: http://www.epa.gov/cpd/annualreports/annualreports.htm

2.1.5 Install Energy Efficient Boilers

Range of Effectiveness: 1.2-18.4% of boiler GHG emissions

Measure Description:

Boilers are used in many non-residential and multi-family housing buildings to provide space heating or steam or facility operations. Boilers combust natural gas to produce steam which can be used directly or as a method to heat a building space. Boilers represent 12% of installed building heating equipment for commercial and other buildings. Boiler efficiencies are regulated and commonly presented as annualized fuel utilization efficiency (AFUE), a ratio of the total useful heat delivered to the heat value from the annual amount of fuel consumed. Improving boiler efficiency decreases natural gas consumption for the same amount of energy output, thus reducing GHG emissions.

Only natural gas boilers are considered under this mitigation measure. The Project Applicant would only need to provide the annual natural gas consumptions to calculate the baseline emissions using heat content and carbon intensity factors from CCAR [3]. To determine the emission reduction, boiler efficiency is also needed, and should be obtainable from manufacturer specifications. The Consortium for Energy Efficiency (CEE) reports that the rate of high efficiency boilers (≥ 85%) has gone from 5-15% of sales in 2002 to 50%-60% of sales in 2007 [2]. The CEE study also noted that technical improvements can be made to existing boiler types to improve efficiency to 88%. Efficiency can be further enhanced to up to 98% using the condensing boiler.

A range of efficiencies from the CEE study has been presented for reference, but to take credit for this mitigation measure, the Project Applicant would also need to provide evidence from manufacturers supporting the higher efficiency from a retrofit or new boiler.

Measure Applicability:

- Natural Gas Boilers

Inputs:

The following information needs to be provided by the Project Applicant:

- Natural gas consumption of boiler
- Original or baseline efficiency of boiler
- Improved efficiency of boiler

Baseline Method:

$$\text{Emission} = \text{Consumption} \times HC \times EF \times C$$

Where:

Emission = MT CO_2e
Consumption = Natural gas consumption (ft^3)
HC = Natural gas heat content = 1,029 BTU/ft^3 (CCAR 2009)
EF = Natural gas carbon intensity factor = 0.1173 lbs CO_2e/kBTU (CCAR 2009)
C = Unit conversion factor

In this case, C = $4.54x10^{-7}$ kBTU x MT/BTU/lbs

Mitigation Method:

The GHG emission from a boiler with improved efficiency is:

$$\text{Mitigated GHG Emission} = \text{Consumption} \times \frac{E_O}{E_I} \times HC \times EF \times C$$

Where:

Emission = MT CO_2e
Consumption = Natural gas consumption (ft^3)
E_O = Original efficiency of boiler
E_I = Improved efficiency of boiler
HC = Natural gas heat content = 1,029 BTU/ft^3 (CCAR 2009)
EF = Natural gas carbon intensity factor = 0.1173 lbs CO_2e/kBTU (CCAR 2009)
C = Unit conversion factor

Emission Reduction Ranges and Variables:

Percentage of emissions reduction using a boiler with improved efficiency for all pollutants are the same and is calculated as follows:

$$\text{Reduction} = 1 - \frac{E_O}{E_I}$$

Where:

E_O = Original efficiency of boiler
E_I = Improved efficiency of boiler

Technology	Range of Efficiencies	Range of Emission Reduction
Atmospheric	80 – 84%	-
Fan assisted, non-condensing	85 – 88%	1.2% – 9.1%
Fan assisted, condensing	88 – 98%	4.5% – 18.4%

Discussion:

Boiler efficiency is included in product specification from manufacturer. ENERGY STAR boilers require minimum efficiency of 85%. The Consortium for Energy Efficiency (CEE) reports natural efficiency breakpoints of 85-88% for fan assisted, non-condensing commercial boilers, and 88-98% for fan assisted, condensing boilers.

Assumptions:

Data based upon the following references:

- California Climate Action Registry 2009. General Reporting Protocol, Version 3.1. Available at: http://www.climateregistry.org/resources/docs/protocols/grp/GRP_3.1_January2009.pdf
- Energy Star. Boilers key Product Criteria. Available at: http://www.energystar.gov/index.cfm?c=boilers.pr_crit_boilers
- Science Applications International Corporation 2009. Prepared for California Climate Action Registry. Development of Issue Papers for GHG Reduction Project Types: Boiler Efficiency Projects. Available at: http://www.climateactionreserve.org/wp-content/uploads/2009/03/future-protocol-development_boiler-efficiency.pdf

Preferred Literature:

Boilers represent 12% of installed building heating equipment. Boiler efficiencies are regulated and commonly presented as annualized fuel utilization efficiency (AFUE), a ratio of the total useful heat delivered to the heat value from the annual amount of fuel consumed. The Climate Action Registry (CAR) Boiler Efficiency Projects estimated potential annual CO_2e emission reductions of 22,673,929 and 6,584,231 MT for commercial and residential boilers, respectively, from boiler efficiency improvement from 77% to 83% [1]. The Consortium for Energy Efficiency (CEE) reports that the rate of high efficiency boilers (≥ 85%) has gone from 5-15% of sales in 2002 to 50%-60% of sales in 2007 [2]. The CEE study also noted that technical improvements can be made to existing boiler types to improve efficiency to 88%. Efficiency can be further enhanced to up to 98% using the condensing boiler.

Only natural gas boilers are considered under this mitigation measure. The Project Applicant would only need to provide the annual natural gas consumptions to calculate the baseline emissions using heat content and carbon intensity factors from CCAR [3]. To determine the emission reduction, boiler efficiency is also needed, and should be obtainable from manufacturer specifications. A range of efficiencies from the CEE study has been presented for reference, but to take credit for this mitigation measure, the Project Applicant would also need to provide evidence from manufacturers supporting the higher efficiency from a retrofit or new boiler.

Alternative Literature:

None

Notes:

[1] Science Applications International Corporation 2009. Prepared for Climate Action Registry (CAR). Development of Issue Papers for GHG Reduction Project Types: Boiler Efficiency Projects. Available at: http://www.climateactionreserve.org/wp-content/uploads/2009/03/future-protocol-development_boiler-efficiency.pdf
[2] Consortium of Energy Efficiency (CEE) Winter Program Meeting 2008. Market Characterization of Commercial Gas Boilers.
[3] CCAR 2009. General Reporting Protocol, Version 3.1. Available at: http://www.climateregistry.org/resources/docs/protocols/grp/GRP_3.1_January2009.pdf

Other Literature Reviewed:

None

2.2 Lighting

2.2.1 Install Higher Efficacy Public Street and Area Lighting

Range of Effectiveness:

16-40% of outdoor lighting

Measure Description:

Lighting sources contribute to GHG emissions indirectly, via the production of the electricity that powers these lights. Public street and area lighting includes streetlights, pedestrian pathway lights, area lighting for parks and parking lots, and outdoor lighting around public buildings. Lighting design should consider the amount of light required for the area intended to be lit. Lumens are the measure of the amount of light perceived by the human eye. Different light fixtures have different efficacies or the amount of lumens produced per watt of power supplied. This is different than efficiency, and it is important that lighting improvements are based on maintaining the appropriate lumens per area when applying this measure. Installing more efficacious lamps will use less electricity while producing the same amount of light, and therefore reduces the associated indirect GHG emissions.

Measure Applicability:

- Public street and area lighting

Inputs:

The following information needs to be provided by the Project Applicant:

- Number of lighting heads (for baseline only)
- Power rating of public street and area lights
- Carbon intensity of local utility (for baseline only)

Baseline Method:

$$\text{GHG emissions} = \text{Heads} \times \text{Hours} \times \text{Days} \times \text{Power}_{baseline} \times \text{Utility}$$

Where:

GHG emissions	=	MT CO_2e/yr
Heads	=	Number of public street and area lighting heads. Provided by Applicant.
Hours	=	Hours of operation per day (12).
Days	=	Days of operation per year (365).
$\text{Power}_{baseline}$	=	Power rating of public street and area lights (kW).
Utility	=	Carbon intensity of Local Utility (CO_2e/kWh)

Mitigation Method:

The minimum reduction in annual energy cost associated with higher efficacy street lighting systems is 16%. Note that a 16% reduction in power rating and GHG emissions is the estimated minimum percent reduction associated with installing higher efficacy public street and area lighting. NYSERDA reports that a 16% reduction is expected for installing metal halide post top lights as opposed to typical mercury cobrahead lights. The percent reduction is expected to increase to 35% for installing metal halide cobrahead or metal halide cutoff lights, and 40% for installing high pressure sodium cutoff lights. For lights operating with a single local utility district, the 16% energy cost reduction is equivalent to a 16% reduction in power rating because the energy cost comparison assumes an equal number of lighting heads and equal operation times. As all other variables remain equal between the baseline and mitigated scenarios, the reduction in GHG emissions is in turn 16%. Therefore, the reduction in GHG emissions associated with installing higher efficacy public street and area lighting is:

$$\text{GHG emission reduction} = \frac{Power_{baseline} - Power_{mitigated}}{Power_{baseline}} = 16\%$$

Where:

GHG emission reduction	=	Percentage reduction in GHG emissions for public street and area lighting.
$Power_{baseline}$	=	Power rating of public street and area lights (kW).
$Power_{mitigated}$	=	Power rating of public street and area lights (kW).

If different types of lampheads result in less heads needing to be installed, the reduction will be as follows:

$$\frac{Head_{baseline} \times Power_{baseline} - Head_{mitigated} \times Power_{mitigated}}{Head_{baseline} \times Power_{baseline}}$$

Where:

$Head_{baseline}$	=	the number of heads in the baseline scenario
$Power_{baseline}$	=	the number of heads in the mitigated scenario

As it can be seen by this equation, the carbon intensity of the local utility does not play a role in determining the percentage reduction in GHG emissions.

Note that a 16% reduction in power rating and GHG emissions is the estimated minimum percent reduction associated with installing higher efficacy public street and area lighting. NYSERDA reports that a 16% reduction is expected for installing metal halide post top lights as opposed to typical mercury cobrahead lights. The percent reduction is expected to increase to 35% for installing metal halide cobrahead or metal halide cutoff lights, and 40% for installing high pressure sodium cutoff lights.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	16% for installing metal halide post top lights; 35% for installing metal halide cobrahead or cutoff lights; 40% for installing high pressure sodium cutoff lights
All other pollutants	Not Quantified[16]

Discussion:

If the applicant uses public street and area lighting, they would calculate baseline emissions as described in the baseline methodologies section. If the applicant then selects to mitigate public street and area lighting by committing to higher efficacy options, the applicant would reduce the amount of GHG emissions associated with public street and area lighting by 16%.

GHG Emissions Reduced = 16%

Assumptions:

Data based upon the following reference:

[1] New York State Energy Research and Development Authority (NYSERDA). 2002. NYSERDA How-to Guide to Effective Energy-Efficient Street Lighting for Municipal Elected/Appointed Officials.

Preferred Literature:

The New York State Energy Research and Development Authority (NYSERDA)'s 2002 How-to Guide to Effective Energy-Efficient Street Lighting reports a minimum reduction in electricity demand of 16% due to the installation of energy-efficient street lights such as metal halide and high-pressure sodium models (see page 4).

Alternative Literature:

None

Other Literature Reviewed:

[16] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

[2] The University of Rochester. Light-Emitting Diode (LED), Organic Light-Emitting Diode (OLED), and laser research for lighting applications. Homepage available online at: http://www.rochester.edu/research/sciences.html. Accessed February 2010.

[3] Chittenden County Regional Planning Commission. 1996. Outdoor Lighting Manual for Vermont Municipalities.

2.2.2 Limit Outdoor Lighting Requirements

Range of Effectiveness:

Best Management Practice, but may be quantified.

Measure Description:

Lighting sources contribute to GHG emissions indirectly, via the production of the electricity that powers these lights. When the operational hours of a light are reduced, GHG emissions are reduced. Strategies for reducing the operational hours of lights include programming lights in public facilities (parks, swimming pools, or recreational centers) to turn off after-hours, or installing motion sensors on pedestrian pathways. Since literature guidance for quantifying these reductions does not exist, this mitigation measure would be employed as a Best Management Practice. In order to take credit for this mitigation measure, the Project Applicant would need to provide detailed and substantial documentation of the reduction in operational hours of lights.

Measure Applicability:

- Outdoor lighting
- Best Management Practice unless Project Applicant supplies substantial evidence.

Inputs:

The following information needs to be provided by the Project Applicant:

- Number of outdoor lights
- Power rating of outdoor lights
- Carbon intensity of local utility (for baseline only)
- Limited hours of operation of outdoor lights

Baseline Method:

$$\text{GHG emissions} = \text{Heads} \times \text{Hours} \times \text{Power}_{baseline} \times \text{Utility}$$

Where:

GHG emissions = MT CO_2e/yr
Heads = Number of outdoor lighting heads. Provided by Applicant.
Hours = Annual hours of operation (4,280)[17].
$\text{Power}_{baseline}$ = Power rating of outdoor lights (kW).
Utility = Carbon intensity of Local Utility (CO_2e/kWh)

[17] Estimated based on the annual number of dark hours (hours between sunset and sunrise) for Los Angeles, California.

Mitigation Method:

Limiting the hours of operation of outdoor lights in turn limits the indirect GHG emissions associated with their electricity usage. Therefore, the reduction in GHG emissions associated with limiting outdoor lighting is:

$$\text{GHG emission reduction} = \frac{\text{Hours}_{\text{baseline}} - \text{Hours}_{\text{limited}}}{\text{Hours}_{\text{baseline}}}$$

Where:

GHG emission reduction	=	Percentage reduction in GHG emissions for outdoor lighting.
$\text{Hours}_{\text{baseline}}$	=	Annual hours of operation (4,280).
$\text{Hours}_{\text{limited}}$	=	Limited hours of operation per day. Provided by Applicant.

As it can be seen by this equation, the carbon intensity of the local utility does not play a role in determining the percentage reduction in GHG emissions.

Emission Reduction Ranges and Variables:

This is a best management practice measure unless the Project Applicant supplies substantial evidence justifying a reduction in hours of operation. Check with local agencies for guidance on any allowed reductions associated with implementation of best management practices.

Pollutant	Category Emissions Reductions
CO_2e	0 to 100%
All other pollutants	Not Quantified[18]

Discussion:

If the applicant uses outdoor lighting, they would calculate baseline emissions as described in the baseline methodologies document. If the applicant then selects to mitigate outdoor lighting by limiting operation to 10 hours per day, the applicant would reduce the amount of GHG emissions associated with outdoor lighting by 20%.

$$\text{GHG Emissions Reduced} = \frac{12 - 10}{10} = 0.20 \text{ or } 20\%$$

Assumptions:

[18] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

None

Preferred Literature:

None

Other Literature Reviewed:

None

2.2.3 Replace Traffic Lights with LED Traffic Lights

Range of Effectiveness:

90% of emissions associated with existing traffic lights.

Measure Description:

Lighting sources contribute to GHG emissions indirectly, via the production of the electricity that powers these lights. Installing higher efficiency traffic lights reduces energy demand and associated GHG emissions. As high efficiency light-emitting diodes (LEDs), which consume about 90% less energy than traditional incandescent traffic lights while still providing adequate light or lumens when viewed, are currently required to meet minimum federal efficiency standards for new traffic lights. Project Applicants may take credit only if they are retrofitting existing incandescent traffic lights.

Measure Applicability:

- Traffic lighting – retrofitting incandescent traffic lights

Inputs:

The following information needs to be provided by the Project Applicant:

- Number of incandescent traffic lights being retrofitted
- Power rating of incandescent traffic lights being retrofitted
- Carbon intensity of local utility (for baseline only)

Baseline Method:

$$\text{GHG emissions} = \text{Lights} \times \text{Hours} \times \text{Days} \times \text{Power}_{baseline} \times \text{Utility}$$

Where:

GHG emissions = MT CO_2e/yr

Lights = Number of incandescent traffic lights being retrofitted. Provided by Applicant.

Hours = Hours of operation per day (24).

Days = Days of operation per year (365).

$\text{Power}_{baseline}$ = Power rating of incandescent traffic lights being retrofitted (kW).

Utility = Carbon intensity of Local Utility (CO_2e/kWh)

Mitigation Method:

Traffic lights using LEDs consume about 90% less power than traditional incandescent traffic lights. Therefore, the reduction in GHG emissions associated with replacing incandescent traffic lights with LED-based traffic lights is:

$$\text{GHG emission reduction} = \frac{Power_{baseline} - Power_{mitigated}}{Power_{baseline}} = 90\%$$

Where:

GHG emission reduction = Percentage reduction in GHG emissions for traffic lighting.

$Power_{baseline}$ = Power rating of incandescent traffic lights (kW).

$Power_{mitigated}$ = Power rating of LED traffic lights (kW).

As it can be seen by this equation, the carbon intensity of the local utility does not play a role in determining the percentage reduction in GHG emissions.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	90%
All other pollutants	Not Quantified[19]

Discussion:

If the applicant uses traffic lights, they would calculate baseline emissions as described in the baseline methodologies document. If the applicant then selects to mitigate traffic lights by committing to replacing all existing incandescent traffic lights with LED traffic lights, the applicant would reduce the amount of GHG emissions associated with traffic lights in an existing area by 90%.

GHG Emissions Reduced = 90%

Assumptions:

Data based upon the following references:

[1] USDOE. 2004. NREL. State Energy Program Case Studies: California Says “Go” to Energy-Saving Traffic Lights. Available online at: http://www.nrel.gov/docs/fy04osti/35551.pdf

[2] USEPA. ENERGY STAR: Traffic Signals. Available online at: http://www.energystar.gov/index.cfm?c=traffic.pr_traffic_signals. Accessed February 2010.

[19] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

Preferred Literature:

NREL reports that traffic lights based on light-emitting diodes (LEDs) consume about 90% less power than traditional incandescent traffic lights. All traffic lights manufactured on or after January 1, 2006 must meet minimum federal efficiency standards, which are consistent with ENERGY STAR specifications for LED traffic lights.

Alternative Literature:

None

Other Literature Reviewed:

[3] The University of Rochester. LED, OLED, and laser research for lighting applications. Homepage available online at: http://www.rochester.edu/research/sciences.html. Accessed February 2010.

2.3 Alternative Energy Generation

2.3.1 Establish Onsite Renewable or Carbon-Neutral Energy Systems-Generic

Range of Effectiveness:

0-100% of emissions associated with electricity use. Note some systems could increase energy use.

Measure Description:

Using electricity generated from renewable or carbon-neutral power systems displaces electricity demand which would ordinarily be supplied by the local utility. Different sources of electricity generation that local utilities use have varying carbon intensities. Renewable energy systems such as fuel cells may have GHG emissions associated with them. Carbon-neutral power systems, such as photovoltaic panels, do not emit GHGs and will be less carbon intense than the local utility. This mitigation measure describes a method to calculate GHG emission reductions from displacing utility electricity with electricity generated from an on-site power system, which may incorporate technology which has not yet been established at the time this document was written.

Measure Applicability:

- Electricity use

Inputs:

The following information needs to be provided by the Project Applicant:

- Total annual electricity demand (kWh)
- Annual amount of electricity to be provided by the on-site power system (kWh) or percent of total electricity demand to be provided by the on-site power system (%)
- Carbon intensity of local utility and on-site power system if not carbon neutral

Baseline Method:

$$\text{GHG emissions} = \text{Electricity}_{\text{baseline}} \times \text{Utility}$$

Where:

GHG emissions = MT CO_2e

$\text{Electricity}_{\text{baseline}}$ = Total electricity demand (kWh) Provided by Applicant

Utility = Carbon intensity of Local Utility (CO_2e/kWh)

Mitigation Method:

If the total amount of electricity to be provided by the carbon-neutral power system is known, then the GHG emission reduction is equivalent to the ratio of electricity from the carbon-neutral power system to the total electricity demand:

$$\text{GHG emission reduction} = \frac{Electricity_{carbon\text{-}neutral}}{Electricity_{baseline}}$$

Where:

GHG emission reduction = Percentage reduction in GHG emissions for electricity use

$Electricity_{carbon\text{-}neutral}$ = Electricity to be provided by the carbon-neutral power system (kWh)

$Electricity_{baseline}$ = Total electricity demand (kWh)

If the percent of total electricity demand to be provided by the carbon-neutral power system is known, then the GHG emission reduction is equivalent to that percentage.

As shown in these equations, the carbon intensity of the local utility does not play a role in determining the percentage reduction in GHG emissions for carbon neutral systems.

If the total amount of electricity to be provided by a renewable energy system that is not carbon neutral, then the GHG emission reduction is equivalent to the following equation:

$$\text{GHG emission reduction} = \frac{Electricity_{renewable}}{Electricity_{baseline}} \times \frac{(Utility - Renewable)}{Utility}$$

Where

$Electricity_{renewable}$ = Electricity provided by renewable power system (kWh)

Renewable = Carbon intensity of renewable system (CO_2e/kWh)

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	Up to 100%, assuming all electricity demand is provided by a carbon-neutral power system
All other pollutants	Not Quantified[20],[21]

Discussion:

[20] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

[21] Assumes that the onsite carbon-neutral system displaces electricity use only.

If a project's total electricity demand is 10,000 kWh, and 1,000 kWh of that is provided by the carbon-neutral system, then the GHG emission reduction is 10%

$$\text{GHG Emission Reduced} = \frac{1,000}{10,000} = 0.10 \text{ or } 10\%$$

If a project instead uses a renewable system with carbon intensity of 500 CO_2e/kWh and the local utility is 100 CO_2e/kWh, then the GHG emission reduction is 5%.

$$\text{GHG Emission Reduced} = \frac{1,000}{10,000} \times \frac{(1,000 - 500)}{1,000} = 0.05 \text{ or } 5\%$$

2.3.2 Establish Onsite Renewable Energy Systems-Solar Power

Range of Effectiveness: 0-100% of GHG emissions associated with electricity use.

Measure Description:

Using electricity generated from photovoltaic (PV) systems displaces electricity demand which would ordinarily be supplied by the local utility. Since zero GHG emissions are associated with electricity generation from PV systems[22], the GHG emissions reductions from this mitigation measure are equivalent to the emissions that would have been produced had electricity been supplied by the local utility.

Measure Applicability:

- Electricity use

Inputs:

The following information needs to be provided by the Project Applicant:

- Total electricity demand (kWh)
- Amount of electricity to be provided by the PV system (kWh) or percent of total electricity demand to be provided by the PV system (%)

Baseline Method:

$$\text{GHG emissions} = \text{Electricity}_{baseline} \times \text{Utility}$$

Where:

GHG emissions = MT CO_2e

$\text{Electricity}_{baseline}$ = Total electricity demand (kWh) Provided by Applicant

Utility = Carbon intensity of Local Utility (CO_2e/kWh)

Mitigation Method:

If the total amount of electricity to be provided by the PV system is known, then the GHG emission reduction is equivalent to the ratio of electricity from the PV system to the total electricity demand:

$$\text{GHG emission reduction} = \frac{\text{Electricity}_{PV}}{\text{Electricity}_{baseline}}$$

[22] This mitigation measure does not account for GHG emissions associated with the embodied energy of PV systems.

Where:

GHG emission reduction	=	Percentage reduction in GHG emissions for electricity use
$Electricity_{PV}$	=	Electricity to be provided by PV system (kWh)
$Electricity_{baseline}$	=	Total electricity demand (kWh)

If the percent of total electricity demand to be provided by the PV system is known, then the GHG emission reduction is equivalent to that percentage.

As shown in these equations, the carbon intensity of the local utility does not play a role in determining the percentage reduction in GHG emissions.

The amount of electricity generated by a PV system depends on the size and type of the PV system and the location of the project. The Project Applicant can use a publically-available solar calculator, such as California's Public Utilities and Energy Commissions Go Solar Clean Power Estimator[23], to estimate the size of the PV system needed to generate the desired amount of electricity. The only input required for this calculator is the location (zip code). Estimates of the amount of electricity that can be generated from 1.5, 3, 5, and 10 kW PV systems in cities around California are shown in Table AE-2.1 below.

Since there is a range of PV system efficiencies, the local agency may consider checking the type of PV efficiency assumed to ensure the system that is installed meets this capacity.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	Up to 100%, assuming all electricity demand is provided by a PV system. Percent reduction would scale down linearly as the percent of electricity provided by a PV system decreases.
All other pollutants	Not Quantified[24]

Discussion:

If a project's total electricity demand is 10,000 kWh, and 1,000 kWh of that is provided by a PV system, then the GHG emission reduction is 10%

[23] Available online at http://gosolarcalifornia.cleanpowerestimator.com/gosolarcalifornia.htm.
[24] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

$$\text{GHG Emission Reduced} = \frac{1{,}000}{10{,}000} = 0.10 \text{ or } 10\%$$

Assumptions:

The data in Table AE-2.1 was generated from California's Public Utilities and Energy Commissions Go Solar Clean Power Estimator, a publically-available solar calculator which the Project Applicant can use to estimate the PV system size needed to generate the desired amount of electricity. It is available online at: http://gosolarcalifornia.cleanpowerestimator.com/gosolarcalifornia.htm.

Other publically-available solar calculators include:

- USDOE. NREL: PVWatts Calculator. Available online at: http://www.nrel.gov/rredc/pvwatts/.
- SolarEstimate.Org. Solar & Wind Estimator. Available online at: http://www.solar-estimate.org/index.php?page=solar-calculator.
- SharpUSA. Solar Calculator. Available online at: http://sharpusa.cleanpowerestimator.com/sharpusa.htm.

Preferred Literature:

None

Other Literature Reviewed:

None

Table AE-2.1
Estimated Electricity Generation from Typical PV Systems

Location			Annual kWh Generated		
Air District	**Major City**	**Zip Code**	**3 kW PV System**	**5 kW PV System**	**10 kW PV System**
Amador County	Ione	95640	4,857	8,094	16,189
Antelope Valley	Lancaster	93534	5,034	8,390	16,781
Bay Area	San Francisco	94101	4,926	8,218	16,436
Butte County	Chico	95926	4,857	8,094	16,189
Calaveras County	Rancho Calaveras	95252	4,857	8,094	16,189
Colusa County	Colusa	95932	4,857	8,094	16,189
El Dorado County	South Lake Tahoe	96150	5,275	8,792	17,584
Feather River	Yuba City	95991	4,857	8,094	16,189
Glenn County	Orland	95963	4,857	8,094	16,189
Great Basin Unified	Bishop	93514	5,507	9,179	18,358
Imperial County	El Centro	92243	5,117	8,528	17,056
Kern County	Bakersfield	93301	5,082	8,470	16,939
Lake County	Lakeport	95453	4,857	8,094	16,189
Lassen County	Susanville	96130	5,275	8,792	17,584
Mariposa County	Mariposa	95338	5,065	8,441	16,882
Mendocino County	Ukiah	95482	4,926	8,218	16,436
Modoc County	Alturas	96101	5,275	8,792	17,584
Mojave Desert	Victorville	92392	5,885	9,808	19,617
Monterey Bay Unified	Monterey	93940	4,926	8,218	16,436
North Coast Unified	Eureka	95501	4,081	6,801	13,602
Northern Sierra	Grass Valley	95949	4,857	8,094	16,189
Northern Sonoma County	Healdsburg	95448	4,931	8,218	16,436
Placer County	Roseville	95678	4,857	8,094	16,189
Sacramento Metro	Sacramento	95864	4,857	8,094	16,189
San Diego County	San Diego	92182	5,102	8,528	17,056
San Joaquin Valley Unified	Fresno	93650	5,065	8,441	16,882
San Luis Obispo County	San Luis Obispo	93405	5,320	8,932	17,865
Santa Barbara County	Santa Barbara	93101	5,320	8,932	17,865
Shasta County	Redding	96001	4,081	6,801	13,602
Siskiyou County	Yreka	96097	4,363	7,271	14,543
South Coast	Los Angeles	90071	5,034	8,390	16,781
Tehama County	Red Bluff	96080	4,857	8,094	16,189
Tuolumne County	Sonora	95370	4,857	8,094	16,189
Ventura County	Oxnard	93030	5,034	8,390	16,781
Yolo-Solano	Davis	95616	4,857	8,094	16,189

2.3.3 Establish Onsite Renewable Energy Systems-Wind Power

Range of Effectiveness: 0-100% of GHG emissions associated with electricity use.

Measure Description:

Using electricity generated from wind power systems displaces electricity demand which would ordinarily be supplied by the local utility. Since zero GHG emissions are associated with electricity generation from wind turbines[25], the GHG emissions reductions from this mitigation measure are equivalent to the emissions that would have been produced had electricity been supplied by the local utility.

Measure Applicability:

- Electricity use

Inputs:

The following information needs to be provided by the Project Applicant:

- Total electricity demand (kWh)
- Amount of electricity to be provided by the wind power system (kWh) or percent of total electricity demand to be provided by the wind power system (%)

Baseline Method:

$$\text{GHG emissions} = \text{Electricity}_{\text{baseline}} \times \text{Utility}$$

Where:

GHG emissions = MT CO_2e

$\text{Electricity}_{\text{baseline}}$ = Total electricity demand (kWh) Provided by Applicant

Utility = Carbon intensity of Local Utility (CO_2e/kWh)

Mitigation Method:

The GHG emission reduction is equivalent to the ratio of electricity from the wind power system to the total electricity demand:

$$\text{GHG emission reduction} = \frac{\text{Electricity}_{\text{wind}}}{\text{Electricity}_{\text{baseline}}}$$

[25] This mitigation measure does not account for GHG emissions associated with the embodied energy of wind turbines.

Where:

GHG emission reduction = Percentage reduction in GHG emissions for electricity use

$Electricity_{wind}$ = Electricity to be provided by wind power system (kWh)

$Electricity_{baseline}$ = Total electricity demand (kWh)

If the percent of total electricity demand to be provided by the wind power system is known, then the GHG emission reduction is equivalent to that percentage.

As shown in these equations, the carbon intensity of the local utility does not play a role in determining the percentage reduction in GHG emissions.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	Up to 100%, assuming all electricity demand is provided by a wind power system. Percent reduction would scale down linearly as the percent of electricity provided by a wind power system decreases.
All other pollutants	None[26]

Discussion:

If a project's total electricity demand is 10,000 kWh, and 1,000 kWh of that is provided by a wind system, then the GHG emission reduction is 10%

$$\text{GHG Emission Reduced} = \frac{1,000}{10,000} = 0.10 \text{ or } 10\%$$

Assumptions:

None

Preferred Literature:

None

[26] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

Other Literature Reviewed:

None

2.3.4 Utilize a Combined Heat and Power System

Range of Effectiveness: 0-46% of GHG emissions associated with electricity use.

Measure Description:

For the same level of power output, combined heat and power (CHP) systems utilize less input energy than traditional separate heat and power (SHP) generation, resulting in fewer CO_2 emissions. In traditional SHP systems, heat created as a by-product is wasted by being released into the environment. In contrast, CHP systems harvest the thermal energy and use it to heat onsite or nearby processes, thus reducing the amount of natural gas or other fuel that would otherwise need to be combusted to heat those processes. In addition CHP systems lower the demand for grid electricity, thereby displacing the CO_2 emissions associated with the production of grid electricity.

This mitigation measure describes how to estimate CO_2 emissions savings (in MT per year) from utilizing a CHP system to supply energy demands which would otherwise be provided by separate heat and power systems (e.g. grid electricity for electricity demand and boilers for thermal demand). CO_2 emissions savings are quantified using the USEPA CHP Emission Calculator which allows users to estimate the CO_2 emissions savings associated with displaced electricity and thermal production from five CHP technologies: microturbine, fuel cell, reciprocating engine, combustion turbine, and backpressure steam turbine. The first three technologies have electricity generation capacities on a scale appropriate for residential neighborhoods, planned communities, and mixed-use and commercial developments. Combustion turbines and backpressure steam turbines are more appropriate for industrial processes or very large commercial developments. The user has the option to input project-specific data such as specific fuels, duct burner operation, cooling demand, and boiler efficiencies.

Table AE-4.1 provides examples of expected CO_2 savings for microturbines, fuel cells, and reciprocating engines of a range of electricity generating capacities for the five major California utilities (Southern California Edison (SCE), Los Angeles Department of Water and Power (LADWP), San Diego Gas and Electric (SDGE), Pacific Gas and Electric (PGE), and the Sacramento Municipal Utility District (SMUD). Default values provided by the USEPA CHP Calculator were used wherever possible (see the Assumptions section below). The magnitude of CO_2 reductions depends on the baseline power sources. For thermal demand, the baseline is assumed to be a new boiler with 80% efficiency. For electricity demand, the baseline is the carbon intensity of the local utility, which varies by utility. For reference, Table AE-4.2 provides the 2006 carbon intensity of delivered electricity for the five utilities. As shown in Table AE-4.1, certain CHP systems may not be appropriate for certain locations, especially in Northern California where PGE and SMUD have relatively low carbon intensities.

Measure Applicability:

- Grid electricity use
- Natural gas combustion

Inputs:

The following information needs to be provided by the Project Applicant:

- Expected CHP technology (microturbine, fuel cell, or reciprocating engine)
- Expected electricity demand

Baseline Method:

GHG emissions = CO_2 emissions displaced

Where:

GHG emissions	=	MT CO_2e
CO_2 emissions displaced	=	MT CO_2 from separate heat and power system Provided in Table AE-4.1 or calculated using USEPA CHP Calculator

Here it is assumed that all GHG emissions produced from fuel combustion and electricity generation are CO_2 emissions.

Mitigation Method:

GHG emission reduction = Percent Reduction in CO_2 emissions

Provided in Table A E-4.1 or calculated using USEPA CHP Calculator

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	Up to 100%, assuming all electricity demand is provided by a CHP system. Percent reduction would scale down linearly as the percent of electricity provided by a CHP system decreases.
All other pollutants	0-70%[27] Depends on CHP technology, electricity generating capacity, sulfur content of fuel, and displaced thermal generation technology. Reductions in CO_2 may produce increases in SO_2 and/or NOx, or vice versa.

[27] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

Discussion:

Assume a project is located in SCE's service area and has an expected electricity demand of 100 kW. Using Table AE-4:

- A 100 kW microturbine will generate more CO_2 emissions than a separate heat and power system of equivalent power capacity.
- A 100 kW fuel cell will generate about the same CO_2 emissions than a separate heat and power system of equivalent power capacity.
- A 100 kW reciprocating engine will generate 14% less CO_2 emissions as a separate heat and power system of equivalent power capacity.

Therefore, the Project Applicant should choose the reciprocating engine. This system would generate 568 MT CO_2 compared to 657 MT CO_2 from the separate heat and power system.

Assumptions:

Table AE-4.1 was prepared using the 2009 USEPA CHP Calculator, a publically-available tool found online at: http://www.epa.gov/chp/basic/calculator.html. The following defaults and assumptions were made to generate the data in Table AE-4.1:

- The range of electricity generating capacity shown in Table AE-4.1 is based on the normal range for the technology (as per Calculator default)
- Operates 8,760 hours per year
- Provides heat only (no cooling)
- Combusts natural gas fuel (116.7 CO_2/MMBtu emission rate and 1,020 Btu/scf HHV as per Calculator defaults)
- No supplementary duct burner
- Assumes 8% transmission loss for displaced electricity

Table AE-4.2 was prepared using data from the California Climate Action Registry (CCAR) Power/Utility Protocol (PUP) public reports for reporting year 2006. These PUP reports are available online at: https://www.climateregistry.org/CARROT/public/reports.aspx.

Preferred Literature:

The USEPA CHP Emissions Calculator compares the anticipated emissions from a CHP system to the emissions from SHP systems. The Calculator was developed by the U.S. Department of Energy's Distributed Energy Program, Oak Ridge National Laboratory, and the U.S. Environmental Protection Agency's CHP Partnership. Users can choose from five different CHP technologies (microturbine, fuel cell, reciprocating engine, combustion turbine, and backpressure steam turbine) and compare their performance to a number of different SHP systems (e.g. local electricity utility and existing or new gas boiler, fuel oil boiler, or heat bump). Additionally, users have the option to refine the analysis with project-specific inputs such as the cooling demand and additional duct burning. Details such as the cooling efficiency of the displaced cooling system must be known to perform more detailed analysis. The calculator can be used to estimate expected reductions in CO_2, SO_2, and NOx emissions as well as fuel usage.

Alternative Literature:

The USEPA Combined Heat and Power Partnership Catalog of CHP Technologies presents performance details of six CHP technologies: gas turbine, microturbine, spark and compression ignition reciprocating engines, steam turbine, and fuel cell. Table I of the Introduction presents the equations necessary to calculate the percent fuel savings from using a CHP system instead of traditional separate heat and power generation. Subsequent chapters describe performance details of each of the CHP technologies, including estimated CO_2 emissions. The GHG emissions reductions associated with this mitigation measure are the change in emissions from using a CHP system rather than a SHP system in a building. The USEPA CHP Calculator methodologies are based in part on this Catalog of CHP Technologies document.

Other Literature Reviewed:

None

Table AE-4.1
Estimated CO_2 Emissions Savings from CHP Systems in California[1,2]

Utility	CHP Technology	Electricity Generating Capacity	Electric Efficiency	Power to Heat Ratio	CO_2 Emissions from CHP	CO_2 Emissions Displaced	Percent Reduction in CO_2 Emissions[3]
		(kW)	(% HHV)	--	(MT/year)	(MT/year)	(%)
SCE	Microturbine	30	24%	0.51	200	200	0%
		50	24%	0.51	334	333	0%
		100	26%	0.7	607	559	-9%
		250	26%	0.92	1517	1229	-23%
	Fuel Cell	5	30%	0.79	26	26	0%
		100	30%	0.79	527	527	0%
		1000	43%	1.95	3679	3783	3%
		2000	46%	1.92	6884	7597	9%
	Reciprocating Engine (Rich Burn)	55	30%	0.63	290	325	11%
		100	28%	0.52	568	657	14%
		1000	29%	0.64	5514	5859	6%
		1200	28%	0.63	6759	7052	4%
LADWP	Microturbine	30	24%	0.51	200	277	28%
		50	24%	0.51	334	462	28%
		100	26%	0.7	607	817	26%
		250	26%	0.92	1517	1875	19%
	Fuel Cell	5	30%	0.79	26	39	33%
		100	30%	0.79	527	786	33%
		1000	43%	1.95	3679	6366	42%
		2000	46%	1.92	6884	12762	46%
	Reciprocating Engine (Rich Burn)	55	30%	0.63	290	466	38%
		100	28%	0.52	568	915	38%
		1000	29%	0.64	5514	8441	35%
		1200	28%	0.63	6759	10188	34%
SDGE	Microturbine	30	24%	0.51	200	218	8%
		50	24%	0.51	334	363	8%
		100	26%	0.7	607	620	2%
		250	26%	0.92	1517	1381	-10%
	Fuel Cell	5	30%	0.79	26	30	12%
		100	30%	0.79	527	588	10%
		1000	43%	1.95	3679	4387	16%
		2000	46%	1.92	6884	8806	22%

Utility	CHP Technology	Electricity Generating Capacity (kW)	Electric Efficiency (% HHV)	Power to Heat Ratio (--)	CO_2 Emissions from CHP (MT/year)	CO_2 Emissions Displaced (MT/year)	Percent Reduction in CO_2 Emissions[3] (%)
	Reciprocating Engine (Rich Burn)	55	30%	0.63	290	358	19%
		100	28%	0.52	568	717	21%
		1000	29%	0.64	5514	6463	15%
		1200	28%	0.63	6759	7814	14%
PGE	Microturbine	30	24%	0.51	200	175	-15%
		50	24%	0.51	334	293	-14%
		100	26%	0.7	607	479	-27%
		250	26%	0.92	1517	1030	-47%
	Fuel Cell	5	30%	0.79	26	23	-16%
		100	30%	0.79	527	447	-18%
		1000	43%	1.95	3679	2984	-23%
		2000	46%	1.92	6884	5999	-15%
	Reciprocating Engine (Rich Burn)	55	30%	0.63	290	280	-4%
		100	28%	0.52	568	577	2%
		1000	29%	0.64	5514	5059	-9%
		1200	28%	0.63	6759	6130	-10%
SMUD	Microturbine	30	24%	0.51	200	188	-7%
		50	24%	0.51	334	314	-6%
		100	26%	0.7	607	522	-16%
		250	26%	0.92	1517	1137	-33%
	Fuel Cell	5	30%	0.79	26	24	-7%
		100	30%	0.79	527	490	-8%
		1000	43%	1.95	3679	3411	-8%
		2000	46%	1.92	6884	6855	0%
	Reciprocating Engine (Rich Burn)	55	30%	0.63	290	304	4%
		100	28%	0.52	568	620	8%
		1000	29%	0.64	5514	5487	0%
		1200	28%	0.63	6759	6643	-2%

Abbreviations:
CHP - combined heat and power
CO_2 - carbon dioxide
HHV - higher heating value
kW - kilowatt
LADWP - Los Angeles Department of Water and Power

PGE - Pacific Gas and Electric
SCE - Southern California Edison
SDGE - San Diego Gas and Electric
SMUD - Sacramento Municipal Utility District
USEPA - United State Environmental Protection Agency

Notes:
1. All data in this table generated using the USEPA CHP Calculator using utility-specific CO_2 intensity factors (see Table B). The following defaults and assumptions for the CHP system were used:
   - electricity generating capacity based on normal range for the technology (as per Calculator default)
   - operate 8,760 hours per year
   - heating only (no cooling)
   - natural gas fuel (116.7 CO_2/MMBtu emission rate and 1,020 Btu/scf HHV as per Calculator defaults)
   - no duct burner
   - assumed 8% transmission loss for displaced electricity
2. All CHP systems were compared to a baseline separate heat and power system consisting of a "new gas boiler" (assumed 80% efficiency as per Calculator default) and the local utility CO_2 intensity factor as provided in Table B.
3. A negative value indicates that the proposed CHP system is expected to generate more CO_2 emissions than the baseline separate heat and power system.

Source:
USEPA. 2009. CHP Emissions Calculator. Available online at: http://www.epa.gov/chp/basic/calculator.html. Accessed April 2010.

Table AE-4.2
Carbon Intensity of California Utilities

Utility	Total From All Generation Sources[1]		
	Electricity	CO_2 Emissions	CO_2 intensity factor
	(MWh)	(MT)	(lb/MWh)
SCE	82,776,309	24,077,133	641
LADWP	29,029,883	16,308,526	1,239
SDGE	19,108,166	6,767,326	781
PGE	79,211,982	16,377,172	456
SMUD	15,133,569	3,811,571	555
eGRID National Average (default in USEPA CHP Calculator)[2,3]			540
eGRID National Fossil Fuel Average (default in USEPA CHP Calculator)[2,4]			1,076

Abbreviations:
CHP - combined heat and power
CO_2 - carbon dioxide
eGRID - Emissions and Generation Resource Integrated Database
LADWP - Los Angeles Department of Water and Power
lb - pound
MWh - megawatt-hour
PGE - Pacific Gas and Electric
SCE - Southern California Edison
SDGE - San Diego Gas and Electric
SMUD - Sacramento Municipal Utility District
USEPA - United State Environmental Protection Agency

Notes:
1. Total electricity and CO_2 emissions reported by the utility in the California Climate Action Registry Power/Utility Protocol (PUP) Reports for reporting year 2006. PUP Reports available online at: https://www.climateregistry.org/CARROT/public/reports.aspx.
2. eGRID is a comprehensive inventory of environmental attributes of electricity generation (such as the carbon intensity of power generation), compiled from data from three federal agencies: EPA, the Energy Information Administration (EIA), and the Federal Energy Regulatory Commission (FERC). The USEPA CHP Calculator provides default 2005 eGRID carbon intensities for the U.S. and California. For more information, see: http://www.epa.gov/rdee/energy-resources/egrid/index.html.
3. eGRID National Average represents the national average carbon intensity for electricity generation from all power sources (hydropower, nuclear, renewables, and fossil fuels including oil, natural gas, and coal).
4. eGRID National Fossil Fuel Average represents the national average carbon intensity for electricity generation from fossil fuel sources only (oil, natural gas, and coal).

2.3.5 Establish Methane Recovery in Landfills

Range of Effectiveness: 73-77% reduction in GHG emissions from landfills without methane recovery

Measure Description:

One of the U.S.'s largest sources of methane emissions is from the decomposition of waste in landfills. Methane (CH_4) is a potent GHG and has a global warming potential (GWP) over 20 times that of CO_2. Capturing methane in landfills and combusting it to generate electricity for on-site energy needs reduces GHG emissions in two ways: it reduces direct methane emissions, and it displaces electricity demand and the associated indirect GHG emissions from electricity production.

Measure Applicability:

- Electricity from utility
- Note: this mitigation measure does not include energy generation from burning municipal solid waste.

Inputs:

The following information needs to be provided by the Project Applicant:

- Amount of mixed solid waste (short tons)

Baseline Method:

In landfills without landfill gas recovery systems, greenhouse gases are emitted directly to the atmosphere.

$$CO_2e_{baseline} = MSW \times LFM \times (44/12)$$

Where

$CO_2e_{baseline}$	=	Amount of CO_2e generated from landfilling mixed solid waste (MT)
MSW	=	Amount of mixed solid waste (short tons) Provided by Applicant
LFM	=	Landfill methane generated from mixed solid waste 0.580 MTCE / short ton MSW
(44/12)	=	Conversion from MTCE to MT CO_2e

Mitigation Method:

Mitigation Option 1 – Methane is captured and flared

USEPA assumes that 10% of the landfill CH4 generated is either converted by bacteria or chemically oxidized to CO_2. The remaining 90% remains as CH4 and is either captured and flared[28] or released directly to the atmosphere as fugitive CH_4 emissions. Assume a 99% combustion conversion efficiency.

$$CO_2e_{Mit1} = MSW \times LFM \times 1/(12/44 \times 21) \times [(CO_{2oxidation} + CO_{2flare}) \times 1 + (CH_{4fugitive} + CH_{4unflare}) \times 21]$$

Where

CO_2e_{Mit1}	=	Amount of CO_2e from flaring landfill methane (MT)
MSW	=	Amount of mixed solid waste (short tons) Provided by Applicant
LFM	=	MTCE[29] methane generated per short ton MSW 0.580 MTCE / short ton MSW
1/(12/44 x 21)	=	Conversion from MTCE to MT CH_4
$CO_{2oxidation}$	=	Contribution from CO_2 generated from chemical or biological oxidation. 0.10
CO_{2flare}	=	Contribution from CO_2 generated from the flaring of methane. (1-0.10) x 0.75 x 0.99 = 0.66825
1	=	Global warming potential of CO_2, used to convert from CO_2 to CO_2e
$CH_{4fugitive}$	=	Contribution from CH_4 which remains unoxidized to CO_2 and is not captured for flaring, and therefore is released directly to the atmosphere. (1-0.10) x (1-0.75) = 0.225

[28] Seek local agency guidance on whether to include CO_{2flare} emissions. USEPA and IPCC consider these emissions to be biogenic; therefore, the emissions are not included in USEPA and IPCC greenhouse gas emissions inventories.

[29] MTCE = metric MTMTMTMT carbon equivalent. The MTCE equivalent of 1 MT of a greenhouse gas is (12/44) multiplied by the greenhouse gas global warming potential.

$CH_{4unflare}$	=	Contribution from CH_4 which remains unoxidized and is captured for flaring, but remains unconverted due to incomplete combustion. (1-0.10) x 0.75 x (1-0.99) = 0.00675
21	=	Global warming potential of CH_4, used to convert from CH_4 to CO_2e

Therefore:

CO_2e_{Mit1} = MSW x 0.580 x 1/(12/44 x 21) x [(0.76825 x 1) + (0.23175 x 21)]

CO_2eMit1 = MSW x 0.571

And then the percent reduction in GHG emissions from Mitigation Option 1 is:

$$\text{GHG reduction}_{Mit1} = \frac{CO_2e_{baseline} - CO_2e_{Mit1}}{CO_2e_{baseline}}$$

$\text{GHG reduction}_{Mit1}$ = 73%

As shown from this equation, the percent reduction in greenhouse gas emissions does not depend on the amount of mixed solid waste in the landfill.

Mitigation Option 2 – Methane is captured and combusted for cogeneration

If a cogeneration system is used to generate electricity from the combusted methane, the following equation is used to calculate the amount of electricity generated:

Electricity = MSW x LFM x 1/(12/44 x 21) x Combust x Density x 10^6 x HHV x ECF x EFF x

Where

Electricity	=	Amount of electricity generated from combustion of methane (kWh)
LFM	=	MTCE methane generated per short ton MSW 0.580 MTCE / short ton MSW
1/(12/44 x 21)	=	Conversion from MTCE to MT CH_4
Combust	=	Fraction of CH_4 captured and combusted for cogeneration

(1-0.10) x 0.75 = 0.675; assumes 10% of methane is oxidized prior to capture and 75% capture efficiency

Density = Density of CH_4
0.05 ft^3 CH_4 / gram CH_4

10^6 = Conversion from grams to MT

HHV = Heating value of CH4
1,012 BTU / ft^3 CH_4

ECF = Energy conversion factor
0.00009 kWh/BTU

EFF = Efficiency Factor
0.85; USEPA assumes a 15% system efficiency loss to account for system down-time

Therefore:

Electricity = MSW x 265

Since this amount of electricity is generated on-site and no longer needs to be supplied by the local electricity utility, the indirect CO_2e emissions associated with that utility electricity generation are also avoided:

$$CO_2e_{displaced} = \text{Electricity} \times \text{Utility}$$

Where

Utility = Carbon intensity of Local Utility (MT CO_2e/kWh) from table below

Power Utility	Carbon-Intensity (lbs CO_2e/MWh)
LADW&P	1,238
PG&E	456
SCE	641
SDGE	781
SMUD	555

Therefore:

$$\mathbf{CO_2e_{Mit2} = CO_2e_{Mit1} - CO_2e_{displaced}}$$

And then the percent reduction in GHG emissions from Mitigation 2 is:

$$\text{GHG reduction}_{Mit2} = \frac{CO_2e_{baseline} - (CO_2e_{Mit1} - CO_2e_{displaced})}{CO_2e_{baseline}}$$

$$\textbf{GHG reductionMit2} = \frac{1.556 + (265 \times \text{Utility})}{2.127}$$

As shown from these equations, the percent reduction in GHG emissions does not depend on the amount of mixed solid waste in the landfill.

Note that further reductions could be achieved if the heat generated from combustion and cogeneration were recovered and used to displace thermal energy that otherwise would have been generated from a separate heat system, such as a boiler. The magnitude of reductions depends on the system being displaced, including the boiler efficiency and the heating value of the fuel as compared to the heating value of methane. To take credit for this additional reduction, the Project Applicant would need to quantify displaced GHG emissions using the baseline document and the Mitigation Measure BE-5, Install Energy Efficient Boilers.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	73-77%
All other pollutants	Not Quantified[30]

Discussion:

In Southern California Edison's service area, a landfill which captures and flares methane achieves a 73% reduction in GHG emissions compared to a landfill without a methane recovery system. A landfill which captures and combusts methane for cogeneration achieves a 77% reduction in GHG emissions compared to a landfill without a methane recovery system:

$$\text{GHG reduction Mit2} = \frac{1.556 + (265 \times 2.909 \times 10^{-4})}{2.127} = 77\%$$

Assumptions:

[30] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

Data based upon the following reference:

- USEPA. 2006. Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks, 3rd Ed. Available online at: http://www.epa.gov/climatechange/wycd/waste/downloads/fullreport.pdf

Preferred Literature:

Section 6 of USEPA's Solid Waste Management and Greenhouse Gases report presents methodology for calculating greenhouse gas emissions associated with three different landfill management systems: landfills which do not capture landfill gas, landfills which recover methane and flare it, and landfills which recover methane and combust it for cogeneration. Column (b) of Exhibit 6-6 shows methane generation factors for various types of landfill waste in MTCE per short ton of waste. For this analysis, the value for mixed solid waste is used. Section 6.2 provides USEPA defaults for percent of methane chemically or biologically oxidized to CO_2 (10%) and the efficiency of methane capture systems (75%). Exhibit 6-7 provides USEPA defaults used for calculating the amount of electricity generated from methane combustion and cogeneration.

Alternative Literature:

None

Other Literature Reviewed:

- CAR. 2009. Landfill Project Protocol: Collecting and Destroying Methane from Landfills. Version 3.0. Available online at: http://www.climateactionreserve.org/how/protocols/adopted/landfill/current-landfill-project-protocol/
- CalRecycle (CIWMB). Climate Change and Solid Waste Management: Draft Final Report and Draft GHG Calculator Tool. Available online at: http://www.calrecycle.ca.gov/Climate/Organics/LifeCycle/default.htm. Accessed February 2010.
- CARB. 2008. Local Government Operations Protocol. Version 1.0. Available online at: http://www.arb.ca.gov/cc/protocols/localgov/pubs/final_lgo_protocol_2008-09-25.pdf
- American Carbon Registry. Standards. Available online at: http://www.americancarbonregistry.org/carbon-accounting/standards/?searchterm=landfill. Accessed February 2010.

2.3.6 Establish Methane Recovery in Wastewater Treatment Plants

Range of Effectiveness: 95-97% reduction in GHG emissions from wastewater treatment plants without recovery.

Measure Description:

Methane (CH_4) is a potent GHG and has a global warming potential (GWP) over 20 times that of CO_2. Capturing methane from wastewater treatment (WWT) plants and combusting it to generate electricity for on-site energy needs reduces GHG emissions in two ways: it reduces direct methane emissions, and it displaces electricity demand and the associated indirect GHG emissions from electricity production.

Measure Applicability:

- Electricity from utility

Inputs:

The following information needs to be provided by the Project Applicant:

- Liters of wastewater

Baseline Method:

Centralized wastewater treatment facilities may use anaerobic or facultative lagoons or anaerobic digesters to treat wastewater. The methane emissions expected from anaerobic or facultative lagoons is calculated using the following equation from the California Air Resources Board (CARB)'s Local Government Reporting Protocol:

$$CO_2e_{baseline} = \text{Wastewater} \times BOD_5 \text{ load} \times 10^{-6} \times Bo \times MCF_{anaerobic} \times 10^{-3} \times 21$$

Where

$CO_2e_{baseline}$	=	Amount of CO_2e generated from wastewater treatment (MT)
Wastewater	=	Volume of wastewater (liters) Provided by Applicant
BOD_5 load	=	Concentration of BOD_5 in wastewater 200 mg / liter wastewater
10^{-6}	=	Conversion from mg to kg
Bo	=	Maximum CH_4-producing capacity for domestic wastewater 0.6 kg CH_4 / kg BOD_5 removed
$MCF_{anaerobic}$	=	CH_4 correction factor for anaerobic systems 0.8
10^{-3}	=	Conversion from kg to MT

21 = Global warming potential of CH_4, used to convert from CH_4 to CO_2e

Therefore:

$$CO_2e_{baseline} = Wastewater \times 2.02 \times 10^{-6}$$

Mitigation Method:

Mitigation Option 1 – Methane is captured and flared

Anaerobic digesters produce methane-rich biogas which can be combusted and converted to CO_2.[31] Inherent inefficiencies in the system results in incomplete combustion of the biogas, which results in remaining methane emissions:

$$CO_2e_{Mit1} = Wastewater \times 0.2642 \times Digester\ Gas \times FCH_4 \times (CH_4unflare + CO_2flare)$$

Where

CO_2e_{Mit1}	=	Amount of CO_2e generated from flaring methane from wastewater treatment plant (MT)
Wastewater	=	Volume of wastewater (liters) Provided by Applicant
0.2642	=	Conversion from liters to gallons
Digester Gas	=	Volume of biogas generated per volume of wastewater treated ft^3 biogas / gallon wastewater 0.01
F_{CH4}	=	Fraction of CH_4 in biogas 0.65
$CH_{4unflare}$	=	Contribution from CH_4 which is captured for flaring, but remains unconverted due to incomplete combustion $CH_{4unflare} = \rho_{CH4} \times (1\text{-}DE) \times 0.0283 \times 10^{-6} \times 21 = 3.93 \times 10^{-6}$
ρ_{CH4}	=	Density of CH4 at standard conditions 662 g/m^3
DE	=	CH_4 destruction efficiency 0.99
0.0283	=	Conversion factor from ft^3 to m^3
10^{-6}	=	Conversion factor from g to MT
21	=	Global warming potential of CH_4, used to convert from CH_4 to CO_2e
CO_2flare	=	Contribution from CO_2 generated from the flaring of methane
CO_2flare	=	$EF / 2204.623 \times 1 = 5.44 \times 10^{-5}$
EF	=	Emission factor for methane combustion

[31] Seek local agency guidance on whether to include CO_2 combustion emissions. USEPA and IPCC consider these emissions to be biogenic; therefore, the emissions are not included in USEPA and IPCC greenhouse gas emissions inventories.

		0.120 lb CO_2/ft^3 CH_4
2204.623	=	Conversion factor from lb to MT
1	=	Global warming potential of CO_2, used to convert from CO_2 to CO_2e

Therefore:

$$\mathbf{CO_2e_{Mit1} = Wastewater \times 1.00 \times 10^{-7}}$$

And then the percent reduction in GHG emissions from Mitigation Option 1 is:

$$\text{GHG reduction}_{Mit1} = \frac{CO_2e_{baseline} - CO_2e_{Mit1}}{CO_2e_{baseline}}$$

$$\mathbf{GHG\ reduction_{Mit1} = 95\%}$$

As shown from this equation, the percent reduction in greenhouse gas emissions does not depend on the amount of wastewater being treated.

Mitigation Option 2 – Methane is captured and combusted for cogeneration

If a cogeneration system is used to generate electricity from the combusted biogas, the following equation is used to calculate the amount of electricity generated:

$$\text{Electricity} = \text{Wastewater} \times 0.2642 \times \text{Digester Gas} \times F_{CH4} \times HHV_{CH4} \times ECF \times EFF$$

Where:

Electricity	=	Amount of electricity generated from combustion of methane (kWh)
Wastewater	=	Volume of wastewater (liters) Provided by Applicant
0.2642	=	Conversion from liters to gallons
Digester Gas	=	Volume of biogas generated per volume of wastewater treated 0.01 ft^3 biogas / gallon wastewater
F_{CH4}	=	Fraction of CH_4 in biogas 0.65
HHV	=	Heating value of methane 1,012 BTU / ft^3 CH_4
ECF	=	Energy conversion factor 0.00009 kWh/BTU
EFF	=	Efficiency Factor 0.85; USEPA assumes a 15% system efficiency loss to account for system down-time

Therefore:

$$\text{Electricity} = \text{Wastewater} \times 1.33 \times 10^{-4}$$

Since this amount of electricity is generated on-site and no longer needs to be supplied by the local electricity utility, the indirect CO_2e emissions associated with that utility electricity generation are also avoided:

$$CO_2e_{displaced} = \text{Electricity} \times \text{Utility}$$

Where

Utility = Carbon intensity of Local Utility (MT CO_2e/kWh) from table below

Power Utility	Carbon-Intensity (lbs CO_2e/MWh)
LADW&P	1,238
PG&E	456
SCE	641
SDGE	781
SMUD	555

Therefore:

$$\mathbf{CO_2e_{Mit2} = CO_2e_{Mit1} - CO_2e_{displaced}}$$

And then the percent reduction in GHG emissions from Mitigation 2 is:

$$\text{GHG reduction}_{Mit2} = \frac{CO2e_{baseline} - (CO2e_{Mit1} - CO2e_{displaced})}{CO2e_{baseline}}$$

$$\textbf{GHG reductionMit2} = \frac{1.92 \times 10^{-6} + (1.33 \times 10^{-4} \times \text{Utility})}{2.02 \times 10^{-6}}$$

As shown from these equations, the percent reduction in GHG emissions does not depend on the amount of wastewater being treated.

Note that further reductions could be achieved if the heat generated from combustion and cogeneration were recovered and used to displace thermal energy that otherwise would have been generated from a separate heat system, such as a boiler. The magnitude of reductions depends on the system being displaced, including the boiler efficiency and the heating value of the fuel as compared to the heating value of methane. To take credit for this additional reduction, the Project Applicant would need to quantify displaced GHG emissions using the baseline document and the Mitigation Measure BE-5, Install Energy Efficient Boilers.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	95-97%
All other pollutants	Not Quantified[32]

Discussion:

In Southern California Edison's service area, a WWT plant which captures and flares methane achieves a 95% reduction in GHG emissions compared to a WWT plant without a methane recovery system. A WWT plant which captures and combusts methane for cogeneration achieves a 97% reduction in GHG emissions compared to a landfill without a methane recovery system:

$$\text{GHG reduction Mit2} = \frac{1.92 \times 10^{-6} + \left(1.33 \times 10^{-4} \times 2.909 \times 10^{-4}\right)}{2.02 \times 10^{-6}} = 97\%$$

Assumptions:

Data based upon the following references:

- CARB. 2008. Local Government Operations Protocol. Chapter 10: Wastewater Treatment Facilities. Available online at: http://www.arb.ca.gov/cc/protocols/localgov/pubs/final_lgo_protocol_2008-09-25.pdf
- USEPA. 2008. Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2006. Chapter 8: Waste. Available online at: http://www.epa.gov/climatechange/emissions/downloads/08_CR.pdf
- USEPA. 2006. Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks, 3rd Ed. Available online at: http://www.epa.gov/climatechange/wycd/waste/downloads/fullreport.pdf

Preferred Literature: Chapter 10 of CARB's Local Government Operations Protocol (LGOP) provides the methodology for calculating methane emissions from wastewater treatment. Centralized wastewater treatment facilities may use anaerobic or facultative lagoons or anaerobic digesters to treat wastewater. Equation 10.3 of the LGOP calculates methane emissions from anaerobic or facultative lagoons. Equation 10.1 of the LGOP calculates the methane emissions remaining due to incomplete combustion of anaerobic digester gas. Default values for the amount of digester gas produced per volume of wastewater and the fraction of methane in digester gas are taken from the 2008 USEPA Inventory of U.S. Greenhouse Gas Emissions and Sinks. Exhibit 6-7 of

[32] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

USEPA's Solid Waste Management and Greenhouse Gases report provides the methodology for calculating the amount of electricity generated from methane combustion and cogeneration.

Alternative Literature:

None

Other Literature Reviewed:

None

3.0 Transportation

3.1 Land Use/Location

3.1.1 Increase Density

Range of Effectiveness: 0.8 – 30.0% vehicle miles traveled (VMT) reduction and therefore a 0.8 – 30.0% reduction in GHG emissions.

Measure Description:

Designing the Project with increased densities, where allowed by the General Plan and/or Zoning Ordinance reduces GHG emissions associated with traffic in several ways. Density is usually measured in terms of persons, jobs, or dwellings per unit area. Increased densities affect the distance people travel and provide greater options for the mode of travel they choose. This strategy also provides a foundation for implementation of many other strategies which would benefit from increased densities. For example, transit ridership increases with density, which justifies enhanced transit service.

The reductions in GHG emissions are quantified based on reductions to VMT. The relationship between density and VMT is described by its elasticity. According to a recent study published by Brownstone, et al. in 2009, the elasticity between density and VMT is 0.12. Default densities are based on the typical suburban densities in North America which reflects the characteristics of the ITE Trip Generation Manual data used in the baseline estimates.

Measure Applicability:

- Urban and suburban context
  - Negligible impact in a rural context
- Appropriate for residential, retail, office, industrial, and mixed-use projects

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Number of housing units per acre or jobs per job acre

Mitigation Method:

% VMT Reduction = A * B [not to exceed 30%]

Where:

A = Percentage increase in housing units per acre or jobs per job acre[33] = (number of housing units per acre or jobs per job acre – number of housing units per acre or jobs per job acre for typical ITE development) / (number of housing units per acre or jobs per job acre for typical ITE development) For small and medium sites (less than ½ mile in radius) the calculation of housing and jobs per acre should be performed for the development site as a whole, so that the analysis does not erroneously attribute trip reduction benefits to measures that simply shift jobs and housing within the site with no overall increase in site density. For larger sites, the analysis should address the development as several ½-mile-radius sites, so that shifts from one area to another would increase the density of the receiving area but reduce the density of the donating area, resulting in trip generation rate decreases and increases, respectively, which cancel one another.

B = Elasticity of VMT with respect to density (from literature)

Detail:

- A: [not to exceed 500% increase]
  - If housing: (Number of housing units per acre – 7.6) / 7.6 (See Appendix C for detail)
  - If jobs: (Number of jobs per acre – 20) / 20 (See Appendix C for detail)
- B: 0.07 (Boarnet and Handy 2010)

Assumptions:

Data based upon the following references:

- Boarnet, Marlon and Handy, Susan. 2010. "DRAFT Policy Brief on the Impacts of Residential Density Based on a Review of the Empirical Literature." http://arb.ca.gov/cc/sb375/policies/policies.htm; Table 1.

[33] This value should be checked first to see if it exceeds 500% in which case A = 500%.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[34]
CO_2e	1.5-30% of running
PM	1.5-30% of running
CO	1.5-30% of running
NOx	1.5-30% of running
SO_2	1.5-30% of running
ROG	0.9-18% of total

Discussion:

The VMT reductions for this strategy are based on changes in density versus the typical suburban residential and employment densities in North America (referred to as "ITE densities"). These densities are used as a baseline to mirror those densities reflected in the ITE Trip Generation Manual, which is the baseline method for determining VMT.

There are two separate maxima noted in the fact sheet: a cap of 500% on the allowable percentage increase of housing units or jobs per acre (variable A) and a cap of 30% on % VMT reduction. The rationale for the 500% cap is that there are diminishing returns to any change in environment. For example, it is reasonably doubtful that increasing residential density by a factor of six instead of five would produce any additional change in travel behavior. The purpose for the 30% cap is to limit the influence of any single environmental factor (such as density). This emphasizes that community designs that implement multiple land use strategies (such as density, design, diversity, etc.) will show more of a reduction than relying on improvements from a single land use factor.

Example:

Sample calculations are provided below for housing:

Low Range % VMT Reduction (8.5 housing units per acre)

$$= (8.5 – 7.6) / 7.6 *0.07 = 0.8\%$$

High Range % VMT Reduction (60 housing units per acre)

$$= \frac{60 - 7.6}{7.6} = 6.9 \text{ or } 690\% \quad \text{Since greater than 500\%, set to 500\%}$$

$$= 500\% \times 0.07 = 0.35 \text{ or } 35\% \quad \text{Since greater than 30\%, set to 30\%}$$

[34] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

Sample calculations are provided below for jobs:

Low Range % VMT Reduction (25 jobs per acre)
= (25 – 20) / 20 *0.12 = 3%
High Range % VMT Reduction (100 jobs per acre)

$$= \frac{100-20}{20} = 4 \text{ or } 400\%$$

=400% x 0.12 = 0.48 or 48% Since greater than 30%, set to 30%

Preferred Literature:

- -0.07 = elasticity of VMT with respect to density

Boarnet and Handy's detailed review of existing literature highlighted three individual studies that used the best available methods for analyzing data for individual households. These studies provided the following elasticities: -0.12 - Brownstone (2009), -0.07 – Bento (2005), and -0.08 – Fang (2008). To maintain a conservative estimate of the impacts of this strategy, the lower elasticity of -0.07 is used in the calculations.

Alternative Literature:

- -0.05 to -0.25 = elasticity of VMT with respect to density

The *TRB Special Report 298* literature suggests that doubling neighborhood density across a metropolitan area might lower household VMT by about 5 to 12 percent, and perhaps by as much as 25 percent, if coupled with higher employment concentrations, significant public transit improvements, mixed uses, and other supportive demand management measures.

Alternative Literature References:

TRB, 2009. *Driving and the Built Environment*, Transportation Research Board Special Report 298. http://onlinepubs.trb.org/Onlinepubs/sr/sr298.pdf . Accessed March 2010. (p. 4)

Other Literature Reviewed:

None

3.1.2 Increase Location Efficiency

Range of Effectiveness: 10-65% vehicle miles traveled (VMT) reduction and therefore 10-65% reduction in GHG emissions

Measure Description:

This measure is not intended as a separate strategy but rather a documentation of empirical data to justify the "cap" for all land use/location strategies. The location of the Project relative to the type of urban landscape such as being located in an urban area, infill, or suburban center influences the amount of VMT compared to the statewide average. This is referred to as the location of efficiency since there are synergistic benefits to these urban landscapes.

To receive the maximum reduction for this location efficiency, the project will be located in an urban area/ downtown central business district. Projects located on brownfield sites/infill areas receive a lower, but still significant VMT reduction. Finally, projects in suburban centers also receive a reduction for their efficient location. Reductions are based on the typical VMT of a specific geographic area relative to the average VMT statewide.

Measure Applicability:

- Urban and suburban context
- Negligible impact in a rural context
- Appropriate for residential, retail, office, industrial and mixed-use projects

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled
$EF_{running}$ = emission factor for running emissions

Inputs:

- No inputs are needed. VMT reduction ranges are based on the geographic location of the project within the region.

Mitigation Method:

% VMT reduction =

- Urban: 65% (representing VMT reductions for the average urban area in California versus the statewide average VMT)
- Compact Infill: 30% (representing VMT reductions for the average compact infill area in California versus the statewide average VMT)
- Suburban Center: 10% (representing VMT reductions for the average suburban center in California versus the statewide average VMT)

Assumptions:

Data based upon the following references:

- Holtzclaw, et al. 2002. "Location Efficiency: Neighborhood and Socioeconomic Characteristics Determine Auto Ownership and Use – Studies in Chicago, Los Angeles, and Chicago." *Transportation Planning and Technology*, Vol. 25, pp. 1–27.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[35]
CO_2e	10-65% of running
PM	10-65% of running
CO	10-65% of running
NOx	10-65% of running
SO_2	10-65% of running
ROG	6-39% of total

Discussion:

Example:

N/A – no calculations needed

Alternative Literature:

- 13-72% reduction in VMT for infill projects

Preferred Literature:

Holtzclaw, et al., [1] studied relationships between auto ownership and mileage per car and neighborhood urban design and socio-economic characteristics in the Chicago, Los

[35] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

Angeles, and San Francisco metro areas. In all three regions, average annual vehicle miles traveled is a function of density, income, household size, and public transit, as well as pedestrian and bicycle orientation (to a lesser extent). The annual VMT for each neighborhood was reviewed to determine empirical VMT reduction "caps" for this report. These location-based caps represent the average and maximum reductions that would likely be expected in urban, infill, suburban center, and suburban locations.

Growing Cooler looked at 10 studies which have considered the effects of regional location on travel and emissions generated by individual developments. The studies differ in methodology and context but they tend to yield the same conclusion: infill locations generate substantially lower VMT per capita than do greenfield locations, ranging from 13 - 72% lower VMT.

Literature References:

[1] Holtzclaw, et al. 2002. "Location Efficiency: Neighborhood and Socioeconomic Characteristics Determine Auto Ownership and Use – Studies in Chicago, Los Angeles, and Chicago." *Transportation Planning and Technology*, Vol. 25, pp. 1–27.

[2] Ewing, et al, 2008. Growing Cooler – The Evidence on Urban Development and Climate Change. Urban Land Institute. (p.88, Figure 4-30)

Other Literature Reviewed:

None

3.1.3 Increase Diversity of Urban and Suburban Developments (Mixed Use)

Range of Effectiveness: 9-30% vehicle miles traveled (VMT) reduction and therefore 9-30% reduction in GHG emissions.

Measure Description:

Having different types of land uses near one another can decrease VMT since trips between land use types are shorter and may be accommodated by non-auto modes of transport. For example when residential areas are in the same neighborhood as retail and office buildings, a resident does not need to travel outside of the neighborhood to meet his/her trip needs. A description of diverse uses for urban and suburban areas is provided below.

Urban:

The urban project will be predominantly characterized by properties on which various uses, such as office, commercial, institutional, and residential, are combined in a single building or on a single site in an integrated development project with functional interrelationships and a coherent physical design. The mixed-use development should encourage walking and other non-auto modes of transport from residential to office/commercial/institutional locations (and vice versa). The residential units should be within ¼-mile of parks, schools, or other civic uses. The project should minimize the need for external trips by including services/facilities for day care, banking/ATM, restaurants, vehicle refueling, and shopping.

Suburban:

The suburban project will have at least three of the following on site and/or offsite within ¼-mile: Residential Development, Retail Development, Park, Open Space, or Office. The mixed-use development should encourage walking and other non-auto modes of transport from residential to office/commercial locations (and vice versa). The project should minimize the need for external trips by including services/facilities for day care, banking/ATM, restaurants, vehicle refueling, and shopping.

Measure Applicability:

- Urban and suburban context
- Negligible impact in a rural context (unless the project is a master-planned community)
- Appropriate for mixed-use projects

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Percentage of each land use type in the project (to calculate land use index)

Mitigation Method:

% VMT Reduction = Land Use * B [not to exceed 30%]

Where

Land Use = Percentage increase in land use index versus single use development

= (land use index – 0.15)/0.15 (see Appendix C for detail)

Land use index = -a / ln(6) (from [2])

$$a = \sum_{i=1}^{6} a_i \times \ln(a_i)$$

a_i = building floor area of land use i / total square feet of area considered

- a_1 = single family residential
- a_2 = multifamily residential
- a_3 = commercial
- a_4 = industrial
- a_5 = institutional
- a_6 = park

if land use is not present and a_i is equal to 0, set a_i equal to 0.01

B = elasticity of VMT with respect to land use index (0.09 from [1])

not to exceed 500% increase

Assumptions:

Data based upon the following references:

[1] Ewing, R., and Cervero, R., "Travel and the Built Environment - A Meta-Analysis." *Journal of the American Planning Association*, <to be published> (2010). Table 4.

[2] Song, Y., and Knaap, G., "Measuring the effects of mixed land uses on housing values." *Regional Science and Urban Economics 34 (2004) 663-680.* (p. 669) http://urban.csuohio.edu/~sugie/papers/RSUE/RSUE2005_Measuring%20the%20effects%20of%20mixed%20land%20use.pdf

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[36]
CO_2e	9-30% of running
PM	9-30% of running
CO	9-30% of running
NOx	9-30% of running
SO_2	9-30% of running
ROG	5.4-18% of total

Discussion:

In the above calculation, a land use index of 0.15 is used as a baseline representing a development with a single land use (see Appendix C for calculations).

There are two separate maxima noted in the fact sheet: a cap of 500% on the allowable percentage increase of land use index (variable A) and a cap of 30% on % VMT reduction. The rationale for the 500% cap is that there are diminishing returns to any change in environment. For example, it is reasonably doubtful that increasing the land use index by a factor of six instead of five would produce any additional change in travel behavior. The purpose for the 30% cap is to limit the influence of any single environmental factor (such as diversity). This emphasizes that community designs that implement multiple land use strategies (such as density, design, diversity, etc.) will show more of a reduction than relying on improvements from a single land use factor.

[36] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

Example:

Sample calculations are provided below:

90% single family homes, 10% commercial

- Land use index = -[0.9*ln(0.9)+ 0.1*ln(0.1)+ 4*0.01*ln(0.01)] / ln(6) = 0.3
- Low Range % VMT Reduction = (0.3 – 0.15)/0.15 *0.09 = 9%

1/6 single family, 1/6 multi-family, 1/6 commercial, 1/6 industrial, 1/6 institutional, 1/6 parks

- Land use index = -[6*0.17*ln(0.17)] / ln(6) = 1
- High Range % VMT Reduction (land use index = 1)
- Land use = (1-0.15)/0.15 = 5.6 or 566%. Since this is greater than 500%, set to 500%.
- % VMT Reduction = (5 x 0.09) = 0.45 or 45%. Since this is greater than 30%, set to 30%.

Preferred Literature:

- -0.09 = elasticity of VMT with respect to land use index

The land use (or entropy) index measurement looks at the mix of land uses of a development. An index of 0 indicates a single land use while 1 indicates a full mix of uses. Ewing's [1] synthesis looked at a total of 10 studies, where none controlled for self-selection[37]. The weighted average elasticity of VMT with respect to the land use mix index is -0.09. The methodology for calculating the land use index is described in Song and Knaap [2].

Alternative Literature:

- Vehicle trip reduction = [1 - (ABS(1.5*h-e) / (1.5*h+e)) - 0.25] / 0.25*0.03

Where :
h = study area housing units, and
e = study area employment.

Nelson\Nygaard's report [3] describes a calculation adapted from Criterion and Fehr & Peers [4]. The formula assumes an "ideal" housing balance of 1.5 jobs per household and a baseline diversity of 0.25. The maximum trip reduction with this method is 9%.

[37] Self selection occurs when residents or employers that favor travel by non-auto modes choose locations where this type of travel is possible. They are therefore more inclined to take advantage of the available options than a typical resident or employee might otherwise be.

Alternative Literature References:

[3] Nelson\Nygaard, 2005. Crediting Low-Traffic Developments (p.12).
http://www.montgomeryplanning.org/transportation/documents/TripGenerationAnalysisUsingURBEMIS.pdf

[4] Criteron Planner/Engineers and Fehr & Peers Associates (2001). Index 4D Method. *A Quick-Response Method of Estimating Travel Impacts from Land-Use Changes*. Technical Memorandum prepared for US EPA, October 2001.

Other Literature Reviewed:

None

3.1.4 Increase Destination Accessibility

Range of Effectiveness: 6.7 – 20% vehicle miles traveled (VMT) reduction and therefore 6.7-20% reduction in GHG emissions.

Measure Description:

The project will be located in an area with high accessibility to destinations. Destination accessibility is measured in terms of the number of jobs or other attractions reachable within a given travel time, which tends to be highest at central locations and lowest at peripheral ones. The location of the project also increases the potential for pedestrians to walk and bike to these destinations and therefore reduces the VMT.

Measure Applicability:

- Urban and suburban context
- Negligible impact in a rural context
- Appropriate for residential, retail, office, industrial and mixed-use projects

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Distance to downtown or major job center

Mitigation Method:

% VMT Reduction = Center Distance * B [not to exceed 30%]

Where

Center Distance = Percentage decrease in distance to downtown or major job center versus typical ITE suburban development = (distance to downtown/job center for typical ITE development – distance to downtown/job center for project) / (distance to downtown/job center for typical ITE development)

Center Distance = 12 - Distance to downtown/job center for project) / 12
See Appendix C for detail

B = Elasticity of VMT with respect to distance to downtown or major job center (0.20 from [1])

Assumptions:

Data based upon the following references:

[1] Ewing, R., and Cervero, R., "Travel and the Built Environment - A Meta-Analysis." Journal of the American Planning Association, <to be published> (2010). Table 4.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[38]
CO_2e	6.7 – 20% of running
PM	6.7 – 20% of running
CO	6.7 – 20% of running
NOx	6.7 – 20% of running
SO_2	6.7 – 20% of running
ROG	4 – 12% of total

Discussion:

The VMT reductions for this strategy are based on changes in distance to key destinations versus the standard suburban distance in North America. This distance is used as a baseline to mirror the distance to destinations reflected in the land uses for the ITE Trip Generation Manual, which is the baseline method for determining VMT.

The purpose for the 30% cap on % VMT reduction is to limit the influence of any single environmental factor (such as destination accessibility). This emphasizes that community designs that implement multiple land use strategies (such as density,

[38] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

design, diversity, destination, etc.) will show more of a reduction than relying on improvements from a single land use factor.

Example:

Sample calculations are provided below:

- Low Range % VMT Reduction (8 miles to downtown/job center) =
  $$\frac{12-8}{12}\times 0.20 = 6.7\%$$
- High Range % VMT Reduction (0.1 miles to downtown/job center) =
  $$\frac{12-0.1}{12}\times 0.20 = 20.0\%$$

Preferred Literature:

- -0.20 = elasticity of VMT with respect to job accessibility by auto
- -0.20 = elasticity of VMT with respect to distance to downtown

The Ewing and Cervero report [1] finds that VMT is strongly related to measures of accessibility to destinations. The weighted average elasticity of VMT with respect to job accessibility by auto is -0.20 (looking at five total studies). The weighted average elasticity of VMT with respect to distance to downtown is -0.22 (looking at four total studies, of which one controls for self selection[39]).

Alternative Literature:

- 10-30% reduction in vehicle trips

The VTPI literature [2] suggests a 10-30% reduction in vehicle trips for “smart growth” development practices that result in more compact, accessible, multi-modal communities where travel distances are shorter, people have more travel options, and it is possible to walk and bicycle more.

Alternative Literature References:

[2] Litman, T., 2009. “Win-Win Emission Reduction Strategies.” Victoria Transport Policy Institute (VTPI). Website: http://www.vtpi.org/wwclimate.pdf. Accessed March 2010. (p. 7, Table 3)

[39] Self selection occurs when residents or employers that favor travel by non-auto modes choose locations where this type of travel is possible. They are therefore more inclined to take advantage of the available options than a typical resident or employee might otherwise be.

Other Literature Reviewed:

None

3.1.5 Increase Transit Accessibility

Range of Effectiveness: 0.5 – 24.6% VMT reduction and therefore 0.5-24.6% reduction in GHG emissions.[40]

Measure Description:

Locating a project with high density near transit will facilitate the use of transit by people traveling to or from the Project site. The use of transit results in a mode shift and therefore reduced VMT. A project with a residential/commercial center designed around a rail or bus station, is called a transit-oriented development (TOD). The project description should include, at a minimum, the following design features:

- A transit station/stop with high-quality, high-frequency bus service located within a 5-10 minute walk (or roughly ¼ mile from stop to edge of development), and/or
    - A rail station located within a 20 minute walk (or roughly ½ mile from station to edge of development)
- Fast, frequent, and reliable transit service connecting to a high percentage of regional destinations
- Neighborhood designed for walking and cycling

In addition to the features listed above, the following strategies may also be implemented to provide an added benefit beyond what is documented in the literature:

- Mixed use development [LUT-3]
- Traffic calmed streets with good connectivity [SDT-2]
- Parking management strategies such as unbundled parking, maximum parking requirements, market pricing implemented to reduce amount of land dedicated to vehicle parking [see PPT-1 through PPT-7]

Measure Applicability:

- Urban and suburban context
- Appropriate in a rural context if development site is adjacent to a commuter rail station with convenient rail service to a major employment center
- Appropriate for residential, retail, office, industrial, and mixed-use projects

Baseline Method:

[40] Transit vehicles may also result in increases in emissions that are associated with electricity production or fuel use. The Project Applicant should consider these potential additional emissions when estimating mitigation for these measures.

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Distance to transit station in project

Mitigation Method:

% VMT = Transit * B [not to exceed 30%]

Where

Transit = Increase in transit mode share = % transit mode share for project - % transit mode share for typical ITE development (1.3% as described in Appendix C)

% transit mode share for project (see Table)

Distance to transit	Transit mode share calculation equation (where x = distance of project to transit)
0 – 0.5 miles	-50*x + 38
0.5 to 3 miles	-4.4*x + 15.2
> 3 miles	no impact
Source: Lund et al, 2004; Fehr & Peers 2010 (see Appendix C for calculation detail)	

B = adjustments from transit ridership increase to VMT (0.67, see Appendix C for detail)

Assumptions:

Data based upon the following references:

[1] Lund, H. and R. Cervero, and R. Willson (2004). *Travel Characteristics of Transit-Oriented Development in California*. (p. 79, Table 5-25)

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[41]
CO_2e	0.5 – 24.6% of running
PM	0.5 – 24.6% of running
CO	0.5 – 24.6% of running
NOx	0.5 – 24.6% of running
SO_2	0.5 – 24.6% of running
ROG	0.3 – 14.8% of total

Discussion:

The purpose for the 30% cap on % VMT reduction is to limit the influence of any single environmental factor (such as transit accessibility). This emphasizes that community designs that implement multiple land use strategies (such as density, design, diversity, transit accessibility, etc.) will show more of a reduction than relying on improvements from a single land use factor.

Example:

Sample calculations are provided below for a rail station:

- Low Range % VMT Reduction (3 miles from station) = [(-4.4*3+15.2) – 1.3%] * 0.67 = 0.5%
- High Range % VMT Reduction (0 miles from station) = [(-50*0+38) – 1.3%] * 0.67 = 24.6%

Preferred Literature:

- 13 to 38% transit mode share (residents in TODs with ½ mile of rail station)
- 5 to 13% transit mode share (residents in TODs from ½ mile to 3 miles of rail station)

The *Travel Characteristics* report [1] surveyed TODs and surrounding areas in San Diego, Los Angeles, San Jose, Sacramento, and Bay Area regions. Survey sites are all located in non-central business district locations, are within walking distance of a transit station with rail service headways of 15 minutes or less, and were intentionally developed as TODs.

[41] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

Alternative Literature:

Alternate:

- -0.05 = elasticity of VMT with respect to distance to nearest transit stop

Ewing and Cervero's meta-analysis [2] provides this weighted average elasticity based on six total studies, of which one controls for self-selection. The report does not provide the range of distances where this elasticity is valid.

Alternate:

- 5.9 – 13.3% reduction in VMT

The Bailey, et al. 2008 report [3] predicted a reduction of household daily VMT of 5.8 miles for a location next to a rail station and 2.6 miles for a location next to a bus station. Using the report's estimate of 43.75 daily average miles driven, the estimated reduction in VMT for rail accessibility is 13.3% (5.8/43.75) and for bus accessibility is 5.9% (2.6/43.75).

Alternate:

- 15% reduction in vehicle trips
- 2 to 5 times higher transit mode share

TCRP Report 128 [4] concludes that transit-oriented developments, compared to typical developments represented by the *ITE Trip Generation Manual*, have 47% lower vehicle trip rates and have 2 to 5 times higher transit mode share. *TCRP Report 128* notes that the *ITE Trip Generation Manual* shows 6.67 daily trips per unit while detailed counts of 17 residential TODs resulted in 3.55 trips per unit (a 47% reduction in vehicle trips). This study looks at mid-rise and high-rise apartments at the residential TOD sites. A more conservative comparison would be to look at the *ITE Trip Generation Manual* rates for high-rise apartments, 4.2 trips per unit. This results in a 15% reduction in vehicle trips.

Alternative Literature References:

[2] Ewing, R., and Cervero, R., "Travel and the Built Environment - A Meta-Analysis." *Journal of the American Planning Association*, <to be published> (2010). Table 4.

[3] Bailey, L., Mokhtarian, P.L., & Little, A. (2008). "The Broader Connection between Public Transportation, Energy Conservation and Greenhouse Gas Reduction." ICF International. (Table 4 and 5)

[4] TCRP, 2008. *TCRP Report 128 - Effects of TOD on Housing, Parking, and Travel.* http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_128.pdf (p. 11, 69).

Other Literature Reviewed:

None

3.1.6 Integrate Affordable and Below Market Rate Housing

Range of Effectiveness: 0.04 – 1.20% vehicle miles traveled (VMT) reduction and therefore 0.04-1.20% reduction in GHG emissions.

Measure Description:

Income has a statistically significant effect on the probability that a commuter will take transit or walk to work [4]. BMR housing provides greater opportunity for lower income families to live closer to jobs centers and achieve jobs/housing match near transit. It also addresses to some degree the risk that new transit oriented development would displace lower income families. This strategy potentially encourages building a greater percentage of smaller units that allow a greater number of families to be accommodated on infill and transit-oriented development sites within a given building footprint and height limit. Lower income families tend to have lower levels of auto ownership, allowing buildings to be designed with less parking which, in some cases, represents the difference between a project being economically viable or not.

Residential development projects of five or more dwelling units will provide a deed-restricted low-income housing component on-site.

Measure Applicability:

- Urban and suburban context
- Negligible impact in a rural context unless transit availability and proximity to jobs/services are existing characteristics
- Appropriate for residential and mixed-use projects

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Percentage of units in project that are deed-restricted BMR housing

Mitigation Method:

% VMT Reduction = 4% * Percentage of units in project that are deed-restricted BMR housing [1]

Assumptions:

Data based upon the following references:

[1] Nelson\Nygaard, 2005. Crediting Low-Traffic Developments (p.15). http://www.montgomeryplanning.org/transportation/documents/TripGenerationAnalysisUsingURBEMIS.pdf

Criteron Planner/Engineers and Fehr & Peers Associates (2001). Index 4D Method. *A Quick-Response Method of Estimating Travel Impacts from Land-Use Changes*. Technical Memorandum prepared for US EPA, October 2001.

Holtzclaw, John; Clear, Robert; Dittmar, Hank; Goldstein, David; and Haas, Peter (2002), "Location Efficiency: Neighborhood and Socio-Economic Characteristics Determine Auto Ownership and Use – Studies in Chicago, Los Angeles and San Francisco", *Transportation Planning and Technology*, 25 (1): 1-27.

All trips affected are assumed average trip lengths to convert from percentage vehicle trip reduction to VMT reduction (%VT = %VMT)

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[42]
CO_2e	0.04 – 1.20% of running
PM	0.04 – 1.20% of running
CO	0.04 – 1.20% of running
NOx	0.04 – 1.20% of running
SO_2	0.04 – 1.20% of running
ROG	0.024 – 0.72% of total

Discussion:

At a low range, 1% BMR housing is assumed. At a medium range, 15% is assumed (based on the requirements of the San Francisco BMR Program[5]). At a high range, the San Francisco program is doubled to reach 30% BMR. Higher percentages of BMR are possible, though not discussed in the literature or calculated.

[42] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

Example:

Sample calculations are provided below:

- Low Range % VMT Reduction = 4% * 1% = 0.04%
- High Range % VMT Reduction = 4% * 30% = 1.20%

Preferred Literature:

Nelson\Nygaard [1] provides a 4% reduction in vehicle trips for each deed-restricted BMR unit. This is calculated from Holtzclaw [3], with the following assumptions: 12,000 average annual VMT per vehicle, $33,000 median per capita income (2002 figures per CA State Department of Finance), and average income in BMR units 25% below median. With a coefficient of -0.0565 (estimate for VMT/vehicle as a function of $/capita) from [3], the VMT reduction is 0.0565*33,000*0.25/12,000 = 4%.

Alternative Literature:

- 50% greater transit school trips than higher income households

Fehr & Peers [6] developed Direct Ridership Models to predict the Bay Area Rapid Transit (BART) ridership activity. One of the objectives of this assessment was to understand the land use and system access factors that influence commute period versus off-peak travel on BART. The analysis focused on the Metropolitan Transportation Commission 2000 Bay Area Travel Survey [7], using the data on household travel behavior to extrapolate relationships between household characteristics and BART mode choice. The study found that regardless of distance from BART, lower income households generate at least 50% higher BART use for school trips than higher income households. More research would be needed to provide more applicable information regarding other types of transit throughout the state.

Other Literature Reviewed:

[4] Bento, Antonio M., Maureen L. Cropper, Ahmed Mushfiq Mobarak, and Katja Vinha. 2005. “The Effects of Urban Spatial Structure on Travel Demand in the United States.” *The Review of Economics and Statistics* 87,3: 466-478. (cited in Measure Description section)

[5] San Francisco BMR Program: http://www.ci.sf.ca.us/site/moh_page.asp?id=48083 (p.1) (cited in Discussion section).

[6] Fehr & Peers. *Access BART*. 2006.

[7] BATS. 2000. 2000 Bay Area Travel Survey.

3.1.7 Orient Project Toward Non-Auto Corridor

Range of Effectiveness: Grouped strategy. [See LUT-3]

Measure Description:

A project that is designed around an existing or planned transit, bicycle, or pedestrian corridor encourages alternative mode use. For this measure, the project is oriented towards a planned or existing transit, bicycle, or pedestrian corridor. Setback distance is minimized.

The benefits of Orientation toward Non-Auto Corridor have not been sufficiently quantified in the existing literature. This measure is most effective when applied in combination of multiple design elements that encourage this use. There is not sufficient evidence that this measure results in non-negligible trip reduction unless combined with measures described elsewhere in this report, including neighborhood design, density and diversity of development, transit accessibility and pedestrian and bicycle network improvements. Therefore, the trip reduction percentages presented below should be used only as reasonableness checks. They may be used to assess whether, when applied to projects oriented toward non-auto corridors, analysis of all of those other development design factors presented in this report produce trip reductions at least as great as the percentages listed below.

Measure Applicability:

- Urban or suburban context; may be applicable in a master-planned rural community
- Appropriate for residential, retail, office, industrial, and mixed-use projects

Alternative Literature:

Alternate:

- 0.25 – 0.5% reduction in vehicle miles traveled (VMT)

The Sacramento Metropolitan Air Quality Management District (SMAQMD) Recommended Guidance for Land Use Emission Reductions attributes 0.5% reduction for a project oriented towards an *existing* corridor. A 0.25% reduction is attributed for a project oriented towards a *planned* corridor. The planned transit, bicycle, or pedestrian corridor must be in a General Plan, Community Plan, or similar plan.

Alternate:

- 0.5% reduction in VMT per 1% improvement in transit frequency
- 0.5% reduction in VMT per 10% increase in transit ridership

The *Center for Clean Air Policy (CCAP) Guidebook* [2] attributes a 0.5 % reduction per 1% improvement in transit frequency. Based on a case study presented in the CCAP report, a 10% increase in transit ridership would result in a 0.5% reduction. (This information is based on a TIAX review for SMAQMD).

The sources cited above reflect existing guidance rather than empirical studies.

Alternative Literature References:

[1] Sacramento Metropolitan Air Quality Management District (SMAQMD). "Recommended Guidance for Land Use Emission Reductions." http://www.airquality.org/ceqa/GuidanceLUEmissionReductions.pdf

[2] Center for Clean Air Policy (CCAP). *Transportation Emission Guidebook*. http://www.ccap.org/safe/guidebook/guide_complete.html
TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD

Other Literature Reviewed:

None

3.1.8 Locate Project near Bike Path/Bike Lane

Range of Effectiveness: Grouped strategy. [See LUT-4]

Measure Description:

A Project that is designed around an existing or planned bicycle facility encourages alternative mode use. The project will be located within 1/2 mile of an existing Class I path or Class II bike lane. The project design should include a comparable network that connects the project uses to the existing offsite facilities.

This measure is most effective when applied in combination of multiple design elements that encourage this use. Refer to Increase Destination Accessibility (LUT-4) strategy. The benefits of Proximity to Bike Path/Bike Lane are small as a standalone strategy. The strategy should be grouped with the Increase Destination Accessibility strategy to increase the opportunities for multi-modal travel.

Measure Applicability:

- Urban or suburban context; may be applicable in a rural master planned community
- Appropriate for residential, retail, office, industrial, and mixed-use projects

Alternative Literature:

Alternate:

- 0.625% reduction in vehicle miles traveled (VMT)

As a rule of thumb, the *Center for Clean Air Policy (CCAP) Guidebook* [1] attributes a 1% to 5% reduction associated with comprehensive bicycle programs. Based on the CCAP guidebook, the TIAX report allots 2.5% reduction for all bicycle-related measures and a 1/4 of that for this measure alone. (This information is based on a TIAX review for SMAQMD).

Alternative Literature References:

[1] Center for Clean Air Policy (CCAP). *Transportation Emission Guidebook*. http://www.ccap.org/safe/guidebook/guide_complete.html; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.

Other Literature Reviewed:

None

3.1.9 Improve Design of Development

Range of Effectiveness: 3.0 – 21.3% vehicle miles traveled (VMT) reduction and therefore 3.0-21.3% reduction in GHG emissions.

Measure Description:

The project will include improved design elements to enhance walkability and connectivity. Improved street network characteristics within a neighborhood include street accessibility, usually measured in terms of average block size, proportion of four-way intersections, or number of intersections per square mile. Design is also measured in terms of sidewalk coverage, building setbacks, street widths, pedestrian crossings, presence of street trees, and a host of other physical variables that differentiate pedestrian-oriented environments from auto-oriented environments.

Measure Applicability:

- Urban and suburban context
- Negligible impact in a rural context
- Appropriate for residential, retail, office, industrial and mixed-use projects

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Number of intersections per square mile

Mitigation Method:

$$\% \text{ VMT Reduction} = \text{Intersections} * B$$

Where

Intersections = Percentage increase in intersections versus a typical ITE suburban development

$$= \frac{\text{Intersections per square mile of project - Intersections per square mile of typical ITE suburban development}}{\text{Intersections per square mile of typical ITE suburban development}}$$

$$= \frac{\text{Intersections per square mile of project} - 36}{36}$$

See Appendix C for detail [not to exceed 500% increase]

B = Elasticity of VMT with respect to percentage of intersections (0.12 from [1])

Assumptions:

Data based upon the following references:

[1] Ewing, R., and Cervero, R., "Travel and the Built Environment - A Meta-Analysis." *Journal of the American Planning Association*, <to be published> (2010). Table 4.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[43]
CO_2e	3.0 – 21.3% of running
PM	3.0 – 21.3% of running
CO	3.0 – 21.3% of running
NOx	3.0 – 21.3% of running
SO_2	3.0 – 21.3% of running
ROG	1.8 – 12.8% of total

Discussion:

The VMT reductions for this strategy are based on changes in intersection density versus the standard suburban intersection density in North America. This standard density is used as a baseline to mirror the density reflected in the *ITE Trip Generation Manual*, which is the baseline method for determining VMT.

The calculations in the Example section look at a low and high range of intersection densities. The low range is simply a slightly higher density than the typical ITE

[43] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

development. The high range uses an average intersection density of mixed use/transit-oriented development sites (TOD Site surveys in the Bay Area for *Candlestick-Hunters Point Phase II TIA,* Fehr & Peers, 2009).

There are two separate maxima noted in the fact sheet: a cap of 500% on the allowable percentage increase of intersections per square mile (variable A) and a cap of 30% on % VMT reduction. The rationale for the 500% cap is that there are diminishing returns to any change in environment. For example, it is reasonably doubtful that increasing intersection density by a factor of six instead of five would produce any additional change in travel behavior. The purpose for the 30% cap is to limit the influence of any single environmental factor (such as design). This emphasizes that community designs that implement multiple land use strategies (such as density, design, diversity, etc.) will show more of a reduction than relying on improvements from a single land use factor.

Example:

Sample calculations are provided below:

- Low Range % VMT Reduction (45 intersections per square mile) = (45 – 36) / 36 * 0.12 = 3.0%
- High Range % VMT Reduction (100 intersections per square mile) = (100 – 36) / 36 * 0.12 = 21.3%

Preferred Literature:

- -0.12 = elasticity of VMT with respect to design (intersection/street density)
- -0.12 = elasticity of VMT with respect to design (% of 4-way intersections)

Ewing and Cervero's [1] synthesis showed a strong relationship of VMT to design elements, second only to destination accessibility. The weighted average elasticity of VMT to intersection/street density was -0.12 (looking at six studies). The weighted average elasticity of VMT to percentage of 4-way intersections was -0.12 (looking at four studies, of which one controlled for self-selection[44]).

Alternative Literature:

Alternate:

- 2-19% reduction in VMT

[44] Self selection occurs when residents or employers that favor travel by non-auto modes choose locations where this type of travel is possible. They are therefore more inclined to take advantage of the available options than a typical resident or employee might otherwise be.

Growing Cooler [2] looked at various reports which studied the effect of site design on VMT, showing a range of 2-19% reduction in VMT. In each case, alternative development plans for the same site were compared to a baseline or trend plan. Results suggest that VMT and CO_2 per capita decline as site density increases as well as the mix of jobs, housing, and retail uses become more balanced. *Growing Cooler* notes that the limited number of studies, differences in assumptions and methodologies, and variability of results make it difficult to generalize.

Alternate:

- 3 – 17% shift in mode share from auto to non-auto

The Marshall and Garrick paper [3] analyzes the differences in mode shares for grid and non-grid ("tree") neighborhoods. For a city with a tributary tree street network, a neighborhood with a tree network had auto mode share of 92% while a neighborhood with a grid network had auto mode share of 89% (3% difference). For a city with a tributary radial street network, a tree neighborhood had auto mode share of 97% while a grid neighborhood had auto mode share of 84% (13% difference). For a city with a grid network, a tree neighborhood had auto mode share of 95% while a grid neighborhood had auto mode share of 78% (17% difference). The research is based on 24 California cities with populations between 30,000 and 100,000.

Alternative Literature References:

[2] Ewing, et al, 2008. Growing Cooler – The Evidence on Urban Development and Climate Change. Urban Land Institute.

[3] Marshall and Garrick, 2009. "The Effect of Street Network Design on Walking and Biking." Submitted to the 89th Annual Meeting of Transportation Research Board, January 2010. (Table 3)

Other Literature Reviewed:

None

3.2 Neighborhood/Site Enhancements

3.2.1 Provide Pedestrian Network Improvements

Range of Effectiveness: 0 - 2% vehicle miles traveled (VMT) reduction and therefore 0 - 2% reduction in GHG emissions.

Measure Description:

Providing a pedestrian access network to link areas of the Project site encourages people to walk instead of drive. This mode shift results in people driving less and thus a reduction in VMT. The project will provide a pedestrian access network that internally links all uses and connects to all existing or planned external streets and pedestrian facilities contiguous with the project site. The project will minimize barriers to pedestrian access and interconnectivity. Physical barriers such as walls, landscaping, and slopes that impede pedestrian circulation will be eliminated.

Measure Applicability:

- Urban, suburban, and rural context
- Appropriate for residential, retail, office, industrial and mixed-use projects
- Reduction benefit only occurs if the project has both pedestrian network improvements on site and connections to the larger off-site network.

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The project applicant must provide information regarding pedestrian access and connectivity within the project and to/from off-site destinations.

Mitigation Method:

Estimated VMT Reduction	Extent of Pedestrian Accommodations	Context
2%	Within Project Site and Connecting Off-Site	Urban/Suburban
1%	Within Project Site	Urban/Suburban
< 1%	Within Project Site and Connecting Off-Site	Rural

Assumptions:

Data based upon the following references:

- Center for Clean Air Policy (CCAP) Transportation Emission Guidebook. http://www.ccap.org/safe/guidebook/guide_complete.html (accessed March 2010)
- 1000 Friends of Oregon (1997) "Making the Connections: A Summary of the LUTRAQ Project" (p. 16): http://www.onethousandfriendsoforegon.org/resources/lut_vol7.html

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[45]
CO_2e	0 - 2% of running
PM	0 - 2% of running
CO	0 - 2% of running
NOx	0 - 2% of running
SO_2	0 - 2% of running
ROG	0 – 1.2% of total

Discussion:

As detailed in the preferred literature section below, the lower range of 1 – 2% VMT reduction was pulled from the literature to provide a conservative estimate of reduction potential. The literature does not speak directly to a rural context, but an assumption was made that the benefits will likely be lower than a suburban/urban context.

Example:

N/A – calculations are not needed.

Preferred Literature:

[45] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

- 1 - 2% reduction in VMT

The Center for Clean Air Policy (CCAP) attributes a 1% reduction in VMT from pedestrian-oriented design assuming this creates a 5% decrease in automobile mode share (e.g. auto split shifts from 95% to 90%). This mode split is based on the Portland Regional Land Use Transportation and Air Quality (LUTRAQ) project. The LUTRAQ analysis also provides the high end of 10% reduction in VMT. This 10% assumes the following features:

– Compact, mixed-use communities
– Interconnected street network
– Narrower roadways and shorter block lengths
– Sidewalks
– Accessibility to transit and transit shelters
– Traffic calming measures and street trees
– Parks and public spaces

Other strategies (development density, diversity, design, transit accessibility, traffic calming) are intended to account for the effects of many of the measures in the above list. Therefore, the assumed effectiveness of the Pedestrian Network measure should utilize the lower end of the 1 - 10% reduction range. If the pedestrian improvements are being combined with a significant number of the companion strategies, trip reductions for those strategies should be applied as well, based on the values given specifically for those strategies in other sections of this report. Based upon these findings, and drawing upon recommendations presented in the alternate literature below, the recommended VMT reduction attributable to pedestrian network improvements, above and beyond the benefits of other measures in the above bullet list, should be 1% for comprehensive pedestrian accommodations within the development plan or project itself, or 2% for comprehensive internal accommodations and external accommodations connecting to off-site destinations.

Alternative Literature:

Alternate:

- Walking is three times more common with enhanced pedestrian infrastructure
- 58% increase in non-auto mode share for work trips

The Nelson\Nygaard [1] report for the City of Santa Monica Land Use and Circulation Element EIR summarized studies looking at pedestrian environments. These studies have found a direct connection between non-auto forms of travel and a high quality pedestrian environment. Walking is three times more common with communities that have pedestrian friendly streets compared to less pedestrian friendly communities. Non-auto mode share for work trips is 49% in a pedestrian friendly community, compared to 31% in an auto-oriented community. Non-auto mode share for non-work trips is 15%, compared to 4% in an auto-oriented community. However, these effects also depend upon other aspects of the pedestrian friendliness being present, which are accounted for separately in this report through land use strategy mitigation measures such as density and urban design.

Alternate:

- 0.5% - 2.0% reduction in VMT

The Sacramento Metropolitan Air Quality Management District (SMAQMD) Recommended Guidance for Land Use Emission Reductions [2] attributes 1% reduction for a project connecting to *existing* external streets and pedestrian facilities. A 0.5% reduction is attributed to connecting to *planned* external streets and pedestrian facilities (which must be included in a pedestrian master plan or equivalent). Minimizing pedestrian barriers attribute an additional 1% reduction in VMT. These recommendations are generally in line with the recommended discounts derived from the preferred literature above.

Preferred and Alternative Literature Notes:

[1] Nelson\Nygaard, 2010. City of Santa Monica Land Use and Circulation Element EIR Report, Appendix – Santa Monica Luce Trip Reduction Impacts Analysis (p.401). http://www.shapethefuture2025.net/

Nelson\Nygaard looked at the following studies: Anne Vernez Moudon, Paul Hess, Mary Catherine Snyder and Kiril Stanilov (2003), Effects of Site Design on Pedestrian Travel in Mixed Use, Medium-Density Environments, http://www.wsdot.wa.gov/research/reports/fullreports/432.1.pdf; Robert Cervero and Carolyn Radisch (1995), Travel Choices in Pedestrian Versus Automobile Oriented Neighborhoods, http://www.uctc.net/papers/281.pdf;

[2] Sacramento Metropolitan Air Quality Management District (SMAQMD) Recommended Guidance for Land Use Emission Reductions. (p. 11) http://www.airquality.org/ceqa/GuidanceLUEmissionReductions.pdf

Other Literature Reviewed:

None

3.2.2 Provide Traffic Calming Measures

Range of Effectiveness: 0.25 – 1.00% vehicle miles traveled (VMT) reduction and therefore 0.25 – 1.00% reduction in GHG emissions.

Measure Description:

Providing traffic calming measures encourages people to walk or bike instead of using a vehicle. This mode shift will result in a decrease in VMT. Project design will include pedestrian/bicycle safety and traffic calming measures in excess of jurisdiction requirements. Roadways will be designed to reduce motor vehicle speeds and encourage pedestrian and bicycle trips with traffic calming features. Traffic calming features may include: marked crosswalks, count-down signal timers, curb extensions, speed tables, raised crosswalks, raised intersections, median islands, tight corner radii, roundabouts or mini-circles, on-street parking, planter strips with street trees, chicanes/chokers, and others.

Measure Applicability:

- Urban, suburban, and rural context
- Appropriate for residential, retail, office, industrial and mixed-use projects

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Percentage of streets within project with traffic calming improvements
- Percentage of intersections within project with traffic calming improvements

Mitigation Method:

		% of streets with improvements			
		25%	50%	75%	100%
		% VMT Reduction			
% of intersections with improvements	25%	**0.25%**	**0.25%**	**0.5%**	**0.5%**
	50%	**0.25%**	**0.5%**	**0.5%**	**0.75%**
	75%	**0.5%**	**0.5%**	**0.75%**	**0.75%**
	100%	**0.5%**	**0.75%**	**0.75%**	**1%**

Assumptions:

Data based upon the following references:

[1] Cambridge Systematics. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.*(p. B-25) http://www.movingcooler.info/Library/Documents/Moving%20Cooler_Appendices_Complete_102209.pdf

[2] Sacramento Metropolitan Air Quality Management District (SMAQMD) *Recommended Guidance for Land Use Emission Reductions.* (p.13) http://www.airquality.org/ceqa/GuidanceLUEmissionReductions.pdf

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[46]
CO_2e	0.25 – 1.00% of running
PM	0.25 – 1.00% of running
CO	0.25 – 1.00% of running
NOx	0.25 – 1.00% of running
SO_2	0.25 – 1.00% of running
ROG	0.15 – 0.6% of total

Discussion:

The table above allows the Project Applicant to choose a range of street and intersection improvements to determine an appropriate VMT reduction estimate. The Applicant will look at the rows on the left and choose the percent of intersections within

[46] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

the project which will have traffic calming improvements. Then, the Applicant will look at the columns along the top and choose the percent of streets within the project which will have traffic calming improvements. The intersection cell of the row and column selected in the matrix is the VMT reduction estimate.

Though the literature provides some difference between a suburban and urban context, the difference is small and thus a conservative estimate was used to be applied to all contexts. Rural context is not specifically discussed in the literature but is assumed to have similar impacts.

For a low range, a project is assumed to have 25% of its streets with traffic calming improvements and 25% of its intersections with traffic calming improvements. For a high range, 100% of streets and intersections are assumed to have traffic calming improvements

Example:

N/A - No calculations needed.

Preferred Literature:

- -0.03 = elasticity of VMT with respect to a pedestrian environment factor (PEF)
- 1.5% - 2.0% reduction in suburban VMT
- 0.5% - 0.6% reduction in urban VMT

Moving Cooler [1] looked at Ewing's synthesis elasticity from the Smart Growth INDEX model (-0.03) to estimate VMT reduction for a suburban and urban location. The estimated reduction in VMT came from looking at the difference between the VMT results for Moving Cooler's strategy of pedestrian accessibility only compared to an aggressive strategy of pedestrian accessibility and traffic calming.

The Sacramento Metropolitan Air Quality Management District (SMAQMD) *Recommended Guidance for Land Use Emission Reductions* [2] attributes 0.25 – 1% of VMT reductions to traffic calming measures. The table above illustrates the range of VMT reductions based on the percent of streets and intersections with traffic calming measures implemented. This range of reductions is recommended because it is generally consistent with the effectiveness ranges presented in the other preferred literature for situations in which the effects of traffic calming are distinguished from the other measures often found to co-exist with calming, and because it provides graduated effectiveness estimates depending on the degree to which calming is implemented.

Alternative Literature:

None

Alternative Literature References:

None

Other Literature Reviewed:

None

3.2.3 Implement a Neighborhood Electric Vehicle (NEV) Network

Range of Effectiveness: 0.5-12.7% vehicle miles traveled (VMT) reduction since Neighborhood Electric Vehicles (NEVs) would result in a mode shift and therefore reduce the traditional vehicle VMT and GHG emissions[47]. Range depends on the available NEV network and support facilities, NEV ownership levels, and the degree of shift from traditional

Measure Description:

The project will create local "light" vehicle networks, such as NEV networks. NEVs are classified in the California Vehicle Code as a "low speed vehicle". They are electric powered and must conform to applicable federal automobile safety standards. NEVs offer an alternative to traditional vehicle trips and can legally be used on roadways with speed limits of 35 MPH or less (unless specifically restricted). They are ideal for short trips up to 30 miles in length. To create an NEV network, the project will implement the necessary infrastructure, including NEV parking, charging facilities, striping, signage, and educational tools. NEV routes will be implemented throughout the project and will double as bicycle routes.

Measure Applicability:

- Urban, suburban, and rural context
- Small citywide or large multi-use developments
- Appropriate for mixed-use projects

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

[47] Transit vehicles may also result in increases in emissions that are associated with electricity production or fuel use. The Project Applicant should consider these potential additional emissions when estimating mitigation for these measures.

Inputs:

The following information needs to be provided by the Project Applicant:

- low vs. high penetration

Mitigation Method:

% VMT reduction = Pop * Number * NEV

Where

Penetration	=	Number of NEVs per household (0.04 to 1.0 from [1])
NEV	=	VMT reduction rate per household (12.7% from [2])

Assumptions:

Data based upon the following reference:

[1] City of Lincoln, MHM Engineers & Surveyors, *Neighborhood Electric Vehicle Transportation Program Final Report*, Issued 04/05/05
[2] City of Lincoln, *A Report to the California Legislature as required by Assembly Bill 2353, Neighborhood Electric Vehicle Transportation Plan Evaluation,* January 1, 2008.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[48]
CO_2e	0.5 – 12.7% of running
PM	0.5 – 12.7% of running
CO	0.5 – 12.7%of running
NOx	0.5 – 12.7% of running
SO_2	0.5 – 12.7% of running
ROG	0.3 – 7.6% of total

Discussion:

The estimated number of NEVs per household may vary based on what the project estimates as a penetration rate for implementing an NEV network. Adjust according to project characteristics. The estimated reduction in VMT is for non-NEV miles traveled. The calculations below assume that NEV miles traveled replace regular vehicle travel.

▪ [48] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

This may not be the case and the project should consider applying an appropriate discount rate on what percentage of VMT is actually replaced by NEV travel..

Example:

Sample calculations are provided below:

- Low Range % VMT Reduction (low penetration) = 0.04 * 12.7% = 0.5%
- High Range % VMT Reduction (high penetration) = 1.0 * 12.7% = 12.7%

Preferred Literature:

- 12.7% reduction in VMT per household
- Penetration rates: 0.04 to 1 NEV / household

The NEV Transportation Program plans to implement the following strategies: charging facilities, striping, signage, parking, education on NEV safety, and NEV/bicycle lines throughout the community. . One estimate of current NEV ownership reported roughly 600 NEVs in the city of Lincoln in 2008[49]. With current estimated households of ~13,500[50], a low estimate of NEV penetration would be 0.04 NEV per household. A high NEV penetration can be estimated at 1 NEV per household. The 2007 survey of NEV users in Lincoln revealed an average use of about 3,500 miles per year [2]. With an estimated annual 27,500 VMT/household[51], this results in a 12.7% reduction in VMT per household.

Alternative Literature:

- 0.5% VMT reduction for neighborhoods with internal NEV connections
- 1% VMT reduction for internal and external connections to surrounding neighborhoods
- 1.5% VMT reduction for internal NEV connections and connections to other existing NEV networks serving all other types of uses.

The Sacramento Metropolitan Air Quality Management District (SMAQMD) Recommended Guidance for Land Use Emission Reductions notes that current studies show NEVs do not replace gas-fueled vehicles as the primary vehicle. For the purpose

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[49] Lincoln, California: A NEV-Friendly Community, Bennett Engineering, the City of Lincoln, and LincolnNEV, August 28, 2008 - http://electrickmotorsports.com/news.php
[50] SACOG Housing Estimates Statistics (http://www.sacog.org/about/advocacy/pdf/fact-sheets/HousingStats.pdf). Linearly interpolated 2008 household numbers between 2005 and 2035 projections.
[51] SACOG SACSim forecasts for VMT per household at 75.4 daily VMT per household * 365 days = 27521 annual VMT per household

of providing incentives for developers to promote NEV use, a project will receive the above listed VMT reductions for implementation.

Alternative Literature Reference:

[1] Sacramento Metropolitan Air Quality Management District (SMAQMD) Recommended Guidance for Land Use Emission Reductions. (p. 21) http://www.airquality.org/ceqa/GuidanceLUEmissionReductions.pdf

Other Literature Reviewed:

None

3.2.4 Create Urban Non-Motorized Zones

Range of Effectiveness: Grouped strategy. [See SDT-1]

Measure Description:

The project, if located in a central business district (CBD) or major activity center, will convert a percentage of its roadway miles to transit malls, linear parks, or other non-motorized zones. These features encourage non-motorized travel and thus a reduction in VMT.

This measure is most effective when applied with multiple design elements that encourage this use. Refer to Pedestrian Network Improvements (SDT-1) strategy for ranges of effectiveness in this category. The benefits of Urban Non-Motorized Zones alone have not been shown to be significant.

Measure Applicability:

- Urban context
- Appropriate for residential, retail, office, industrial, and mixed-use projects

Alternative Literature:

Alternate:

- 0.01 – 0.2% annual Vehicle Miles Traveled (VMT) reduction

Moving Cooler [1] assumes 2 – 6% of U.S. CBDs/activity centers will convert to non-motorized zones for the purpose of calculating the potential impact. At full implementation, this would result in a range of CBD/activity center annual VMT reduction of 0.07-0.2% and metro VMT reduction of 0.01-0.03%.

Alternate:

Pucher, Dill, and Handy (2010) [2] note several international case studies of urban non-motorized zones. In Bologna, Italy, vehicle traffic declined by 50%, and 8% of those arriving in the CBD came by bicycle after the conversion. In Lubeck, Germany, of those who used to drive, 12% switched to transit, walking, or bicycling with the conversion. In Aachen, Germany, car travel declined from 44% to 36%, but bicycling stayed constant at 3%

Notes:

No literature was identified that quantifies the benefits of this strategy at a smaller scale.

Alternative Literature References:

[1] Cambridge Systematics. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Technical Appendices. Prepared for the Urban Land Institute. http://www.movingcooler.info/Library/Documents/Moving%20Cooler_Appendix%20B_Effectiveness_102209.pdf

[2] Pucher J., Dill, J., and Handy, S. *Infrastructure, Programs and Policies to Increase Bicycling: An International Review.* February 2010. *Preventive Medicine 50 (2010) S106–S125.* http://policy.rutgers.edu/faculty/pucher/Pucher_Dill_Handy10.pdf

Other Literature Reviewed:

None

3.2.5 Incorporate Bike Lane Street Design (on-site)

Range of Effectiveness: Grouped strategy. [See LUT-9]

Measure Description:

The project will incorporate bicycle lanes, routes, and shared-use paths into street systems, new subdivisions, and large developments. These on-street bike accommodations will be created to provide a continuous network of routes, facilitated with markings and signage. These improvements can help reduce peak-hour vehicle trips by making commuting by bike easier and more convenient for more people. In addition, improved bicycle facilities can increase access to and from transit hubs, thereby expanding the "catchment area" of the transit stop or station and increasing ridership. Bicycle access can also reduce parking pressure on heavily-used and/or heavily-subsidized feeder bus lines and auto-oriented park-and-ride facilities.

Refer to Improve Design of Development (LUT-9) strategy for overall effectiveness levels. The benefits of Bike Lane Street Design are small and should be grouped with the Improve Design of Development strategy to strengthen street network characteristics and enhance multi-modal environments.

Measure Applicability:

- Urban and suburban context
- Appropriate for residential, retail, office, industrial, and mixed-use projects

Alternative Literature:

Alternate:

- 1% increase in share of workers commuting by bicycle (for each additional mile of bike lanes per square mile)

Dill and Carr (2003) [1] showed that each additional mile of Type 2 bike lanes per square mile is associated with a 1% increase in the share of workers commuting by bicycle. Note that increasing by 1 mile is significant compared to the current average of 0.34 miles per square mile. Also, an increase in 1% in share of bicycle commuters would double the number of bicycle commuters in many areas with low existing bicycle mode share.

Alternate:

- 0.05 – 0.14% annual greenhouse gas (GHG) reduction
- 258 – 830% increase in bicycle community

Moving Cooler [2], based off of a national baseline, estimates 0.05% annual reduction in GHG emissions and 258% increase in bicycle commuting assuming 2 miles of bicycle lanes per square mile in areas with density > 2,000 persons per square mile. For 4 miles of bicycle lanes, estimates 0.09% GHG reductions and 449% increase in bicycle commuting. For 8 miles of bicycle lanes, estimates 0.14% GHG reductions and 830% increase in bicycle commuting. Companion strategies assumed include bicycle parking at commercial destinations, busses fitted with bicycle carriers, bike accessible rapid transit lines, education, bicycle stations, end-trip facilities, and signage.

Alternate:

- 0.075% increase in bicycle commuting with each mile of bikeway per 100,000 residents

A before-and-after study by Nelson and Allen (1997) [3] of bicycle facility implementation found that each mile of bikeway per 100,000 residents increases bicycle commuting 0.075%, all else being equal.

Alternative Literature References:

[1] Dill, Jennifer and Theresa Carr (2003). "Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Tem, Commuters Will Use Them – Another Look." *TRB 2003 Annual Meeting CD-ROM*.

[2] Cambridge Systematics. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Technical Appendices. Prepared for the Urban Land Institute. http://www.movingcooler.info/Library/Documents/Moving%20Cooler_Appendix%20B_Effectiveness_102209.pdf

[3] Nelson, Arthur and David Allen (1997). "If You Build Them, Commuters Will Use Them; Cross-Sectional Analysis of Commuters and Bicycle Facilities." *Transportation Research Record 1578.*

Other Literature Reviewed:

None

3.2.6 Provide Bike Parking in Non-Residential Projects

Range of Effectiveness: Grouped strategy. [See LUT-9]

Measure Description:

A non-residential project will provide short-term and long-term bicycle parking facilities to meet peak season maximum demand. Refer to Improve Design of Development (LUT-9) strategy for overall effectiveness ranges. Bike Parking in Non-Residential Projects has minimal impacts as a standalone strategy and should be grouped with the Improve Design of Development strategy to encourage bicycling by providing strengthened street network characteristics and bicycle facilities.

Measure Applicability:

- Urban, suburban, and rural contexts
- Appropriate for retail, office, industrial, and mixed-use projects

Alternative Literature:

Alternate:

- 0.625% reduction in Vehicle Miles Traveled (VMT)

As a rule of thumb, the Center for Clean Air Policy (CCAP) guidebook [1] attributes a 1% to 5% reduction in VMT to the use of bicycles, which reflects the assumption that their use is typically for shorter trips. Based on the *CCAP Guidebook*, the TIAX report allots 2.5% reduction for all bicycle-related measures and a quarter of that for this bicycle parking alone. (This information is based on a TIAX review for Sacramento Metropolitan Air Quality Management District (SMAQMD).)

Alternate:

- 0.05 – 0.14% annual greenhouse gas (GHG) reduction
- 258 – 830% increase in bicycle community

Moving Cooler [2], based off of a national baseline, estimates 0.05% annual reduction in GHG emissions and 258% increase in bicycle commuting assuming 2 miles of bicycle lanes per square mile in areas with density > 2,000 persons per square mile. For 4 miles of bicycle lanes, *Moving Cooler* estimates 0.09% GHG reductions and 449% increase in bicycle commuting. For 8 miles of bicycle lanes, *Moving Cooler* estimates 0.14% GHG reductions and 830% increase in bicycle commuting. Companion strategies assumed include bicycle parking at commercial destinations, busses fitted with bicycle carriers, bike accessible rapid transit lines, education, bicycle stations, end-trip facilities, and signage.

Alternative Literature References:

[1]*Center For Clean Air Policy (CCAP) Transportation Emission Guidebook*. http://www.ccap.org/safe/guidebook/guide_complete.html; Based on results of 2005 literature search conducted by TIAX on behalf of SMAQMD.

[2] Cambridge Systematics. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Technical Appendices. Prepared for the Urban Land Institute. http://www.movingcooler.info/Library/Documents/Moving%20Cooler_Appendix%20B_Effectiveness_102209.pdf

Other Literature Reviewed:

None

3.2.7 Provide Bike Parking with Multi-Unit Residential Projects

Range of Effectiveness: Grouped strategy. [See LUT-9]

Measure Description:

Long-term bicycle parking will be provided at apartment complexes or condominiums without garages. Refer to Improve Design of Development (LUT-9) strategy for effectiveness ranges in this category. The benefits of Bike Parking with Multi-Unit Residential Projects have no quantified impacts and should be grouped with the Improve Design of Development strategy to encourage bicycling by providing strengthened street network characteristics and bicycle facilities.

Measure Applicability:

- Urban, suburban, or rural contexts
- Appropriate for residential projects

Alternative Literature:

No literature was identified that specifically looks at the quantitative impact of including bicycle parking at multi-unit residential sites.

Alternative Literature References:

None

Other Literature Reviewed:

None

3.2.8 Provide Electric Vehicle Parking

Range of Effectiveness: Grouped strategy. [See SDT-3]

Measure Description:

This project will implement accessible electric vehicle parking. The project will provide conductive/inductive electric vehicle charging stations and signage prohibiting parking for non-electric vehicles. Refer to Neighborhood Electric Vehicle Network (SDT-3) strategy for effectiveness ranges in this category. The benefits of Electric Vehicle Parking may be quantified when grouped with the use of electric vehicles and or Neighborhood Electric Vehicle Network.

Measure Applicability:

- Urban or suburban contexts
- Appropriate for residential, retail, office, mixed use, and industrial projects

Alternative Literature:

No literature was identified that specifically looks at the quantitative impact of implementing electric vehicle parking.

Alternative Literature References:

None

Other Literature Reviewed:

None

3.2.9 Dedicate Land for Bike Trails

Range of Effectiveness: Grouped strategy. [See LUT-9]

Measure Description:

Larger projects may be required to provide for, contribute to, or dedicate land for the provision of off-site bicycle trails linking the project to designated bicycle commuting routes in accordance with an adopted citywide or countywide bikeway plan.

Refer to Improve Design of Development (LUT-9**)** strategy for ranges of effectiveness in this category. The benefits of Land Dedication for Bike Trails have not been quantified and should be grouped with the Improve Design of Development strategy to strengthen street network characteristics and improve connectivity to off-site bicycle networks.

Measure Applicability:

- Urban, suburban, or rural contexts
- Appropriate for large residential, retail, office, mixed use, and industrial projects

Alternative Literature:

No literature was identified that specifically looks at the quantitative impact of implementing land dedication for bike trails.

Alternative Literature References:

None

Other Literature Reviewed:

None

3.3 Parking Policy/Pricing

3.3.1 Limit Parking Supply

Range of Effectiveness: 5 – 12.5% vehicle miles travelled (VMT) reduction and therefore 5 – 12.5% reduction in GHG emissions.

Measure Description:

The project will change parking requirements and types of supply within the project site to encourage "smart growth" development and alternative transportation choices by project residents and employees. This will be accomplished in a multi-faceted strategy:

- Elimination (or reduction) of minimum parking requirements[52]
- Creation of maximum parking requirements
- Provision of shared parking

Measure Applicability:

- Urban and suburban context
- Negligible in a rural context
- Appropriate for residential, retail, office, industrial and mixed-use projects
- Reduction can be counted only if spillover parking is controlled (via residential permits and on-street market rate parking) [See PPT-5 and PPT-7]

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled
$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- ITE parking generation rate for project site
- Actual parking provision rate for project site

[52] This may require changes to local ordinances and regulations.

Mitigation Method:

$$\% \text{ VMT Reduction} = \frac{\text{Actual parking provision} - \text{ITE parking generation rate}}{\text{ITE parking generation rate}} \times 0.5$$

Assumptions:

Data based upon the following references:

[1] Nelson\Nygaard, 2005. Crediting Low-Traffic Developments (p. 16) http://www.montgomeryplanning.org/transportation/documents/TripGenerationAnalysisUsingURBEMIS.pdf

All trips affected are assumed average trip lengths to convert from percentage vehicle trip reduction to VMT reduction (% vehicle trips = %VMT).

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[53]
CO_2e	5 – 12.5% of running
PM	5 – 12.5% of running
CO	5 – 12.5% of running
NOx	5 – 12.5% of running
SO_2	5 – 12.5% of running
ROG	3 – 7.5% of total

Discussion:

The literature suggests that a 50% reduction in conventional parking provision rates (per ITE rates) should serve as a typical ceiling for the reduction calculation. The upper range of VMT reduction will vary based on the size of the development (total number of spaces provided). ITE rates are used as baseline conditions to measure the effectiveness of this strategy.

Though not specifically documented in the literature, the degree of effectiveness of this measure will vary based on the level of urbanization of the project and surrounding areas, level of existing transit service, level of existing pedestrian and bicycle networks and other factors which would complement the shift away from single-occupant vehicle travel.

[53] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis.

Example:

If the ITE parking generation rate for the project is 100 spaces, for a low range a 5% reduction in spaces is assumed. For a high range a 25% reduction in spaces is assumed.

- Low range % VMT Reduction = [(100 - 95)/100] * 0.5 = 2.5%
- High range % VMT Reduction = [(100 - 75)/100] * 0.5 = 12.5%

Preferred Literature:

To develop this model, Nelson\Nygaard [1] used the Institute of Transportation Engineers' *Parking Generation* handbook as the baseline figure for parking supply. This is assumed to be unconstrained demand. Trip reduction should only be credited if measures are implemented to control for spillover parking in and around the project, such as residential parking permits, metered parking, or time-limited parking.

Alternative Literature:

- 100% increase in transit ridership
- 100% increase in transit mode share

According to *TCRP Report 95, Chapter 18* [2], the central business district of Portland, Oregon implemented a maximum parking ratio of 1 space per 1,000 square feet of new buildings and implemented surface lot restrictions which limited conditions where buildings could be razed for parking. A "before and after" study was not conducted specifically for the maximum parking requirements and data comes from various surveys and published reports. Based on rough estimates the approximate parking ratio of 3.4 per 1,000 square feet in 1973 (for entire downtown) had been reduce to 1.5 by 1990. Transit mode share increased from 20% to 40%. The increases in transit ridership and mode share are not solely from maximum parking requirements. Other companion strategies, such as market parking pricing and high fuel costs, were in place.

Alternative Literature Sources:

[1] TCRP Report 95, Chapter 18: Parking Management and Supply: Traveler Response to *Transportation System Changes*. (p. 18-6) http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_95c18.pdf

Other Literature Reviewed:

None

3.3.2 Unbundle Parking Costs from Property Cost

Range of Effectiveness: 2.6 – 13% vehicles miles traveled (VMT) reduction and therefore 2.6 – 13% reduction in GHG emissions.

Measure Description:

This project will unbundle parking costs from property costs. Unbundling separates parking from property costs, requiring those who wish to purchase parking spaces to do so at an additional cost from the property cost. This removes the burden from those who do not wish to utilize a parking space. Parking will be priced separately from home rents/purchase prices or office leases. An assumption is made that the parking costs are passed through to the vehicle owners/drivers utilizing the parking spaces.

Measure Applicability:

- Urban and suburban context
- Negligible impact in a rural context
- Appropriate for residential, retail, office, industrial and mixed-use projects
- Complementary strategy includes Workplace Parking Pricing. Though not required, implementing workplace parking pricing ensures the market signal from unbundling parking is transferred to the employee.

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Monthly parking cost for project site

Mitigation Method:

% Reduction in VMT = Change in vehicle cost * elasticity * A

Where:

- -0.4 = elasticity of vehicle ownership with respect to total vehicle costs (lower end per VTPI)
- Change in vehicle cost = monthly parking cost * (12 / $4,000), with $4,000 representing the annual vehicle cost per VTPI [1]
- A: 85% = adjustment from vehicle ownership to VMT (see Appendix C for detail)

Assumptions:

Data based upon the following references:

[1] Victoria Transport Policy Institute, *Parking Requirement Impacts on Housing Affordability;* http://www.vtpi.org/park-hou.pdf; January 2009; accessed March 2010. (Annual/monthly parking fees estimated by VTPI in 2009) (p. 8, Table 3)

- For the elasticity of vehicle ownership, VTPI cites Phil Goodwin, Joyce Dargay and Mark Hanly (2003), *Elasticities Of Road Traffic And Fuel Consumption With Respect To Price And Income: A Review*, ESRC Transport Studies Unit, University College London (www.transport.ucl.ac.uk), commissioned by the UK Department of the Environment, Transport and the Regions (now UK Department for Transport); J.O. Jansson (1989), "Car Demand Modeling and Forecasting," *Journal of Transport Economics and Policy*, May 1989, pp. 125-129; Stephen Glaister and Dan Graham (2000), *The Effect of Fuel Prices on Motorists*, AA Motoring Policy Unit (www.theaa.com) and the UK Petroleum Industry Association (http://195.167.162.28/policyviews/pdf/effect_fuel_prices.pdf); and Thomas F. Golob (1989), "The Casual Influences of Income and Car Ownership on Trip Generation by Mode", *Journal of Transportation Economics and Policy*, May 1989, pp. 141-162

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[54]
CO_2e	2.6 – 13% of running
PM	2.6 – 13% of running
CO	2.6 – 13% of running

[54] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

NOx	2.6 – 13% of running
SO_2	2.6 – 13% of running
ROG	1.6 – 7.8% of total

Discussion:

As discussed in the preferred literature section, monthly parking costs typically range from $25 to $125. The lower end of the elasticity range provided by VTPI is used here to be conservative.

Example:

Sample calculations are provided below:

- Low Range % VMT Reduction = $25* 12 / $4000 * 0.4 * 85% = 2.6%
- High Range % VMT Reduction = $125* 12 / $4000 * 0.4 * 85%= 12.8%

Preferred Literature:

- -0.4 to -1.0 = elasticity of vehicle ownership with respect to total vehicle costs

The above elasticity comes from a synthesis of literature. As noted in the VTPI report [1], a 10% increase in total vehicle costs (operating costs, maintenance, fuel, parking, etc.) reduces vehicle ownership between 4% and 10%. The report, estimating $4,000 in annual costs per vehicle, calculated vehicle ownership reductions from residential parking pricing.

Vehicle Ownership Reductions from Residential Parking Pricing

Annual (Monthly) Parking Fee	-0.4 Elasticity	-0.7 Elasticity	-1.0 Elasticity
$300 ($25)	4%	6%	8%
$600 ($50)	8%	11%	15%
$900 ($75)	11%	17%	23%
$1,200 ($100)	15%	23%	30%
$1,500 ($125)	19%	28%	38%

Alternative Literature:

None

Alternative Literature Notes:

None

Other Literature Reviewed:

None

3.3.3 Implement Market Price Public Parking (On-Street)

Range of Effectiveness: 2.8 – 5.5% vehicle miles traveled (VMT) reduction and therefore 2.8 – 5.5% reduction in GHG emissions.

Measure Description:

This project and city in which it is located will implement a pricing strategy for parking by pricing all central business district/employment center/retail center on-street parking. It will be priced to encourage "park once" behavior. The benefit of this measure above that of paid parking at the project only is that it deters parking spillover from project-supplied parking to other public parking nearby, which undermine the vehicle miles traveled (VMT) benefits of project pricing. It may also generate sufficient area-wide mode shifts to justify increased transit service to the area.

Measure Applicability:

- Urban and suburban context
- Negligible impact in a rural context
- Appropriate for retail, office, and mixed-use projects
- Applicable in a specific or general plan context only
- Reduction can be counted only if spillover parking is controlled (via residential permits)
- Study conducted in a downtown area, and thus should be applied carefully if project is not in a central business/activity center

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Location of project site: low density suburb, suburban center, or urban location

- Percent increase in on-street parking prices (minimum 25% needed)

Mitigation Method:

% VMT Reduction = Park$ * B

Where:

Park$ = Percent increase in on-street parking prices (minimum of 25% increase [1])

B = Elasticity of VMT with respect to parking price (0.11, from [2])

Assumptions:

Data based upon the following references:

[1] Cambridge Systematics. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Technical Appendices. Prepared for the Urban Land Institute. (p. B-10)

Moving Cooler's parking pricing analysis cited Victoria Transport Policy Institute, *How Prices and Other Factors Affect Travel Behavior* (http://www.vtpi.org/tdm/tdm11.htm#_Toc161022578). The VTPI paper summarized the elasticities found in the Hensher and King paper. David A. Hensher and Jenny King (2001), "Parking Demand and Responsiveness to Supply, Price and Location in Sydney Central Business District," *Transportation Research A*, Vol. 35, No. 3 (www.elsevier.com/locate/tra), March 2001, pp. 177-196.

[2] J. Peter Clinch and J. Andrew Kelly (2003), *Temporal Variance Of Revealed Preference On-Street Parking Price Elasticity*, Department of Environmental Studies, University College Dublin (www.environmentaleconomics.net). (p. 2) http://www.ucd.ie/gpep/research/workingpapers/2004/04-02.pdf As referenced in VTPI: http://www.vtpi.org/tdm/tdm11.htm#_Toc161022578

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[55]
CO_2e	2.8 – 5.5% of running

[55] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

PM	2.8 – 5.5% of running
CO	2.8 – 5.5% of running
NOx	2.8 – 5.5% of running
SO_2	2.8 – 5.5% of running
ROG	1.7 – 3.3% of total

Discussion:

The range of parking price increases should be a minimum of 25% and a maximum of 50%. The minimum is based on Moving Cooler [1] discussions which state that a less than 25% increase would not be a sufficient amount to reduce VMT. The case study [2] looked at a 50% price increase, and thus no conclusions can be made on the elasticities above a 50% increase. This strategy may certainly be implemented at a higher price increase, but VMT reductions should be capped at results from a 50% increase to be conservative.

Example:

Assuming a baseline on-street parking price of $1, sample calculations are provided below:

- Low Range % VMT Reduction (25% increase) = ($1.25 - $1)/$1 * 0.11 = 2.8%
- High Range % VMT Reduction (50% increase) = ($1.50 - $1)/$1 * 0.11 = 5.5%

Preferred Literature:

- -0.11 parking demand elasticity with respect to parking prices

The Clinch & Kelly study [2] of parking meters looked at the impacts of a 50% price increase in the cost of on-street parking. The case study location was a central on-street parking area with a 3-hour time limit and a mix of business and non-business uses. The study concluded the parking increases resulted in an estimated average price elasticity of demand of -0.11, while factoring in parking duration results in an elasticity of -0.2 (cost increases also affect the amount of time cars are parked). Though this study is international (Dublin, Ireland), it represents a solid study of parking meter price increases and provides a conservative estimate of elasticity compared to the alternate literature.

Alternative Literature:

Alternate:

- -0.19 shopper parking elasticity with respect to parking price
- -0.48 commuter parking elasticity with respect to parking price

The *TCRP 95 Chapter 13* [3] report looked at a case study of the city of San Francisco implementing a parking tax on all public and private off-street parking (in 1970). Based on the number of cars parked, the report estimated parking price elasticities of -0.19 to -0.48, an average over a three year period.

Alternate:

- -0.15 VMT elasticity with respect to parking prices (for low density regions)
- -0.47 VMT elasticity with respect to parking prices (for high density regions)

The Moving Cooler analysis assumes a 25 percent increase in on-street parking fees is a starting point sufficient to reduce VMT. Using the elasticities stated above, Moving Cooler estimates an annual percent VMT reduction from 0.42% - 1.14% for a range of regions from a large low density region to a small high density region. The calculations assume that pricing occurs at the urban central business district/employment cent/retail center, one-fourth of all person trips are commute based trips, and approximately 15% of commute trips are to the CBD or regional activity centers.

Alternative Literature References:

[3] TCRP Report 95. *Chapter 13: Parking Pricing and Fees - Traveler Response to Transportation System Changes.* http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_95c13.pdf. (p.13-42)

Other Literature Reviewed:

None

3.3.4 Require Residential Area Parking Permits

Range of Effectiveness: Grouped strategy. (See PPT-1, PPT-2, and PPT-3)

Measure Description:

This project will require the purchase of residential parking permits (RPPs) for long-term use of on-street parking in residential areas. Permits reduce the impact of spillover parking in residential areas adjacent to commercial areas, transit stations, or other locations where parking may be limited and/or priced. Refer to Parking Supply Limitations (PPT-1), Unbundle Parking Costs from Property Cost (PPT-2), or Market Rate Parking Pricing (PPT-3) strategies for the ranges of effectiveness in these categories. The benefits of Residential Area Parking Permits strategy should be combined with any or all of the above mentioned strategies, as providing RPPs are a key complementary strategy to other parking strategies.

Measure Applicability:

- Urban context
- Appropriate for residential, retail, office, mixed use, and industrial projects

Alternative Literature:

- -0.45 = elasticity of vehicle miles traveled (VMT) with respect to price
- 0.08% greenhouse gas (GHG) reduction
- 0.09-0.36% VMT reduction

Moving Cooler [1] suggested residential parking permits of $100-$200 annually. This mitigation would impact home-based trips, which are reported to represent approximately 60% of all urban trips. The range of VMT reductions can be attributed to the type of urban area. VMT reductions for $100 annual permits are 0.09% for large, high-density; 0.12% for large, low-density; 0.12% for medium, high-density; 0.18% for medium, low-density; 0.18% for small, high-density; and 0.12% for small, low-density. VMT reductions for $200 annual permits are 0.18% for large, high-density; 0.24% for large, low-density; 0.24% for medium, high-density; 0.36% for medium, low-density; 0.36% for small, high-density; and 0.24% for small, low-density.

Alternative Literature References:

[1] Cambridge Systematics. Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions. Technical Appendices. Prepared for the Urban Land Institute. http://www.movingcooler.info/Library/Documents/Moving%20Cooler_Appendix%20B_Effectiveness_102209.pdf

3.4 Commute Trip Reduction Programs

3.4.1 Implement Commute Trip Reduction Program - Voluntary

Commute Trip Reduction Program – Voluntary, is a multi-strategy program that encompasses a combination of individual measures described in sections 3.4.3 through 3.4.9. It is presented as a means of preventing double-counting of reductions for individual measures that are included in this strategy. It does so by setting a maximum level of reductions that should be permitted for a combined set of strategies within a voluntary program.

Range of Effectiveness: 1.0 – 6.2% commute vehicle miles traveled (VMT) Reduction and therefore 1.0 – 6.2% reduction in commute trip GHG emissions.

Measure Description:

The project will implement a voluntary Commute Trip Reduction (CTR) program with employers to discourage single-occupancy vehicle trips and encourage alternative modes of transportation such as carpooling, taking transit, walking, and biking. The main difference between a voluntary and a required program is:

- Monitoring and reporting is not required
- No established performance standards (i.e. no trip reduction requirements)

The CTR program will provide employees with assistance in using alternative modes of travel, and provide both “carrots” and “sticks” to encourage employees. The CTR program should include all of the following to apply the effectiveness reported by the literature:

- Carpooling encouragement
- Ride-matching assistance
- Preferential carpool parking
- Flexible work schedules for carpools
- Half time transportation coordinator
- Vanpool assistance
- Bicycle end-trip facilities (parking, showers and lockers)

Other strategies may also be included as part of a voluntary CTR program, though they are not included in the reductions estimation and thus are not incorporated in the estimated VMT reductions. These include: new employee orientation of trip reduction and alternative mode options, event promotions and publications, flexible work schedule for all employees, transit subsidies, parking cash-out or priced parking, shuttles, emergency ride home, and improved on-site amenities.

Measure Applicability:

- Urban and suburban context
- Negligible in a rural context, unless large employers exist, and suite of strategies implemented are relevant in rural settings
- Appropriate for retail, office, industrial and mixed-use projects

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Percentage of employees eligible
- Location of project site: low density suburb, suburban center, or urban location

Mitigation Method:

% VMT Reduction = A * B

Where

A = % reduction in commute VMT (from [1])

B = % employees eligible

Detail:

- A: 5.2% (low density suburb), 5.4% (suburban center), 6.2% (urban) annual reduction in commute VMT (from [1])

Assumptions:

Data based upon the following references:

- Cambridge Systematics. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Technical Appendices. Prepared for the Urban Land Institute. (Table 5.13) http://www.movingcooler.info/Library/Documents/Moving%20Cooler_Appendix%20B_Effectiveness_102209.pdf

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[56]
CO_2e	1.0 – 6.2% of running
PM	1.0 – 6.2% of running
CO	1.0 – 6.2% of running
NOx	1.0 – 6.2% of running
SO_2	1.0 – 6.2% of running
ROG	0.6 –3.7% of total

Discussion:

This set of strategies typically serves as a complement to the more effective workplace CTR strategies such as pricing and parking cash out.

Example:

Sample calculations are provided below:

- Low Range % VMT Reduction (low density suburb and 20% eligible) = 5.2% * 0.2 = 1.0%
- High Range % VMT Reduction (urban and 100% eligible) = 6.2% * 1 = 6.2%

Preferred Literature:

- 5.2 - 6.2% commute VMT reduction

Moving Cooler assumes the employer support program will include: carpooling, ride-matching, preferential carpool parking, flexible work schedules for carpools, a half-time transportation coordinator, vanpool assistance, bicycle parking, showers, and locker facilities. The report assigns 5.2% reduction to large metropolitan areas, 5.4% to medium metropolitan areas, and 6.2% to small metropolitan areas.

[56] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

Alternative Literature:

Alternate:

- 15-19% reduction in commute vehicle trips

TCRP 95 Draft Chapter 19 [2] looked at a sample of 82 Transportation Demand Management (TDM) programs. Low support TDM programs had a 15% reduction, medium support programs 15.9%, and high support 19%. Low support programs had little employer effort. These programs may include rideshare matching, distribution of transit flyers, but have little employer involvement. With medium support programs, employers were involved with providing information regarding commute options and programs, a transportation coordinator (even if part-time), and assistance for ridesharing and transit pass purchases. With high support programs, the employer was providing most of the possible strategies. The sample of programs should not be construed as a random sample and probably represent above average results.

Alternate:

- 4.16 – 4.76% reduction in commute VMT

The Herzog study [3] compared a group of employees, who were eligible for comprehensive commuter benefits (with financial incentives, services such as guaranteed ride home and carpool matching, and informational campaigns) and general marketing information, to a reference group of employees not eligible for commuter benefits. The study showed a 4.79% reduction in VMT, assuming 75% of the carpoolers were traveling to the same worksite. There was a 4.16% reduction in VMT, assuming only 50% of carpoolers were traveling to the same worksite.

Alternate:

- 8.5% reduction in vehicle commute trips

Employer survey results [4] showed that employees at the surveyed companies made 8.5% fewer vehicle trips to work than had been found in the baseline surveys conducted by large employers under the area's trip reduction regulation (i.e. comparing voluntary program with a mandatory regulation). This implied that the 8.5% reduction is a conservative estimate as it is compared to another trip reduction strategy, rather than comparing to a baseline with no reduction strategies implemented. Another survey also showed that 68% of commuters drove alone to work when their employer did not encourage trip reduction. It revealed that with employer encouragement, the drive-alone rate fell 5 percentage points to 63%.

This strategy assumes a companion strategy of employer encouragement. The literature did not specify what commute options each employer provided as part of the program. Options provided may have ranged from simply providing public transit information to implementing a full TDM program with parking cash out, flex hours, emergency ride home, etc. This San Francisco Bay Area survey worked to determine the extent and impact of the emissions saved through voluntary trip reduction efforts (www.cleanairpartnership.com). It identified 454 employment sites with voluntary trip reduction programs and conducted a selected random survey of the more than 400,000 employees at those sites. The study concluded that employer encouragement makes a significant difference in employees' commute choices.

Alternative Literature References:

[2] Pratt, Dick. Personal Communication Regarding the Draft of TCRP 95 Traveler Response to Transportation System Changes – Chapter 19 Employer and Institutional TDM Strategies.

[3] Herzog, Erik, Stacey Bricka, Lucie Audette, and Jeffra Rockwell. 2006. "Do Employee Commuter Benefits Reduce Vehicle Emissions and Fuel Consumption? Results of Fall 2004 Survey of Best Workplaces for Commuters." *Transportation Research Record 1956*, 34-41. (Table 8)

[4] Transportation Demand Management Institute of the Association for Commuter Transportation. *TDM Case Studies and Commuter Testimonials*. Prepared for the US EPA. 1997. (p. 25-28) http://www.epa.gov/OMS/stateresources/rellinks/docs/tdmcases.pdf

Other Literature Reviewed:

None

3.4.2 Implement Commute Trip Reduction Program – Required Implementation/Monitoring

Commute Trip Reduction Program – Required, is a multi-strategy program that encompasses a combination of individual measures described in sections 3.4.3 through 3.4.9. It is presented as a means of preventing double-counting of reductions for individual measures that are included in this strategy. It does so by setting a maximum level of reduction that should be permitted for a combined set of strategies within a program that is contractually required of the development sponsors and managers and accompanied by a regular performance monitoring and reporting program.

Range of Effectiveness: 4.2 – 21.0% commute vehicle miles traveled (VMT) reduction and therefore 4.2 – 21.0% reduction in commute trip GHG emissions.

Measure Description:

The jurisdiction will implement a Commute Trip Reduction (CTR) ordinance. The intent of the ordinance will be to reduce drive-alone travel mode share and encourage alternative modes of travel. The critical components of this strategy are:

- Established performance standards (e.g. trip reduction requirements)
- Required implementation
- Regular monitoring and reporting

Regular monitoring and reporting will be required to assess the project's status in meeting the ordinance goals. The project should use existing ordinances, such as those in the cities of Tucson, Arizona and South San Francisco, California, as examples of successful CTR ordinance implementations. The City of Tucson requires employers with 100+ employees to participate in the program. An Alternative Mode Usage (AMU) goal and VMT reduction goal is established and each year the goal is increased. Employers persuade employees to commute via an alternative mode of transportation at least one day a week (including carpooling, vanpooling, transit, walking, bicycling, telecommuting, compressed work week, or alternatively fueled vehicle). The Transportation Demand Management (TDM) Ordinance in South San Francisco requires all non-residential developments that produce 100 average daily vehicle trips or more to meet a 35% non-drive-alone peak hour requirement with fees assessed for non-compliance. Employers have established significant CTR programs as a result.

Measure Applicability:

- Urban and suburban context
- Negligible in a rural context, unless large employers exist, and suite of strategies implemented are relevant in rural settings
- Jurisdiction level only
- Strategies in this case study calculations included:

- Parking cash out
- Employer sponsored shuttles to transit station
- Employer sponsored bus servicing the Bay Area
- Transit subsidies

Baseline Method:
See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:
The following information needs to be provided by the Project Applicant:

- Percentage of employees eligible

Mitigation Method:

% VMT Reduction = A * B

Where

A = % shift in vehicle mode share of commute trips (from [1])
B = % employees eligible
C = Adjustment from vehicle mode share to commute VMT

Detail:
- A: 21% reduction in vehicle mode share (from [1])
- C: 1.0 (see Appendix C for detail)

Assumptions:

Data based upon the following references:

[1] Nelson/Nygaard (2008). *South San Francisco Mode Share and Parking Report for Genentech, Inc.*(p. 8)

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[57]
CO_2e	4.2 – 21.0% of running
PM	4.2 – 21.0% of running
CO	4.2 – 21.0% of running
NOx	4.2 – 21.0% of running
SO_2	4.2 – 21.0% of running
ROG	2.5 – 12.6% of total

Discussion:

Example:

Sample calculations are provided below:

- Low Range % VMT Reduction (20% eligibility) = 21% * 20% = 4.2%
- High Range % VMT Reduction (100% eligibility) = 21% * 100% = 21%

Preferred Literature:

- 21% reduction in vehicle mode share

Genentech, in South San Francisco [1], achieved a 34% non-single-occupancy vehicle (non-SOV) mode share (66% SOV) in 2008. Since 2006 when SOV mode share was 74% (26% non-SOV), there has been a reduction of over 10% in drive alone share. Carpool share was 12% in 2008, compared to 11.57% in 2006. Genentech has a significant TDM program including parking cash out ($4/day), express GenenBus service around the Bay Area, free shuttles to Bay Area Rapid Transit (BART) and Caltrain, and transit subsidies. The Genentech campus surveyed for this study is a large, single-tenant campus. Taking an average transit mode share in a suburban development of 1.3% (NHTS,

[57] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

http://www.dot.ca.gov/hq/tsip/tab/documents/travelsurveys/Final2001_Stw Travel Survey WkdayRpt.pdf (SCAG, SANDAG, Fresno County)), this is an estimated decrease from 98.7% to 78% vehicle mode share (66% SOV + 12% carpool), a 21% reduction in vehicle mode share.

Alternative Literature:

Alternate:

- 10.7% average annual increase in use of non-SOV commute modes

For the City of Tucson [2], use of alternative commute modes increased 64.3% between 1989 and 1995. Employers integrated several key activities into their TDM plans: disseminating information, developing company policies to support TDM, investing in facility enhancements, conducting promotional campaigns, and offering subsidies or incentives to encourage AMU.

Alternative Literature References:

[2] Transportation Demand Management Institute of the Association for Commuter Transportation. *TDM Case Studies and Commuter Testimonials*. Prepared for the US EPA. 1997. (p. 17-19) http://www.epa.gov/OMS/stateresources/rellinks/docs/tdmcases.pdf

Other Literature Reviewed:

None

3.4.3 Provide Ride-Sharing Programs

Range of Effectiveness: 1 – 15% commute vehicle miles traveled (VMT) reduction and therefore 1 - 15% reduction in commute trip GHG emissions.

Measure Description:

Increasing the vehicle occupancy by ride sharing will result in fewer cars driving the same trip, and thus a decrease in VMT. The project will include a ride-sharing program as well as a permanent transportation management association membership and funding requirement. Funding may be provided by Community Facilities, District, or County Service Area, or other non-revocable funding mechanism. The project will promote ride-sharing programs through a multi-faceted approach such as:

- Designating a certain percentage of parking spaces for ride sharing vehicles
- Designating adequate passenger loading and unloading and waiting areas for ride-sharing vehicles
- Providing a web site or message board for coordinating rides

Measure Applicability:

- Urban and suburban context
- Negligible impact in many rural contexts, but can be effective when a large employer in a rural area draws from a workforce in an urban or suburban area, such as when a major employer moves from an urban location to a rural location.
- Appropriate for residential, retail, office, industrial, and mixed-use projects

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Percentage of employees eligible

- Location of project site: low density suburb, suburban center, or urban location

Mitigation Method:

% VMT Reduction = Commute * Employee

Where

Commute = % reduction in commute VMT (from [1])
Employee = % employees eligible

Detail:

- Commute: 5% (low density suburb), 10% (suburban center), 15% (urban) annual reduction in commute VMT (from [1])

Assumptions:

Data based upon the following references:

[1] VTPI. *TDM Encyclopedia*. http://www.vtpi.org/tdm/tdm34.htm; Accessed 3/5/2010.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[58]
CO_2e	1 – 15% of running
PM	1 – 15% of running
CO	1 – 15% of running
NOx	1 – 15% of running
SO_2	1 – 15% of running
ROG	0.6 – 9% of total

Discussion:

This strategy is often part of Commute Trip Reduction (CTR) Program, another strategy documented separately (see TRT-1 and TRT-2). The Project Applicant should take care not to double count the impacts.

Example:

Sample calculations are provided below:

[58] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

- Low Range % VMT Reduction (low density suburb and 20% eligible) = 5% * 20% = 1%
- High Range % VMT Reduction (urban and 100% eligible) = 15% * 1 = 15%

Preferred Literature:

- 5 – 15% reduction of commute VMT

The *Transportation Demand Management (TDM) Encyclopedia* notes that because rideshare passengers tend to have relatively long commutes, mileage reductions can be relatively large with rideshare. If ridesharing reduces 5% of commute trips it may reduce 10% of vehicle miles because the trips that are reduced are twice as long as average. Rideshare programs can reduce up to 8.3% of commute VMT, up to 3.6% of total regional VMT, and up to 1.8% of regional vehicle trips (Apogee, 1994; TDM Resource Center, 1996). Another study notes that ridesharing programs typically attract 5-15% of commute trips if they offer only information and encouragement, and 10-30% if they also offer financial incentives such as parking cash out or vanpool subsidies (York and Fabricatore, 2001).

Alternative Literature:

- Up to 1% reduction in VMT (if combined with two other strategies)

Per the Nelson\Nygaard report [2], ride-sharing would fall under the category of a minor TDM program strategy. The report allows a 1% reduction in VMT for projects with at least three minor strategies.

Alternative Literature References:

[2] Nelson\Nygaard, 2005. *Crediting Low-Traffic Developments* (p.12). http://www.montgomeryplanning.org/transportation/documents/TripGenerationAnalysisUsingURBEMIS.pdf

Criteron Planner/Engineers and Fehr & Peers Associates (2001). Index 4D Method. *A Quick-Response Method of Estimating Travel Impacts from Land-Use Changes*. Technical Memorandum prepared for US EPA, October 2001.

Other Literature Reviewed:

None

3.4.4 Implement Subsidized or Discounted Transit Program

Range of Effectiveness: 0.3 – 20.0% commute vehicle miles traveled (VMT) reduction and therefore a 0.3 – 20.0% reduction in commute trip GHG emissions.

Measure Description:

This project will provide subsidized/discounted daily or monthly public transit passes. The project may also provide free transfers between all shuttles and transit to participants. These passes can be partially or wholly subsidized by the employer, school, or development. Many entities use revenue from parking to offset the cost of such a project.

Measure Applicability:

- Urban and suburban context
- Negligible in a rural context
- Appropriate for residential, retail, office, industrial, and mixed-use projects

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Percentage of project employees eligible
- Transit subsidy amount
- Location of project site: low density suburb, suburban center, or urban location

Mitigation Method:

$$\% \text{ VMT Reduction} = A * B * C$$

Where

A = % reduction in commute vehicle trips (VT) (from [1])

B = % employees eligible
C = Adjustment from commute VT to commute VMT

Detail:

- A:

	Daily Transit Subsidy			
	$0.75	$1.49	$2.98	$5.96
Worksite Setting	**% Reduction in Commute VT**			
Low density suburb	**1.5%**	**3.3%**	**7.9%**	**20.0%***
Suburban center	**3.4%**	**7.3%**	**16.4%**	**20.0%***
Urban location	**6.2%**	**12.9%**	**20.0%***	**20.0%***
* Discounts greater than 20% will be capped, as they exceed levels recommended by TCRP 95 Draft Chapter 19 and other literature.				

- C: 1.0 (see Appendix C for detail)

Assumptions:

Data based upon the following references:

[1] Nelson\Nygaard, 2010. *City of Santa Monica Land Use and Circulation Element EIR Report, Appendix – Santa Monica Luce Trip Reduction Impacts Analysis* (p.401).

[2] Nelson\Nygaard used the following literature sources: VTPI, Todd Litman, *Transportation Elasticities, http://www.vtpi.org/elasticities.pdf*. Comsis Corporation (1993), *Implementing Effective Travel Demand Management Measures: Inventory of Measures and Synthesis of Experience*, USDOT and Institute of Transportation Engineers (www.ite.org); www.bts.gov/ntl/DOCS/474.html.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[59]
CO_2e	0.3 - 20% of running
PM	0.3 - 20% of running
CO	0.3 - 20% of running
NOx	0.3 - 20% of running
SO_2	0.3 - 20% of running
ROG	0. 18 - 12% of total

[59] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

Discussion:

This strategy is often part of a Commute Trip Reduction (CTR), another strategy documented separately (see TRT-1 and TRT-2). The Project Applicant should take care not to double count the impacts.

The literature evaluates this strategy in relation to the employer, but keep in mind that this strategy can also be implemented by a school or the development as a whole.

Example:

Sample calculations are provided below:

- Low Range % VMT Reduction ($0.75, low density suburb, 20% eligible) = 1.5% * 20% = 0.3%
- High Range % VMT Reduction ($5.96, urban, 100% eligible) = 20% * 100% = 20%

Preferred Literature:

Commute Vehicle Trip Reduction	**Daily Transit Subsidy**			
Worksite Setting	**$0.75**	**$1.49**	**$2.98**	**$5.96**
Low density suburb, rideshare oriented	0.1%	0.2%	0.6%	1.9%
Low density suburb, mode neutral	1.5%	3.3%	7.9%	21.7%*
Low density suburb, transit oriented	2.0%	4.2%	9.9%	23.2%*
Activity center, rideshare oriented	1.1%	2.4%	5.8%	16.5%
Activity center, mode neutral	3.4%	7.3%	16.4%	38.7%*
Activity center, transit oriented	5.2%	10.9%	23.5%*	49.7%*
Regional CBD/Corridor, rideshare oriented	2.2%	4.7%	10.9%	28.3%*
Regional CBD/Corridor, mode neutral	6.2%	12.9%	26.9%*	54.3%*
Regional CBD/Corridor, transit oriented	9.1%	18.1%	35.5%*	64.0%*

* Discounts greater than 20% will be capped, as they exceed levels recommended by *TCRP 95 Draft Chapter 19* and other literature.

Nelson\Nygaard (2010) updated a commute trip reduction table from VTPI Transportation Elasticities to account for inflation since the data was compiled. Data regarding commute vehicle trip reductions was originally from a study conducted by Comsis Corporation and the Institute of Transportation Engineers (ITE).

Alternative Literature:

Alternate:

- 2.4-30.4% commute vehicle trip reduction (VTR)

TCRP 95 Draft Chapter 19 [2] indicates transit subsidies in areas with good transit and restricted parking have a commute VTR of 30.4%; good transit but free parking, a commute VTR of 7.6%; free parking and limited transit 2.4%. Programs with transit subsidies have an average commute VTR of 20.6% compared with an average commute VTR of 13.1% for sites with non-transit fare subsidies.

Alternate:

- 0.03-0.12% annual greenhouse gas (GHG) reduction

Moving Cooler [3] assumed price elasticities of -0.15, -0.2, and -0.3 for lower fares 25%, 33%, and 50%, respectively. *Moving Cooler* assumes average vehicle occupancy of 1.43 and a VMT/trip of 5.12.

Alternative Literature References:

[2] Pratt, Dick. Personal Communication Regarding the Draft of TCRP 95 Traveler Response to Transportation System Changes – Chapter 19 Employer and Institutional TDM Strategies.

[3] Cambridge Systematics. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Technical Appendices. Prepared for the Urban Land Institute. (Table D.3) http://www.movingcooler.info/Library/Documents/Moving%20Cooler_Appendix%20B_Effectiveness_102209.pdf

Other Literature Reviewed:

None

3.4.5 Provide End of Trip Facilities

Range of Effectiveness: Grouped strategy (see TRT-1 through TRT-3)

Measure Description:

Non-residential projects will provide "end-of-trip" facilities for bicycle riders including showers, secure bicycle lockers, and changing spaces. End-of-trip facilities encourage the use of bicycling as a viable form of travel to destinations, especially to work. End-of-trip facilities provide the added convenience and security needed to encourage bicycle commuting.

End-of-trip facilities have minimal impacts when implemented alone. This strategy's effectiveness in reducing vehicle miles traveled (VMT) depends heavily on the suite of other transit, pedestrian/bicycle, and demand management measures offered. End-of-trip facilities should be grouped with Commute Trip Reduction (CTR) Programs (TRT-1 through TRT-2).

Measure Applicability:

- Urban, suburban, and rural context
- Appropriate for residential, retail, office, industrial, and mixed-use projects

Alternative Literature:

Alternate:

- 22% increase in bicycle mode share

The bicycle study documents a multivariate analysis of UK National Travel Survey (Wardman et al. 2007) which found significant impacts on bicycling to work. Compared to base bicycle mode share of 5.8% for work trips, outdoor parking would raise the share to 6.3%, indoor secure parking to 6.6%, and indoor parking plus showers to 7.1%. This results in an estimate 22% increase in bicycle mode share ((7.1%-5.8%)/5.8% = 22%). This suggests that such end of trip facilities have an important impact on the decision to bicycle to work. However, these effects represent reductions in VMT no greater than 0.02% (see Appendix C for calculation detail).

Alternate:

- 2 - 5% reduction in commute vehicle trips

The *Transportation Demand Management (TDM) Encyclopedia*, citing Ewing (1993), documents Sacramento's TDM ordinance. The City allows developers to claim trip reduction credits for worksite showers and lockers of 5% in central business districts, 2% within 660 feet of a transit station, and 2% elsewhere.

Alternate:

- 0.625% reduction in VMT

The *Center for Clean Air Policy (CCAP) Guidebook* attributes a 1% to 5% reduction associated with the use of bicycles, which reflects the assumption that their use is typically for shorter trips. Based on the *CCAP Guidebook*, a 2.5% reduction is allocated for all bicycle-related measures and a 1/4 of that for this measure alone. (This information is based on a TIAX review for SMAQMD).

Alternative Literature References:

[1] Pucher J., Dill, J., and Handy, S. *Infrastructure, Programs and Policies to Increase Bicycling: An International Review.* February 2010. (Table 2, pg. S111) http://policy.rutgers.edu/faculty/pucher/Pucher_Dill_Handy10.pdf

[2] Victoria Transportation Policy Institute (VTPI). *TDM Encyclopedia,* http://www.vtpi.org/tdm/tdm9.htm; accessed 3/4/2010; last update 1/25/2010). VTPI citing: Reid Ewing (1993), "TDM, Growth Management, and the Other Four Out of Five Trips," *Transportation Quarterly*, Vol. 47, No. 3, Summer 1993, pp. 343-366.

[3] Center for Clean Air Policy (CCAP), *CCAP Transportation Emission Guidebook*. http://www.ccap.org/safe/guidebook/guide_complete.html; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD

Other Literature Reviewed:

None

3.4.6 Encourage Telecommuting and Alternative Work Schedules

Range of Effectiveness: 0.07 – 5.50% commute vehicle miles traveled (VMT) reduction and therefore 0.07 – 5.50% reduction in commute trip GHG emissions.

Measure Description:

Encouraging telecommuting and alternative work schedules reduces the number of commute trips and therefore VMT traveled by employees. Alternative work schedules could take the form of staggered starting times, flexible schedules, or compressed work weeks.

Measure Applicability:

- Urban, suburban, and rural context
- Appropriate for retail, office, industrial, and mixed-use projects

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Percentage of employees participating (1 – 25%)
- Strategy implemented: 9-day/80-hour work week, 4-day/40-hour work week, or 1.5 days of telecommuting

Mitigation Method:

% Commute VMT Reduction = Commute

Where

Commute = % reduction in commute VMT (See table below)

	Employee Participation				
	1%	**3%**	**5%**	**10%**	**25%**
	% Reduction in Commute VMT				
9-day/80-hour work week	0.07%	0.21%	0.35%	0.70%	1.75%
4-day/40-hour work week	0.15%	0.45%	0.75%	1.50%	3.75%
telecommuting 1.5 days	0.22%	0.66%	1.10%	2.20%	5.5%
Source: Moving Cooler Technical Appendices, Fehr & Peers Notes: The percentages from Moving Cooler incorporate a discount of 25% for rebound effects. The percentages beyond 1% employee participation are linearly extrapolated.					

Assumptions:

Data based upon the following references:

[1] Cambridge Systematics. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Technical Appendices. Prepared for the Urban Land Institute. (p. B-54) http://www.movingcooler.info/Library/Documents/Moving%20Cooler_Appendix%20B_Effectiveness_102209.pdf

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[60]
CO_2e	0.07 – 5.50% of running
PM	0.07 – 5.50% of running
CO	0.07 – 5.50% of running
NOx	0.07 – 5.50% of running
SO_2	0.07 – 5.50% of running
ROG	0.04 – 3.3% of total

Discussion:

This strategy is often part of a Commute Trip Reduction Program, another strategy documented separately (see TRT-1 and TRT-2). The Project Applicant should take care not to double count the impacts.

The employee participation rate should be capped at a maximum of 25%. *Moving Cooler* [1] notes that roughly 50% of a typical workforce could participate in alternative

▪ [60] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

work schedules (based on job requirements) and roughly 50% of those would choose to participate.

The 25% discount for rebound effects is maintained to provide a conservative estimate and support the literature results. The project may consider removing this discount from their calculations if deemed appropriate.

Example:

N/A – no calculations are needed.

Preferred Literature:

- 0.07% - 0.22% reduction in commuting VMT

Moving Cooler [1] estimates that if 1% of employees were to participate in a 9 day/80 hour compressed work week, commuting VMT would be reduced by 0.07%. If 1% of employees were to participate in a 4 day/40 hour compressed work week, commuting VMT would reduce by 0.15%; and 1% of employees participating in telecommuting 1.5 days per week would reduce commuting VMT by 0.22%. These percentages incorporate a discounting of 25% to account for rebound effects (i.e., travel for other purposes during the day while not at the work site). The percentages beyond 1% employee participation are linearly extrapolated (see table above).

Alternative Literature:

Alternate:

- 9-10% reduction in VMT for participating employees

As documented in *TCRP 95 Draft Chapter 19* [2], a Denver federal employer's implementation of compressed work week resulted in a 14-15% reduction in VMT for participating employees. This is equivalent to the 0.15% reduction for each 1% participation cited in the preferred literature above. In the Denver example, there was a 65% participation rate out of a total of 9,000 employees. *TCRP 95* states that the compressed work week experiment has no adverse effect on ride-sharing or transit use. Flexible hours have been shown to work best in the presence of medium or low transit availability.

Alternate:

- 0.5 vehicle trips reduced per employee per week
- 13 – 20 VMT reduced per employee per week

As documented in *TCRP 95 Draft Chapter 19* [2], a study of compressed work week for 2,600 Southern California employees resulted in an average reduction of 0.5 trips per week (per participating employee). Participating employees also reduced their VMT by 13-20 miles per week. This translates to a reduction of between 5% and 10% in commute VMT, and so is lower than the 15% reduction cited for Denver government employees.

Alternative Literature References:

[2] Pratt, Dick. Personal Communication Regarding the Draft of TCRP 95 Traveler Response to Transportation System Changes – Chapter 19 Employer and Institutional TDM Strategies.

Other Literature Reviewed:

None

3.4.7 Implement Commute Trip Reduction Marketing

Range of Effectiveness: 0.8 – 4.0% commute vehicle miles traveled (VMT) reduction and therefore 0.8 – 4.0% reduction in commute trip GHG emissions.

Measure Description:

The project will implement marketing strategies to reduce commute trips. Information sharing and marketing are important components to successful commute trip reduction strategies. Implementing commute trip reduction strategies without a complementary marketing strategy will result in lower VMT reductions. Marketing strategies may include:

- New employee orientation of trip reduction and alternative mode options
- Event promotions
- Publications

CTR marketing is often part of a CTR program, voluntary or mandatory. CTR marketing is discussed separately here to emphasis the importance of not only providing employees with the options and monetary incentives to use alternative forms of transportation, but to clearly and deliberately promote and educate employees of the various options. This will greatly improve the impact of the implemented trip reduction strategies.

Measure Applicability:

- Urban and suburban context
- Negligible in a rural context
- Appropriate for residential, retail, office, industrial and mixed-use projects

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled
$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Percentage of project employees eligible (i.e. percentage of employers choosing to participate)

Mitigation Method:

% Commute VMT Reduction = A * B * C

Where

A = % reduction in commute vehicle trips (from [1])
B = % employees eligible
C = Adjustment from commute VT to commute VMT

Detail:

- A: 4% (per [1])
- C: 1.0 (see Appendix C for detail)

Assumptions:

Data based upon the following references:

[1] Pratt, Dick. Personal communication regarding the *Draft of TCRP 95 Traveler Response to Transportation System Changes – Chapter 19 Employer and Institutional TDM Strategies.* Transit Cooperative Research Program.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[61]
CO_2e	0.8 – 4.0% of running
PM	0.8 – 4.0% of running
CO	0.8 – 4.0% of running
NOx	0.8 – 4.0% of running
SO_2	0.8 – 4.0% of running
ROG	0.5 – 2.4% of total

[61] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

Discussion:

The effectiveness of commute trip reduction marketing in reducing VMT depends on which commute reduction strategies are being promoted. The effectiveness levels provided below should only be applied if other programs are offered concurrently, and represent the total effectiveness of the full suite of measures.

This strategy is often part of a CTR Program, another strategy documented separately (see strategy T# E1). Take care not to double count the impacts.

Example:

Sample calculations are provided below:

- Low Range % VMT Reduction (20% eligible) = 4% * 20% = 0.8%
- High Range % VMT Reduction (100% eligible) = 4% * 100% = 4.0%

Preferred Literature:

- 4-5% commute vehicle trips reduced with full-scale employer support

TCRP 95 Draft Chapter 19 notes the average empirically-based estimate of reductions in vehicle trips for full-scale, site-specific employer support programs alone is 4-5%. This effectiveness assumes there are alternative commute modes available which have on-going employer support. For a program to receive credit for such outreach and marketing efforts, it should contain guarantees that the program will be maintained permanently, with promotional events delivered regularly and with routine performance monitoring.

Alternative Literature:

- 5-15% reduction in commute vehicle trips
- 3% increase in effectiveness of marketed transportation demand management (TDM) strategies

VTPI [2] notes that providing information on alternative travel modes by employers was one of the most important factors contributing to mode shifting. One study (Shadoff,1993) estimates that marketing increases the effectiveness of other TDM strategies by up to 3%. Given adequate resources, marketing programs may reduce vehicle trips by 5-15%. The 5 – 15% range comes from a variety of case studies across the world. U.S. specific case studies include: 9% reduction in vehicle trips with TravelSmart in Portland (12% reduction in VMT), 4-8% reduction in vehicle trips from four cities with individualized marketing pilot projects from the Federal Transit Administration (FTA). Averaged across the four pilot projects, there was a 6.75% reduction in VMT.

Alternative Literature References:

[2] VTPI, TDM Encyclopedia – TDM Marketing; http://www.vtpi.org/tdm/tdm23.htm; accessed 3/5/2010. Table 7 (citing FTA, 2006)

Other Literature Reviewed:

None

3.4.8 Implement Preferential Parking Permit Program

Range of Effectiveness: Grouped strategy (see TRT-1 through TRT-3)

Measure Description:

The project will provide preferential parking in convenient locations (such as near public transportation or building front doors) in terms of free or reduced parking fees, priority parking, or reserved parking for commuters who carpool, vanpool, ride-share or use alternatively fueled vehicles. The project will provide wide parking spaces to accommodate vanpool vehicles.

The impact of preferential parking permit programs has not been quantified by the literature and is likely to have negligible impacts when implemented alone. This strategy should be grouped with Commute Trip Reduction (CTR) Programs (TRT-1 and TRT-2) as a complementary strategy for encouraging non-single occupant vehicle travel.

Measure Applicability:

- Urban, suburban context
- Appropriate for residential, retail, office, mixed use, and industrial projects

Alternative Literature:

No quantitative results are available. The case study in the literature implemented a preferential parking permit program as a companion strategy to a comprehensive TDM program. Employees who carpooled at least three times a week qualified to use the spaces.

Alternative Literature References:

[1] Transportation Demand Management Institute of the Association for Commuter Transportation. *TDM Case Studies and Commuter Testimonials*. Prepared for the US EPA. 1997. http://www.epa.gov/OMS/stateresources/rellinks/docs/tdmcases.pdf

Other Literature Reviewed:

None

3.4.9 Implement Car-Sharing Program

Range of Effectiveness: 0.4 – 0.7% vehicle miles traveled (VMT) reduction and therefore 0.4 – 0.7% reduction in GHG emissions.

Measure Description:

This project will implement a car-sharing project to allow people to have on-demand access to a shared fleet of vehicles on an as-needed basis. User costs are typically determined through mileage or hourly rates, with deposits and/or annual membership fees. The car-sharing program could be created through a local partnership or through one of many existing car-share companies. Car-sharing programs may be grouped into three general categories: residential- or citywide-based, employer-based, and transit station-based. Transit station-based programs focus on providing the “last-mile” solution and link transit with commuters’ final destinations. Residential-based programs work to substitute entire household based trips. Employer-based programs provide a means for business/day trips for alternative mode commuters and provide a guaranteed ride home option.

Measure Applicability:

- Urban and suburban context
- Negligible in a rural context
- Appropriate for residential, retail, office, industrial, and mixed-use projects

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Urban or suburban context

Mitigation Method:

% VMT Reduction = A * B / C

Where

A = % reduction in car-share member annual VMT (from the literature)

B = number of car share members per shared car (from the literature)

C = deployment level based on urban or suburban context

Detail:

- A: 37% *(per [1])*
- B: 20 *(per [2])*
- C:

Project setting	1 shared car per X population
Urban	1,000
Suburban	2,000
Source: *Moving Cooler*	

Assumptions:

Data based upon the following references:

[1] Millard-Ball, Adam. "Car-Sharing: Where and How it Succeeds," (2005) Transit Cooperative Research Program (108). P. 4-22

[2] Cambridge Systematics. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Technical Appendices. Prepared for the Urban Land Institute. (p. B-52, Table D.3) http://www.movingcooler.info/Library/Documents/Moving%20Cooler_Appendices_Complete_102209.pdf

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[62]
CO_2e	0.4 – 0.7% of running
PM	0.4 – 0.7% of running
CO	0.4 – 0.7% of running
NOx	0.4 – 0.7% of running
SO_2	0.4 – 0.7% of running
ROG	0.24 – 0.42% of total

[62] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

Discussion:

Variable C in the mitigation method section represents suggested levels of deployment based on the literature. Levels of deployment may vary based on the characteristics of the project site and the needs of the project residents and employees. This variable should be adjusted accordingly.

The methodology for calculation of VMT reduction utilizes *Moving Cooler's* rule of thumb[63] for the estimated number of car share members per vehicle. An estimate of 50% reduction in car-share member annual VMT (from *Moving Cooler*) was high compared to other literature sources, and *TCRP 108's* 37% reduction was used in the calculations instead.

Example:

Sample calculations are provided below:

- Low Range % VMT Reduction (suburban) = 37% * 20 / 2000 = 0.4%
- High Range % VMT Reduction (urban) = 37% * 20 / 1000 = 0.7%

Preferred Literature:

- 37% reduction in car-share member VMT

The *TCRP 108* [1] report conducted a survey of car-share members in the United States and Canada in 2004. The results of the survey showed that respondents, on average, drove only 63% of the average mileage they previously drove when not car-share members.

Alternative Literature:

Alternate – Residential or Citywide Based:

- 0.05-0.27% reduction in GHG
- 0.33% reduction in VMT in urban areas

Moving Cooler [2] assumed an aggressive deployment of one car per 2,000 inhabitants of medium-density census tracks and of one car per 1,000 inhabitants of high-density census tracks. This strategy assumes providing a subsidy to a public, private, or nonprofit car-sharing organization and providing free or subsidized lease for usage of public street parking. *Moving Cooler* assumed 20 members per shared car and 50% reduction in VMT per equivalent car. The percent reduction calculated assumes a percentage of urban areas are low, medium, and high density, thus resulting in a lower

▪ [63] See discussion in Alternative Literature section for "rule of thumb" detail.

than expected reduction in VMT assuming an aggressive deployment in medium and high density areas.

Alternate – Transit Station and Employer Based:

- 23-44% reduction in drive-alone mode share
- Average daily VMT reduction of 18 – 23 miles

TCRP 95 Draft Chapter 19 [3] looked at two demonstrations, CarLink I and CarLink II, in the San Francisco Bay Area. CarLink I ran from January to November 1999. It involved 54 individuals and 12 rental cars stationed at the Dublin-Pleasanton BART station. CarLink II ran from July 2001 to June 2002 and involved 107 individuals and 19 rental cars. CarLink II was based in Palo Alto in conjunction with Caltrain commuter rail service and several employers in the Stanford Research Park. Both CarLink demonstrations were primarily targeted for commuters. CarLink I had a 23% increase in rail mode share, a reduction in drive-alone mode share of 44%, and a decrease in Average Daily VMT of 18 miles. CarLink II had a VMT for round-trip commuters decrease of 23 miles per day and a mode share for drive alone decrease of 22.9%.

Alternate:

- 50% reduction in driving for car-share members

A UC Berkeley study of San Francisco's City CarShare [4] found that members drive nearly 50% less after joining. The study also found that when people joined the car-sharing organization, nearly 30% reduced their household vehicle ownership and two-thirds avoided purchasing another car. The UC Berkeley study found that almost 75% of vehicle trips made by car-sharing members were for social trips such as running errands and visiting friends. Only 25% of trips were for commuting to work or for recreation. Most trips were also made outside of peak periods. Therefore, car-sharing may generate limited impact on peak period traffic.

Alternative Literature References:

[3] Cambridge Systematics. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Technical Appendices. Prepared for the Urban Land Institute. (p. B-52, Table D.3) http://www.movingcooler.info/Library/Documents/Moving%20Cooler_Appendices_Complete_102209.pdf

[4] Pratt, Dick. *Personal Communication Regarding the Draft of TCRP 95 Traveler Response to Transportation System Changes – Chapter 19 Employer and Institutional TDM Strategies.* Transit Cooperative Research Program.

Cervero, Robert and Yu-Hsin Tsai. *San Francisco City CarShare: Travel-Demand Trends and Second-Year Impacts,* 2005. (Figure 7, p. 35, Table 7, Table 12) http://escholarship.org/uc/item/4f39b7b4

Other Literature Reviewed:

None

3.4.10 Implement a School Pool Program

Range of Effectiveness: 7.2 – 15.8% school vehicle miles traveled (VMT) Reduction and therefore 7.2 – 15.8% reduction in school trip GHG emissions.

Measure Description:

This project will create a ridesharing program for school children. Most school districts provide bussing services to public schools only. SchoolPool helps match parents to transport students to private schools, or to schools where students cannot walk or bike but do not meet the requirements for bussing.

Measure Applicability:

- Urban, suburban, and rural context
- Appropriate for residential and mixed-use projects

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Degree of implementation of SchoolPool Program(moderate to aggressive)

Mitigation Method:

$$\% \text{ VMT Reduction} = \text{Families} * B$$

Where

Families = % families that participate (from [1] and [2])
B = adjustments to convert from participation to daily VMT to annual school VMT

Detail:

- Families: 16% (moderate implementation), 35% (aggressive implementation), (from [1] and [2])
- B: 45% (see Appendix C for detail)

Assumptions:

Data based upon the following references:

[1] Transportation Demand Management Institute of the Association for Commuter Transportation. *TDM Case Studies and Commuter Testimonials*. Prepared for the US EPA. 1997. (p. 10, 36-38) http://www.epa.gov/OMS/stateresources/rellinks/docs/tdmcases.pdf

[2] Denver Regional Council of Governments (DRCOG). *Survey of Schoolpool Participants, April 2008.* http://www.drcog.org/index.cfm?page=SchoolPool. Obtained from Schoolpool Coordinator, Mia Bemelen.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[64]
CO_2e	7.2 – 15.8% of running
PM	7.2 – 15.8% of running
CO	7.2 – 15.8% of running
NOx	7.2 – 15.8% of running
SO_2	7.2 – 15.8% of running
ROG	4.3 – 9.5% of total

Discussion:

This strategy reflects the findings from only one case study.

Example:

Sample calculations are provided below:

- Low Range % School VMT Reduction (moderate implementation) = 16% * 45% = 7.2%
- High Range % School VMT Reduction (aggressive implementation) = 35% * 45% = 15.8%

[64] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

Preferred Literature:

- 7,711 – 18,659 daily VMT reduction

As presented in the TDM Case Studies [1] compilation, the SchoolPool program in Denver saved 18,659 VMT per day in 1995, compared with 7,711 daily in 1994 – a 142% increase. The Denver Regional Council of Governments (DRCOG) [2] enrolled approximately 7,000 families and 32 private schools in the program. The DRCOG staff surveyed a school or interested families to collect home location and schedules of the students. The survey also identified prospective drivers. DRCOG then used carpool-matching software and GIS to match families. These match lists were sent to the parents for them to form their own school pools. 16% of families in the database formed carpools. The average carpool carried 3.1 students.

The SchoolPool program is still in effect and surveys are conducted every few years to monitor the effectiveness of the program. The latest survey report received was in 2008. The report showed that the participant database had increased to over 10,000 families, an 18% increase from 2005. 29% of participants used the list to form a school carpool. This percentage was lower than 35% in 2005 but higher than prior to 2005, at 24%. The average number of families in each carpool ranged from 2.1 prior to 2005 to 2.8 in 2008. The average number of carpool days per week was roughly 4.7. The number of school weeks per year was 39. Per discussions with the Schoolpool Coordinator, a main factor of success was establishing a large database. This was achieved by having parents opt-out of the database versus opting-in.

Alternative Literature:

None

Alternative Literature References:

None

Other Literature Reviewed:

None

3.4.11 Provide Employer-Sponsored Vanpool/Shuttle

Range of Effectiveness: 0.3 – 13.4% commute vehicle miles traveled (VMT) reduction and therefore 0.3 – 13.4% reduction in commute trip GHG emissions.

Measure Description:

This project will implement an employer-sponsored vanpool or shuttle. A vanpool will usually service employees' commute to work while a shuttle will service nearby transit stations and surrounding commercial centers. Employer-sponsored vanpool programs entail an employer purchasing or leasing vans for employee use, and often subsidizing the cost of at least program administration, if not more. The driver usually receives personal use of the van, often for a mileage fee. Scheduling is within the employer's purview, and rider charges are normally set on the basis of vehicle and operating cost.

Measure Applicability:

- Urban, suburban, and rural context
- Appropriate for office, industrial, and mixed-use projects

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled
$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Percentage of employees eligible

Mitigation Method:

$$\% \text{ VMT Reduction} = A * B * C$$

Where
A = % shift in vanpool mode share of commute trips (from [1])
B = % employees eligible
C = adjustments from vanpool mode share to commute VMT

Detail:

- A: 2-20% annual reduction in vehicle mode share (*from [1]*)
  - Low range: low degree of implementation, smaller employers
  - High range: high degree of implementation, larger employers
- C: 0.67 (See Appendix C for detail)

Assumptions:

Data based upon the following references:

[1] TCRP Report 95. *Chapter 5: Vanpools and Buspools - Traveler Response to Transportation System Changes.* http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_95c5.pdf. (p.5-8)

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[65]
CO_2e	0.3 – 13.4% of running
PM	0.3 – 13.4% of running
CO	0.3 – 13.4% of running
NOx	0.3 – 13.4% of running
SO_2	0.3 – 13.4% of running
ROG	0.18 – 8.0% of total

Discussion:

Vanpools are generally more successful with the largest of employers, as large employee counts create the best opportunities for employees to find a suitable number of travel companions to form a vanpool. In the San Francisco Bay Area several large companies (such as Google, Apple, and Genentech) provide regional bus transportation for their employees. No specific studies of these large buspools were identified in the literature. However, the GenenBus serves as a key element of the overall commute trip reduction (CTR) program for Genentech, as discussed in the CTR Program – Required strategy.

This strategy is often part of a CTR Program, another strategy documented separately (see strategy T# E1). Take care not to double count the impacts.

Example:

Sample calculations are provided below:

[65] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

- Low Range % VMT Reduction (low implementation/small employer, 20% eligible) = 2% * 20% * 0.67 = 0.3%
- High Range % VMT Reduction (high implementation/large employer, 100% eligible) = 20% * 100% * 0.67 = 13.4%

Preferred Literature:

- 2-20% vanpool mode share

TCRP Report 95 [1] notes that vanpools can capture 2 to 20% mode share. This range can be attributed to differences in programs, access to high-occupancy vehicle (HOV) lanes, and geographic range. The *TCRP Report* highlights a case study of the 3M Corporation, which with the implementation of a vanpooling program saw drive alone mode share decrease by 10 percentage points and vanpooling mode share increase to 7.8 percent. The *TCRP Report* notes most vanpools programs do best where one-way trip lengths exceed 20 miles, where work schedules are fixed and regular, where employer size is sufficient to allow matching of 5 to 12 people from the same residential area, where public transit is inadequate, and were some congestion or parking problems exist.

Alternative Literature:

In *TDM Case Studies* [2], a case study of Kaiser Permanente Hospital has shown their employer-sponsored shuttle service eliminated 380,100 miles per month, or nearly 4 million miles of travel per year, and four tons of smog precursors annually.

Alternative Literature References:

[2] Transportation Demand Management Institute of the Association for Commuter Transportation. *TDM Case Studies and Commuter Testimonials*. Prepared for the US EPA. 1997. http://www.epa.gov/OMS/stateresources/rellinks/docs/tdmcases.pdf

Other Literature Reviewed:

None

3.4.12 Implement Bike-Sharing Programs

Range of Effectiveness: Grouped strategy (see SDT-5 and LUT-9)

Measure Description:

This project will establish a bike sharing program. Stations should be at regular intervals throughout the project site. The number of bike-share kiosks throughout the project area should vary depending on the density of the project and surrounding area. Paris' bike-share program places a station every few blocks throughout the city (approximately 28 bike stations/square mile). Bike-station density should increase around commercial and transit hubs.

Bike sharing programs have minimal impacts when implemented alone. This strategy's effectiveness is heavily dependent on the location and context. Bike-sharing programs have worked well in densely populated areas (examples in Barcelona, London, Lyon, and Paris) with existing infrastructure for bicycling. Bike sharing programs should be combined with **Bike Lane Street Design (SDT-5)** and **Improve Design of Development (LUT-9)**.

Taking evidence from the literature, a 135-300% increase in bicycling (of which roughly 7% are shifting from vehicle travel) results in a negligible impact (around 0.03% vehicle miles traveled (VMT) reduction (see Appendix C for calculations)).

Measure Applicability:

- Urban and suburban-center context only
- Negligible in a rural context
- Appropriate for residential, retail, office, industrial, and mixed-use projects

Alternative Literature:

Alternate:

The International Review [1] found bike mode share increases:

- from 0.75% in 2005 to 1.76% in 2007 in Barcelona (Romero, 2008) (135% increase)
- From 1% in 2001 to 2.5% in 2007 in Paris (Nadal, 2007; City of Paris, 2007) (150% increase)
- From 0.5% in 1995 to 2% in 2006 in Lyon (Bonnette, 2007; Velo'V, 2009) (300% increase)

London [2] is the only study that reports the breakdown of the prior mode In London: 6% of users reported shifting from driving, 34% from transit, 23% said they would not have travelled (Noland and Ishaque, 2006). Additionally, 68% of the bike trips were for leisure or recreation. Companion strategies included concurrent improvements in bicycle facilities.

The London program was implemented west of Central London in a densely populated area, mainly residential, with several employment centers. A relatively well developed bike network existed, including over 1,000 bike racks. The program implemented 25 locker stations with 70 bikes total.

Alternate:

- 1/3 vehicle trip reduced per day per bicycle (1,000 vehicle trips reduced per day in Lyon)

The Bike Share Opportunities [3] report looks at two case studies of bike-sharing implementation in France. In Lyon, the 3,000 bike-share system shifts 1,000 car trips to bicycle each day. Surveys indicate that 7% of the bike share trips would have otherwise been made by car. Lyon saw a 44% increase in bicycle riding within the first year of their program while Paris saw a 70% increase in bicycle riding and a 5% reduction in car use and congestion within the first year and a half of their program. The Bike Share Opportunities report found that population density is an important part of a successful program. Paris' bike share subscription rates range between 6% and 9% of the total population. This equates to an average of 75,000 rentals per day. The effectiveness of bike share programs at sub-city scales are not addressed in the literature.

Alternative Literature References:

[1] Pucher J., Dill, J., and Handy, S. Infrastructure, Programs and Policies to Increase Bicycling: An International Review. February 2010. (Table 4)

[2] Noland, R.B., Ishaque, M.M., 2006. "Smart Bicycles in an urban area: Evaluation of a pilot scheme in London." *Journal of Public Transportation*. 9(5), 71-95. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.117.8173&rep=rep1&type=pdf#page=76

[3] NYC Department of City Planning, *Bike-Share Opportunities in New York City,* 2009. (p. 11, 14, 24, 68) http://www.nyc.gov/html/dcp/html/transportation/td_bike_share.shtml

Other Literature Reviewed:

None

3.4.13 Implement School Bus Program

Measure Effectiveness Range: 38 – 63% School VMT Reduction and therefore 38 – 63% reduction in school trip GHG emissions[66]

Measure Description:

The project will work with the school district to restore or expand school bus services in the project area and local community.

Measure Applicability:

- Urban, suburban, and rural context
- Appropriate for residential and mixed-use projects

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Percentage of families expected to use/using school bus program

Mitigation Method:

$$\% \text{ VMT Reduction} = A * B$$

Where

A = % families expected to use/using school bus program

B = adjustments to convert from participation to school day VMT to annual school VMT

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[66] Transit vehicles may also result in increases in emissions that are associated with electricity production or fuel use. The Project Applicant should consider these potential additional emissions when estimating mitigation for these measures.

Detail:

- A: a typical range of 50 – 84% (see discussion section)
- B: 75% (see Appendix C for detail)

Assumptions:

Data based upon the following references:

[1] JD Franz Research, Inc.; *Lamorinda School Bus Program, 2003 Parent Survey, Final Report;* January 2004; obtained from Juliet Hansen, Program Manager. (p. 5)

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[67]
CO_2e	38 – 63% of running
PM	38 – 63% of running
CO	38 – 63% of running
NOx	38 – 63% of running
SO_2	38 – 63% of running
ROG	23 – 38% of total

Discussion:

The literature presents a high range of effectiveness showing 84% participation by families. 50% is an estimated low range assuming the project has a minimum utilization goal. Note that the literature presents results from a single case study.

Example:

Sample calculations are provided below:

- Low Range % VMT Reduction (50% participation) = 50% * 75% = 38%
- High Range % VMT Reduction (85% participation) = 84% * 75% = 63%

Preferred Literature:

- 84% penetration rate
- 2,451 – 2,677 daily vehicle trips reduced
- 441,180 – 481,860 annual vehicle trips reduced

[67] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

The Lamorinda School Bus Program was implemented to reduce traffic congestion in the communities of Lafayette, Orinda, and Moraga, California. In 2003, a parent survey was conducted to determine the extent to which the program diverted or eliminated vehicle trips. This survey covered a representative sample of all parents (not just those signed up for the school bus program). The range of morning trips prevented is 1,266 to 1,382; the range of afternoon trips prevented is 1,185 to 1,295. Annualized, the estimated total trip prevention is between 441,180 to 481,860. 83% of parents surveyed reported that their child usually rides the bus to school in the morning. 84% usually rode the bus back home in the afternoons. The data came from surveys and the results are unique to the location and extent of the program. The report did not indicate the number of school buses in operation during the time of the survey.

Alternative Literature:

None

Alternative Literature References:

None

Other Literature Reviewed:

None

3.4.14 Price Workplace Parking

Range of Effectiveness: 0.1 – 19.7% commute vehicle miles traveled (VMT) reduction and therefore 0.1 -19.7% reduction in commute trip GHG emissions.

Measure Description:

The project will implement workplace parking pricing at its employment centers. This may include: explicitly charging for parking for its employees, implementing above market rate pricing, validating parking only for invited guests, not providing employee parking and transportation allowances, and educating employees about available alternatives.

Though similar to the Employee Parking "Cash-Out" strategy, this strategy focuses on implementing market rate and above market rate pricing to provide a price signal for employees to consider alternative modes for their work commute.

Measure Applicability:

- Urban and suburban context
- Negligible impact in a rural context
- Appropriate for retail, office, industrial, and mixed-use projects
- Reductions applied only if complementary strategies are in place:
    - Residential parking permits and market rate public on-street parking - to prevent spill-over parking
    - Unbundled parking - is not required but provides a market signal to employers to transfer over the, now explicit, cost of parking to the employees. In addition, unbundling parking provides a price with which employers can utilize as a means of establishing workplace parking prices.

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Location of project site: low density suburb, suburban center, or urban location
- Daily parking charge ($1 - $6)
- Percentage of employees subject to priced parking

Mitigation Method:

% VMT Reduction = A * B

Where

A = Percentage reduction in commute VMT (from [1] and [2])

B = Percent of employees subject to priced parking

Detail:

- A:

Project Location	Daily Parking Charge			
	$1	$2	$3	$6
Low density suburb	0.5%	1.2%	1.9%	2.8%
Suburban center	1.8%	3.7%	5.4%	6.8%
Urban Location	6.9%	12.5%	16.8%	19.7%
Moving Cooler, VTPI, Fehr & Peers. Note: 2009 dollars.				

Assumptions:

Data based upon the following references:

[1] Cambridge Systematics. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Technical Appendices. Prepared for the Urban Land Institute. (Table 5.13, Table D.3) http://www.movingcooler.info/Library/Documents/Moving%20Cooler_Appendices_Complete_102209.pdf

[2] VTPI, Todd Litman, *Transportation Elasticities,*(Table 15) *http://www.vtpi.org/elasticities.pdf.*

Comsis Corporation (1993), *Implementing Effective Travel Demand Management Measures: Inventory of Measures and Synthesis of Experience*, USDOT and Institute of Transportation Engineers (www.ite.org); www.bts.gov/ntl/DOCS/474.html.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[68]
CO_2e	0.1 – 19.7% of running
PM	0.1 – 19.7% of running
CO	0.1 – 19.7% of running
NOx	0.1 – 19.7% of running
SO_2	0.1 – 19.7% of running
ROG	0.06 – 11.8% of total

Discussion:

Priced parking can result in parking spillover concerns. The highest VMT reductions should be given only with complementary strategies such as parking time limits or neighborhood parking permits are in place in surrounding areas.

Example:

Sample calculations are provided below:

- Low Range % Commute VMT Reduction (low density suburb, $1/day, 20% priced) = 0.5% * 20% = 0.1%
- High Range % Commute VMT Reduction (urban, $6/day, 100% priced) = 19.7% * 100% = 19.7%

Preferred Literature:

The table above (variable A) was calculated using the percent commute VMT reduction from *Moving Cooler* (0.5% - 6.9% reduction for $1/day parking charge). The percentage reductions for $2 - $6 / day parking charges were extrapolated by multiplying the *Moving Cooler* percentages with the ratios from the VTPI table below (percentage increases). For example, to obtain a percent VMT reduction for a $6/day parking charge for a low density suburb, 0.5% * ((36.1%-6.5%) /6.5%) = 2.3%. The methodology was utilized to capture the non-linear effect of parking charges on trip reduction (VTPI) while maintaining a conservative estimate of percent reductions (*Moving Cooler*).

Preferred:

- 0.5-6.9% reduction in commuting VMT
- 0.44-2.07% reduction in greenhouse gas (GHG) emissions

[68] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

Moving Cooler Technical Appendices indicate that increasing employee parking costs $1 per day ($0.50 per vehicle for carpool and free for vanpools) can reduce GHG between 0.44% and 2.07% and reduce commuting VMT between 0.5% and 6.9%. The reduction in GHG varies based on how extensive the implementation of the program is. The reduction in commuting VMT differs for type of urban area as shown in the table below. Please note that these numbers are independent of results for employee parking cash-out strategy (discussed in its own fact sheet).

		Percent Change in Commuting VMT					
Strategy	Description	Large Metropolitan (higher transit use)	Large Metropolitan (lower transit use)	Medium Metro (higher)	Medium Metro (lower)	Small Metro (higher)	Small Metro (lower)
Parking Charges	Parking charge of $1/day	6.9%	0.9%	1.8%	0.5%	1.3%	0.5%
Source: *Moving Cooler*							

Preferred:

Commute Vehicle trip reduction	**Daily Parking Charges**			
Worksite Setting	**$0.75**	**$1.49**	**$2.98**	**$5.96**
Suburb	6.5%	15.1%	25.3%*	36.1%*
Suburban Center	12.3%	25.1%*	37.0%*	46.8%*
Central Business District	17.5%	31.8%*	42.6%*	50.0%*
Source: VTPI [2]				

* Discounts greater than 20% should be capped, as they exceed levels recommended by *TCRP 95* and other literature.

The reduction in commute trips varies by parking fee and worksite setting [2]. For daily parking fees between $1.49 and $5.96, worksites set in low-density suburbs could decrease vehicle trips by 6.5-36.1%, worksites set in activity centers could decrease vehicle trips by 12.3-46.8%, and worksites set in regional central business districts could decrease vehicles by 17.5-50%. (Note that adjusted parking fees (from 1993 dollars to 2009 dollars) were used. Adjustments were taken from the *Santa Monica General Plan EIR Report, Appendix*, Nelson\Nygaard).

Alternative Literature:

Alternate:

- 1 percentage point reduction in auto mode share
- 12.3% reduction in commute vehicle trips

TCRP 95 Draft Chapter 19 [4] found that an increase of $8 per month in employee parking charges was necessary to decrease employee SOV mode split rates by one percentage point. *TCRP 95* compared 82 sites with TDM programs and found that programs with parking fees have an average commute vehicle trip reduction of 24.6%, compared with 12.3% for sites with free parking.

Alternate:

- 1% reduction in VMT ($1 per day charge)
- 2.6% reduction in VMT ($3 per day charge)

The Deakin, et al. report [5] for the California Air Resources Board (CARB) analyzed transportation pricing measures for the Los Angeles, Bay Area, San Diego, and Sacramento metropolitan areas.

Alternative Literature References:

[4] Pratt, Dick. Personal Communication Regarding the Draft of TCRP 95 Traveler Response to Transportation System Changes – Chapter 19 Employer and Institutional TDM Strategies. (Table 19-9)

[5] Deakin, E., Harvey, G., Pozdena, R., and Yarema, G., 1996. *Transportation Pricing Strategies for California: An Assessment of Congestion, Emissions, Energy and Equity Impacts.* Final Report. Prepared for California Air Resources Board (CARB), Sacramento, CA (Table 7.2)

Other Literature Reviewed:

None

3.4.15 Implement Employee Parking "Cash-Out"

Range of Effectiveness: 0.6 – 7.7% commute vehicle miles traveled (VMT) reduction and therefore 0.6 – 7.7% reduction in commute trip GHG emissions

Measure Description:

The project will require employers to offer employee parking "cash-out." The term "cash-out" is used to describe the employer providing employees with a choice of forgoing their current subsidized/free parking for a cash payment equivalent to the cost of the parking space to the employer.

Measure Applicability:

- Urban and suburban context
- Not applicable in a rural context
- Appropriate for retail, office, industrial, and mixed-use projects
- Reductions applied only if complementary strategies are in place:
  - Residential parking permits and market rate public on-street parking -to prevent spill-over parking
  - Unbundled parking - is not required but provides a market signal to employers to forgo paying for parking spaces and "cash-out" the employee instead. In addition, unbundling parking provides a price with which employers can utilize as a means of establishing "cash-out" prices.

Baseline Method:

See introduction section.

Inputs:

The following information needs to be provided by the Project Applicant:

- Percentage of employees eligible
- Location of project site: low density suburb, suburban center, or urban location

Mitigation Method:

$$\% \text{ VMT Reduction} = A * B$$

Where

A = % reduction in commute VMT (from the literature)
B = % of employees eligible

Detail:

- A: Change in Commute VMT: 3.0% (low density suburb), 4.5% (suburban center), 7.7% (urban) change in commute VMT (source: Moving Cooler)

Assumptions:

Data based upon the following references:

- Cambridge Systematics. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Technical Appendices. Prepared for the Urban Land Institute. (Table 5.13, Table D.3) http://www.movingcooler.info/Library/Documents/Moving%20Cooler_Appendix%20B_Effectiveness_102209.pdf

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[69]
CO_2e	0.6 – 7.7% of running
PM	0.6 – 7.7% of running
CO	0.6 – 7.7% of running
NOx	0.6 – 7.7% of running
SO_2	0.6 – 7.7% of running
ROG	0.36 – 4.62% of running

Discussion:

Please note that these estimates are independent of results for workplace parking pricing strategy (see strategy number T# E5 for more information).

If work site parking is not unbundled, employers cannot utilize this unbundled price as a means of establishing “cash-out” prices. The table below shows typical costs for parking facilities in large urban and suburban areas in the US. This can be utilized as a reference point for establishing reasonable “cash-out” prices. Note that the table does not include external costs to parking such as added congestion, lost opportunity cost of land devoted to parking, and greenhouse gas (GHG) emissions.

	Structured (urban)	Surface (suburban)
Land (Annualized)	$1,089	$215
Construction (Annualized)	$2,171	$326

[69] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

O & M Costs	$575	$345
Annual Total	$3,835	$885
Monthly Costs	$320	$74
Source: VTPI, *Transportation Costs and Benefit Analysis II – Parking Costs*, April 2010 (p.5.4-10)		

Example:

Sample calculations are provided below:

- Low Range % VMT Reduction (low density suburb and 20% eligible) = 3% * 0.2 = 0.6%
- High Range % VMT Reduction (urban and 100% eligible) = 7.7% * 1 = 7.7%

Preferred Literature:

- 0.44% - 2.07% reduction in GHG emissions
- 3.0% - 7.7% reduction in commute VMT

Moving Cooler Technical Appendices indicate that reimbursing "cash-out" participants $1/day can reduce GHG between 0.44% and 2.07% and reduce commuting VMT between 3.0% and 7.7%. The reduction in GHG varies based on how extensive the implementation of the program is. The reduction in commuting VMT differs for type of urban area is shown in the table below.

		Percent Change in Commuting VMT					
Strategy	Description	Large Metropolitan (higher transit use)	Large Metropolitan (lower transit use)	Medium Metro (higher)	Medium Metro (lower)	Small Metro (higher)	Small Metro (lower)
Parking Cash-Out	Subsidy of $1/day	7.7%	3.7%	4.5%	3.0%	4.0%	3.0%

Alternative Literature:

Alternate:

- 2-6% reduction in vehicle trips

VTPI used synthesis data to determine parking cash out could reduce commute vehicle trips by 10-30%. VTPI estimates that the portion of vehicle travel affected by parking cash-out would be about 20% and therefore there would be only about a 2-6% total reduction in vehicle trips attributed to parking cash-out.

Alternate:

- 12% reduction in VMT per year per employee
- 64% increase in carpooling
- 50% increase in transit mode share
- 39% increase in pedestrian/bike share

Shoup looked at eight California firms that complied with California's 1992 parking cash-out law, applicable to employers of 50 or more persons in regions that do not meet the state's clean air standards. To comply, a firm must offer commuters the option to choose a cash payment equal to any parking subsidy offered. Six of companies went beyond compliance and subsidized one or more alternatives to parking (more than the parking subsidy price). The eight companies ranged in size between 120 and 300 employees, and were located in downtown Los Angeles, Century City, Santa Monica, and West Hollywood. Shoup states that an average of 12% fewer VMT per year per employee is equivalent to removing one of every eight cars driven to work off the road.

Alternative Literature Notes:

Litman, T., 2009. "Win-Win Emission Reduction Strategies." Victoria Transport Policy Institute. Website: http://www.vtpi.org/wwclimate.pdf. Accessed March 2010. (p. 5)

Donald Shoup, "Evaluating the Effects of Cashing Out Employer-Paid Parking: Eight Case Studies." *Transport Policy*, Vol. 4, No. 4, October 1997, pp. 201-216. (Table 1, p. 204)

Other Literature Reviewed:

None

3.5 Transit System Improvements

3.5.1 Provide a Bus Rapid Transit System

Range of Effectiveness: 0.02 – 3.2% vehicle miles traveled (VMT) reduction and therefore 0.02 – 3% reduction in GHG emissions.

Measure Description:

The project will provide a Bus Rapid Transit (BRT) system with design features for high quality and cost-effective transit service. These include:

- Grade-separated right-of-way, including bus only lanes (for buses, emergency vehicles, and sometimes taxis), and other Transit Priority measures. Some systems use guideways which automatically steer the bus on portions of the route.
- Frequent, high-capacity service
- High-quality vehicles that are easy to board, quiet, clean, and comfortable to ride.
- Pre-paid fare collection to minimize boarding delays.
- Integrated fare systems, allowing free or discounted transfers between routes and modes.
- Convenient user information and marketing programs.
- High quality bus stations with Transit Oriented Development in nearby areas.
- Modal integration, with BRT service coordinated with walking and cycling facilities, taxi services, intercity bus, rail transit, and other transportation services.

BRT systems vary significantly in the level of travel efficiency offered above and beyond “identity” features and BRT branding. The following effectiveness ranges represent general guidelines. Each proposed BRT should be evaluated specifically based on its characteristics in terms of time savings, cost, efficiency, and way-finding advantages. These types of features encourage people to use public transit and therefore reduce VMT.

Measure Applicability:

- Urban and suburban context
- Negligible in a rural context. Other measures are more appropriate to rural areas, such as express bus service to urban activity centers with park-and-ride lots at system-efficient rural access points.
- Appropriate for specific or general plans

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Existing transit mode share
- Percentage of lines serving Project converting to BRT

The following are optional inputs. Average (default) values are included in the calculations but can be updated to project specificity if desired. Please see Appendix C for calculation detail:

- Average vehicle occupancy

Mitigation Method:

% VMT Reduction = Riders * Mode * Lines * D

Where

Riders = % increase in transit ridership on BRT line (28% from [1])

Mode = Existing transit mode share (see table below)

Lines = Percentage of lines serving project converting to BRT

D = Adjustments from transit ridership increase to VMT (0.67, see Appendix C)

Project setting	Transit mode share
Suburban	1.3%
Urban	4%
Urban Center	17%
Source: NHTS, 2001 http://www.dot.ca.gov/hq/tsip/tab/documents/travelsurveys/Final2001_StwTravelSurveyWkdayRpt.pdf (Urban – MTC, SACOG. Suburban – SCAG, SANDAG, Fresno County.) Urban Center from San Francisco County Transportation Authority Countywide Transportation Plan, 2000.	

- D: 0.67 (see Appendix C for detail)

Assumptions:

Data based upon the following references:

[1] FTA, August 2005. "Las Vegas Metropolitan Area Express BRT Demonstration Project", NTD, http://www.ntdprogram.gov/ntdprogram/cs?action=showRegionAgencies&region=9

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[70]
CO_2e	0.02 – 3.2% of running
PM	0.02 – 3.2% of running
CO	0.02 – 3.2% of running
NOx	0.02 – 3.2% of running
SO_2	0.02 – 3.2% of running
ROG	0.012 – 1.9% of total

Discussion:

Increases in transit ridership due to shifts from other lines do not need to be addressed since it is already incorporated in the literature.

In general, transit operational strategies alone are not enough for a large modal shift [2], as evidenced by the low range in VMT reductions. Through case study analysis, the TCRP report [2] observed that strategies that focused solely on improving level of service or quality of transit were unsuccessful at achieving a significant shift. Strategies that reduce the attractiveness of vehicle travel should be implemented in combination to attract a larger shift in transit ridership. The three following factors directly impact the attractiveness of vehicle travel: urban expressway capacity, urban core density, and downtown parking availability.

Example:

Sample calculations are provided below:

- Low Range % VMT Reduction (suburban,10% of lines) = 28% * 1.3% * 10% * 0.67 = 0.02%

[70] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

- High Range % VMT Reduction (urban, 100% of lines) = 28% * 17% * 100% * 0.67 = 3.2%

Preferred Literature:

- 28% increase in transit ridership in the existing corridor

The FTA study [1] looks at the implementation of the Las Vegas BRT system. The BRT supplemented an existing route along a 7.5 mile corridor. The existing route was scaled back. Total ridership on the corridor (both routes combined) increased 61,704 monthly riders, 28% increase on the existing corridor and 1.4% increase in system ridership. The route represented an increase in 2.1% of system service miles provided.

Alternative Literature:

Alternate:

- 27-84% increase in total transit ridership

Various bus rapid transit systems obtained the following total transit ridership growth: Vancouver 96B (30%), Las Vegas Max (35-40%), Boston Silver Line (84%), Los Angeles (27-42%), and Oakland (66%). VTPI [3] obtained the BRT data from BC Transit's unpublished research. The effectiveness of a BRT strategy depends largely on the land uses the BRT serves and their design and density.

Alternate:

- 50% increase in weekly transit ridership
- 60 – 80% shorter travel time compared to vehicle trip

The Martin Luther King, Jr. East Busway in Pennsylvania opened in 1983 as a separate roadway exclusively for public buses. The busway was 6.8 miles long with six stations. Ridership has grown from 20,000 to 30,000 weekday riders over 10 years. The busway saves commuters significant time compared with driving: 12 minutes versus 30-45 minutes in the AM or an hour in the PM [4].

Alternative Literature References:

[2] Transit Cooperative Research Program. TCRP 27 – Building Transit Ridership: An Exploration of Transit's Market Share and the Public Policies That Influence It (p.47-48). 1997. [cited in discussion section above]

[3] TDM Encyclopedia; Victoria Transport Policy Institute (2010). Bus Rapid Transit; (http://www.vtpi.org/tdm/tdm120.htm); updated 1/25/2010; accessed 3/3/2010.

[4] Transportation Demand Management Institute of the Association for Commuter Transportation. *TDM Case Studies and Commuter Testimonials*. Prepared for the US EPA. 1997. (p.55-56) http://www.epa.gov/OMS/stateresources/rellinks/docs/tdmcases.pdf

3.5.2 Implement Transit Access Improvements

Range of Effectiveness: Grouped strategy. [See TST-3 and TST-4]

Measure Description:

This project will improve access to transit facilities through sidewalk/ crosswalk safety enhancements and bus shelter improvements. The benefits of Transit Access Improvements alone have not been quantified and should be grouped with Transit Network Expansion (TST-3) and Transit Service Frequency and Speed (TST-4).

Measure Applicability:

- Urban, suburban context
- Appropriate for residential, retail, office, mixed use, and industrial projects

Alternative Literature:

No literature was identified that specifically looks at the quantitative impact of improving transit facilities as a standalone strategy.

Alternative Literature References:

None

Other Literature Reviewed:

None

3.5.3 Expand Transit Network

Range of Effectiveness: 0.1 – 8.2% vehicle miles travelled (VMT) reduction and therefore 0.1 – 8.2% reduction in GHG emissions[71]

Measure Description:

The project will expand the local transit network by adding or modifying existing transit service to enhance the service near the project site. This will encourage the use of transit and therefore reduce VMT.

Measure Applicability:

- Urban and suburban context
- May be applicable in a rural context but no literature documentation available (effectiveness will be case specific and should be based on specific assessment of levels of services and origins/destinations served)
- Appropriate for specific or general plans

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Percentage increase transit network coverage
- Existing transit mode share
- Project location: urban center, urban, or suburban

[71] Transit vehicles may also result in increases in emissions that are associated with electricity production or fuel use. The Project Applicant should consider these potential additional emissions when estimating mitigation for these measures.

The following are optional inputs. Average (default) values are included in the calculations but can be updated to project specificity if desired. Please see Appendix C for calculation detail:

- Average vehicle occupancy

Mitigation Method:

% VMT Reduction = Coverage * B * Mode * D

Where

Coverage = % increase in transit network coverage
B = elasticity of transit ridership with respect to service coverage (see Table below)
Mode = existing transit mode share
D = adjustments from transit ridership increase to VMT (0.67, from Appendix C)

B:

Project setting	Elasticity
Suburban	1.01
Urban	0.72
Urban Center	0.65
Source: TCRP 95, Chapter 10	

Mode: Provide existing transit mode share for project or utilize the following averages

Project setting	Transit mode share
Suburban	1.3%
Urban	4%
Urban Center	17%
Source: NHTS, 2001http://www.dot.ca.gov/hq/tsip/tab/documents/travelsurveys/Final2001_StwTravelSurveyWkdayRpt.pdf (Urban – MTC, SACOG. Suburban – SCAG, SANDAG, Fresno County.) Urban Center from San Francisco County Transportation Authority Countywide Transportation Plan, 2000.	

Assumptions:

Data based upon the following references:

[1] Transit Cooperative Research Program. TCRP Report 95 Traveler Response to System Changes – Chapter 10: Bus Routing and Coverage. 2004. (p. 10-8 to 10-10)

Emission Reduction Ranges and Variables:

Pollut0ant	Category Emissions Reductions[72]
CO_2e	0.1 – 8.2% of running
PM	0.1 – 8.2% of running
CO	0.1 – 8.2% of running
NOx	0.1 – 8.2% of running
SO_2	0.1 – 8.2% of running
ROG	0.06 – 4.9% of total

Discussion:

In general, transit operational strategies alone are not enough for a large modal shift [2], as evidenced by the low range in VMT reductions. Through case study analysis, the TCRP report [2] observed that strategies that focused solely on improving level of service or quality of transit were unsuccessful at achieving a significant shift. Strategies that reduce the attractiveness of vehicle travel should be implemented in combination to attract a larger shift in transit ridership. The three following factors directly impact the attractiveness of vehicle travel: urban expressway capacity, urban core density, and downtown parking availability.

Example:

Sample calculations are provided below:

- Low Range % VMT Reduction (10% expansion, suburban) = 10% * 1.01 * 1.3% * .67 = 0.1%
- High Range % VMT Reduction (100% expansion, urban) = 100% * 0.72 * 17% * .67 = 8.2%

The low and high ranges are estimates and may vary based on the characteristics of the project.

[72] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

Preferred Literature:

- 0.65 = elasticity of transit ridership with respect to service coverage/expansion (in radial routes to central business districts)
- 0.72 = elasticity of transit ridership with respect to service coverage/expansion (in central city routes)
- 1.01 = elasticity of transit ridership with respect to service coverage/expansion (in suburban routes)

TCRP 95 Chapter 10 [1] documents the results of system-wide service expansions in San Diego. The least sensitivity to service expansion came from central business districts while the largest impacts came from suburban routes. Suburban locations, with traditionally low transit service, tend to have greater ridership increases compared to urban locations which already have established transit systems. In general, there is greater opportunity in suburban locations.

Alternative Literature:

- -0.06 = elasticity of VMT with respect to transit revenue miles

Growing Cooler [3] modeled the impact of various urban variables (including transit revenue miles and transit passenger miles) on VMT, using data from 84 urban areas around the U.S.

Alternative Literature References:

[2] Transit Cooperative Research Program. TCRP 27 – Building Transit Ridership: An Exploration of Transit's Market Share and the Public Policies That Influence It (p.47-48). 1997. [cited in discussion section above]

[3] Ewing, et al, 2008. Growing Cooler – The Evidence on Urban Development and Climate Change. Urban Land Institute.

3.5.4 Increase Transit Service Frequency/Speed

Range of Effectiveness: 0.02 – 2.5% vehicle miles traveled (VMT) reduction and therefore 0.02 – 2.5% reduction in GHG emissions[73]

Measure Description:

This project will reduce transit-passenger travel time through more reduced headways and increased speed and reliability. This makes transit service more attractive and may result in a mode shift from auto to transit which reduces VMT.

Measure Applicability:

- Urban and suburban context
- May be applicable in a rural context but no literature documentation available (effectiveness will be case specific and should be based on specific assessment of levels of services and origins/destinations served)
- Appropriate for specific or general plans

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Percentage reduction in headways (increase in frequency)
- Level of implementation
- Project setting: urban center, urban, suburban
- Existing transit mode share

[73] Transit vehicles may also result in increases in emissions that are associated with electricity production or fuel use. The Project Applicant should consider these potential additional emissions when estimating mitigation for these measures.

The following are optional inputs. Average (default) values are included in the calculations but can be updated to project-specific values if desired. Please see Appendix C for calculation detail:

- Average vehicle occupancy

Mitigation Method:

% VMT Reduction = Headway * B * C * Mode * E

Where

Headway = % reduction in headways
B = elasticity of transit ridership with respect to increased frequency of service (from [1])
C = adjustment for level of implementation
Mode = existing transit mode share
E = adjustments from transit ridership increase to VMT

Detail:

- Headway: reasonable ranges from 15 – 80%
- B:

Setting	Elasticity
Urban	0.32
Suburban	0.36
Source: TCRP Report 95 Chapter 9	

- C:

Level of implementation = number of lines improved / total number of lines serving project	Adjustment
<50%	50%
>=50%	85%
Fehr & Peers, 2010.	

- Mode: Provide existing transit mode share for project or utilize the following averages

Project setting	Transit mode share
Suburban	1.3%
Urban	4%
Urban Center	17%
Source: NHTS, 2001http://www.dot.ca.gov/hq/tsip/tab/documents/travelsurveys/Final2001_StwTravelSurveyWkdayRpt.pdf (Urban – MTC, SACOG. Suburban – SCAG, SANDAG, Fresno County.)	

Urban Center from San Francisco County Transportation Authority Countywide Transportation Plan, 2000.

- E: 0.67 (see Appendix C for detail)

Assumptions:

Data based upon the following references:

[1] Transit Cooperative Research Program. TCRP Report 95 Traveler Response to System Changes – Chapter 9: Transit Scheduling and Frequency (p. 9-14)

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[74]
CO_2e	0.02 – 2.5% % of running
PM	0.02 – 2.5% % of running
CO	0.02 – 2.5% % of running
NOx	0.02 – 2.5% % of running
SO_2	0.02 – 2.5% % of running
ROG	0.01 – 1.5% % of total

Discussion:

Reasonable ranges for reductions were calculated assuming existing 30-minute headways reduced to 25 minutes and 5 minutes to establish the estimated low and high reductions, respectively.

The level of implementation adjustment is used to take into account increases in transit ridership due to shifts from other lines. If increases in frequency are only applied to a percentage of the lines serving the project, then we conservatively estimate that 50% of the transit ridership increase is a shift from the existing lines. If frequency increases are applied to a majority of the lines serving the project, we conservatively assume at least some of the transit ridership (15%) comes from existing riders.

In general, transit operational strategies alone are not enough for a large modal shift [2], as evidenced by the low range in VMT reductions. Through case study analysis, the TCRP report [2] observed that strategies that focused solely on improving level of service or quality of transit were unsuccessful at achieving a significant shift. Strategies that reduce the attractiveness of vehicle travel should be implemented in combination to attract a larger shift in transit ridership. The three following factors directly impact the

[74] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

attractiveness of vehicle travel: urban expressway capacity, urban core density, and downtown parking availability.

Example:
Sample calculations are provided below:

- Low Range % VMT Reduction (15% reduction in headways, suburban, <50% implementation) = 15% * 0.36 * 50% * 1.3% *0.67 = 0.02%
- High Range % VMT Reduction (80% reduction in headways, urban, >50% implementation) = 80% * 0.32 * 85% * 17% * 0.67 = 2.5%

Preferred Literature:
- 0.32 = elasticity of transit ridership with respect to transit service (urban)
- 0.36 – 0.38 = elasticity of transit ridership with respect to transit service (suburban)

TCRP 95 Chapter 9 [1] documents the results of frequency changes in Dallas. Increases in frequency are more sensitive in a suburban environment. Suburban locations, with traditionally low transit service, tend to have greater ridership increases compared to urban locations which already have established transit systems. In general, there is greater opportunity in suburban locations

Alternative Literature:
- 0.5 = elasticity of transit ridership with respect to increased frequency of service
- 1.5 to 2.3% increase in annual transit trips due to increased frequency of service
- 0.4-0.5 = elasticity of ridership with respect to increased operational speed
- 4% - 15% increase in annual transit trips due to increased operational speed
- 0.03-0.09% annual GHG reduction (for bus service expansion, increased frequency, and increased operational speed)

For increased frequency of service strategy, *Moving Cooler* [3] looked at three levels of service increases, 3%, 3.5% and 4.67% increases in service, resulting in a 1.5 – 2.3% increase in annual transit trips. For increased speed and reliability, Moving Cooler looked at three levels of speed/reliability increases. Improving travel speed by 10% assumed implementing signal prioritization, limited stop service, etc. over 5 years. Improving travel speed by 15% assumed all above strategies plus signal synchronization and intersection reconfiguration over 5 years. Improving travel speed by 30% assumed all above strategies and an improved reliability by 40%, integrated fare system, and implementation of BRT where appropriate. *Moving Cooler* calculates estimated 0.04-0.14% annual GHG reductions in combination with bus service expansion strategy.

Alternative Literature References:

[2] Transit Cooperative Research Program. TCRP 27 – Building Transit Ridership: An Exploration of Transit's Market Share and the Public Policies That Influence It (p.47-48). 1997. [cited in discussion section]

[3] Cambridge Systematics. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Technical Appendices. Prepared for the Urban Land Institute. (p B-32, B-33, Table D.3) http://www.movingcooler.info/Library/Documents/Moving%20Cooler_Appendices_Complete_102209.pdf

3.5.5 Provide Bike Parking Near Transit

Range of Effectiveness: Grouped strategy. [See TST-3 and TST-4]

Measure Description:

Provide short-term and long-term bicycle parking near rail stations, transit stops, and freeway access points. The benefits of Station Bike Parking have no quantified impacts as a standalone strategy and should be grouped with Transit Network Expansion (TST-3) and Increase Transit Service Frequency and Speed (TST-4) to encourage multi-modal use in the area and provide ease of access to nearby transit for bicyclists.

Measure Applicability:

- Urban, suburban context
- Appropriate for residential, retail, office, mixed use, and industrial projects

Alternative Literature:

No literature was identified that specifically looks at the quantitative impact of including transit station bike parking.

Alternative Literature References:

None

Other Literature Reviewed:

None

3.5.6 Provide Local Shuttles

Range of Effectiveness: Grouped strategy. [See TST-4 and TST-5]

Measure Description:

The project will provide local shuttle service through coordination with the local transit operator or private contractor. The local shuttles will provide service to transit hubs, commercial centers, and residential areas. The benefits of Local Shuttles alone have not been quantified and should be grouped with Transit Network Expansion (TST-4) and Transit Service Frequency and Speed (TST-5) to solve the "first mile/last mile" problem. In addition, many of the CommuteTrip Reduction Programs (Section 2.4, TRP 1-13) also included local shuttles.

Measure Applicability:

- Urban, suburban context
- Appropriate for large residential, retail, office, mixed use, and industrial projects

Alternative Literature:

No literature was identified to support the effectiveness of this strategy alone.

Alternative Literature References:

None

Other Literature Reviewed:

None

3.6 Road Pricing/Management

3.6.1 Implement Area or Cordon Pricing

Range of Effectiveness: 7.9 – 22.0% vehicle miles traveled (VMT) reduction and therefore 7.9 – 22.0% reduction in GHG emissions.

Measure Description:
This project will implement a cordon pricing scheme. The pricing scheme will set a cordon (boundary) around a specified area to charge a toll to enter the area by vehicle. The cordon location is usually the boundary of a central business district (CBD) or urban center, but could also apply to substantial development projects with limited points of access, such as the proposed Treasure Island development in San Francisco. The cordon toll may be static/constant, applied only during peak periods, or be variable, with higher prices during congested peak periods. The toll price can be based on a fixed schedule or be dynamic, responding to real-time congestion levels. It is critical to have an existing, high quality transit infrastructure for the implementation of this strategy to reach a significant level of effectiveness. The pricing signals will only cause mode shifts if alternative modes of travel are available and reliable.

Measure Applicability:
- Central business district or urban center only

Baseline Method:
See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:
The following information needs to be provided by the Project Applicant:

- Percentage increase in pricing for passenger vehicles to cross cordon
- Peak period variable price or static all-day pricing (London scheme)

The following are optional inputs. Average (default) values are included in the calculations but can be updated to project-specific values if desired. Please see Appendix C for calculation detail:

- % (due to pricing) route shift, time-of-day shift, HOV shift, trip reduction, shift to transit/walk/bike

Mitigation Method:

% VMT Reduction = Cordon$ * B * C

Where

Cordon$	= % increase in pricing for passenger vehicles to cross cordon
B	= Elasticity of VMT with respect to price (from [1])
C	= Adjustment for % of VMT impacted by congestion pricing and mode shifts

Detail:

- Cordon$: reasonable range of 100 – 500% (See Appendix C for detail))
- B: 0.45 [1]
- C:

Cordon pricing scheme	Adjustment
Peak-period variable pricing	8.8%
Static all-day pricing	21%
Source: See Appendix C for detail	

Assumptions:

Data based upon the following references:

[1] Cambridge Systematics. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Technical Appendices. Prepared for the Urban Land Institute. (p. B-13, B-14) http://www.movingcooler.info/Library/Documents/Moving%20Cooler_Appendix%20B_Effectiveness_102209.pdf

- Referencing: VTPI, *Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior.* July 2008. www.vtpi.org

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[75]
CO_2e	7.9 - 22.0% of running
PM	7.9 - 22.0% of running
CO	7.9 - 22.0% of running
NOx	7.9 - 22.0% of running
SO_2	7.9 - 22.0% of running
ROG	4.7 – 13.2% of total

Discussion:

The amount of pricing will vary on a case-by-case basis. The 100 – 500% increase is an estimated range of increases and should be adjusted to reflect the specificities of the pricing scheme implemented. Take care in calculating the percentage increase in price if baseline is $0.00. An upper limit of 500% may be a good check point. If baseline is zero, the Project Applicant may want to conduct calculations with a low baseline such as $1.00.

These calculations assume that the project is within the area cordon, essentially assuming that 100% of project trips will be affected. See Appendix C to make appropriate adjustments.

Example:

Sample calculations are provided below:

- Low Range % VMT Reduction (100% increase in price, peak period pricing) = 100% * 0.45 * 8.8% = 4.0%
- High Range % VMT Reduction (500% increase in price, all-day pricing) = 500% * 0.45 * 21% = 47.3% = 22% (established maximum based on literature)

Preferred Literature:

- -0.45 VMT elasticity with regard to pricing
- 0.04-0.08% greenhouse gas (GHG) reduction

Moving Cooler [1] assumes an average of 3% of regional VMT would cross the CBD cordon. A VMT reduction of 20% was estimated to require an average of 65 cents/mile applied to all congested VMT in the CBD, major employment, and retail centers. The

[75] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

range in GHG reductions is attributed to the range of implementation and start date. *Moving Cooler* reports an elasticity range from -0.15 to -0.47 from VTPI. *Moving Cooler* utilizes a stronger elasticity (0.45) to represent greater impact cordon pricing will have on users compared to other pricing strategies.

Alternative Literature:

- 6.5-14.0% reduction in carbon emissions
- 16-22% reduction in vehicles
- 6-9% increase in transit use

The Center for Clean Air Policy (CCAP) [2] cites two case studies in Europe, one in London and one in Stockholm, which show vehicle reductions of 16% and 22%, respectively. London's fee reduced CO_2 by 6.5%. Stockholm's program reduced injuries by 10%, increased transit use by 6-9%, and reduced carbon emissions by 14% in the central city within months of implementation.

Alternative Literature References:

[2] Center for Clean Air Policy (CCAP), *Short-term Efficiency Measures.* (p. 1) http://www.ccap.org/docs/resources/715/Short-Term%20Travel%20Efficiency%20Measures%20cut%20GHGs%209%2009%20final.pdf

CCAP cites Transport for London. *Central London Congestion Charging: Impacts Monitoring*, *Sixth Annual Report*. July 2008 http://www.tfl.gov.uk/assets/downloads/sixth-annual-impacts-monitoring-report-2008-07.pdf (p. 6) and Leslie Abboud and Jenny Clevstrom, "Stockholm's Syndrome," August 29, 2006, *Wall Street Journal.*http://transportation.northwestern.edu/mahmassani/Media/WSJ_8.06.pdf (p. 2)

Other Literature Reviewed:

None

3.6.2 Improve Traffic Flow

Range of Effectiveness: 0 - 45% reduction in GHG emissions

Measure Description:

The project will implement improvements to smooth traffic flow, reduce idling, eliminate bottlenecks, and management speed. Strategies may include signalization improvements to reduce delay, incident management to increase response time to breakdowns and collisions, Intelligent Transportation Systems (ITS) to provide real-time information regarding road conditions and directions, and speed management to reduce high free-flow speeds.

This measure does not take credit for any reduction in GHG emissions associated with changes to non-project traffic VMT. If Project Applicant wants to take credit for this benefit, the non-project traffic VMT would also need to be covered in the baseline conditions.

Measure Applicability:

- Urban, suburban, and rural context

Baseline Method:

See introduction to transportation section for a discussion of how to estimate trip rates and VMT. The CO_2 emissions are calculated from VMT as follows:

$$CO_2 = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled

$EF_{running}$ = emission factor for running emissions

Inputs:

The following information needs to be provided by the Project Applicant:

- Average base-year travel speed (miles per hour (mph)) on implemented roads (congested[76] condition)

[76] A roadway is considered "congested" if operating at Level of Service (LOS) E or F

- Future travel speed (mph) on implemented roads for both a) congested and b) free-flow[77] condition
- Total vehicle miles traveled (VMT) on implemented roadways
- Total project-generated VMT

Mitigation Method:

$$\% \; CO_2 \text{ Emissions Reduction} = 1 - \frac{\text{Project GHG Emission}_{\text{post strategy}}}{\text{Project GHG emission}_{\text{baseline}}}$$

Where

Project GHG $\text{emission}_{\text{post strategy}}$ = $EF_{running}$ after strategy implementation * project VMT
Project GHG $\text{emission}_{\text{baseline}}$ = $EF_{running}$ before strategy implementation * project VMT
$EF_{running}$ = emission factor for running emissions [from table presented under "Detail" below]

Detail:

mph	Grams of CO_2 / mile	
	congested	Free-flow
5	1,110	823
10	715	512
15	524	368
20	424	297
25	371	262
30	343	247
35	330	244
40	324	249
45	323	259
50	325	273
55	328	289
60	332	306
65	339	325
70	353	347
75	377	375
80	420	416
85	497	478
Source: Barth, 2008, Fehr & Peers [1]		

[77] A roadway is considered "free flow" if operating at LOS D or better

By only including the project VMT portion, the reduction is typically on scale with the percentage of cost for traffic improvements and full reduction calculated for project VMT should be used. However, if the project cost is a greater share than their contribution to the VMT on the road, than the project and non-project VMT should be calculated and the percent reduction should be multiplied by the percent cost allocation. The GHG emission reductions associated with non-project VMT (if applicable) would be calculated as follows:

$$\text{Metric Tonnes GHG reduced due to improving non-Project traffic flow} = \text{\% Cost Allocation} * \text{Non-Project VMT} * (EF_{congested} - EF_{freeflow}) / (1{,}000{,}000 \text{ gram/MT})$$

Where:

Non-Project VMT that the Project's cost share impacts = portion of non-project VMT

$EF_{congested}$ = emissions for congested road in g/VMT

$EF_{freeflow}$ = emissions for freeflow road in g/VMT

Assumptions:

Data based upon the following references:

[1] Barth and Boriboonsomsin, "Real World CO_2 Impacts of Traffic Congestion", *Transportation Research Record, Journal of the Transportation Research Board,* No. 2058, Transportation Research Board, National Academy of Science, 2008.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions[78]
CO_2e	0 - 45% of running
PM	0 - 45% of running
CO	0 - 45% of running

[78] The percentage reduction reflects emission reductions from running emissions. The actual value will be less than this when starting and evaporative emissions are factored into the analysis. ROG emissions have been adjusted to reflect a ratio of 40% evaporative and 60% exhaust emissions based on a statewide EMFAC run of all vehicles.

NOx	0 - 45% of running
SO_2	0 - 45% of running
ROG	0 - 27% of total

Discussion:

Care must be taken when estimating effectiveness since significantly improving traffic flow essentially lowers the cost and delay involved in travel, which under certain circumstances may induce additional VMT. [See Appendix C for a discussion on induced travel.]

The range of effectiveness presented above is a very rough estimate as emissions reductions will be highly dependent on the level of implementation and degree of congestion on the existing roadways. In addition, the low range of effectiveness was stated at 0% to highlight the potential of induced travel negating benefits achieved from this strategy.

Example:

Sample calculations are provided below:

- Signal timing coordination implementation:
  - Existing congested speeds of 25 mph
  - Conditions post-implementation: would improve to 25 mph free flow speed
  - Proposed project daily traffic generation is 200,000 VMT
  - Project CO_2 $Emissions_{baseline}$ = (371 g CO_2/mile) * (200,000 VMT daily) * (1 MT / 1 x 10^6 g) = 74 MT of CO_2 daily
  - Project CO_2 $Emissions_{post\ strategy}$ = (262 g CO_2/mile) * (200,000 VMT daily) * (1 MT / 1 x 10^6 g) = 52.4 MT of CO_2 daily
  - Percent CO_2emissions reduction = 1- (52.4 MT/ 74 MT) = 29%
- Speed management technique:
  - Existing free-flow speeds of 75 mph
  - Conditions post-implementation: reduce to 55 mph free flow speed
  - Proposed project daily traffic generation is 200,000 VMT
  - Project CO_2 $Emissions_{baseline}$ = (375 g CO_2/mile) * (200,000 VMT daily) * (1 MT / 1 x 10^6 g) = 75 MT of CO_2 daily
  - Project CO_2 $Emissions_{post\ strategy}$ = (289 g CO_2/mile) * (200,000 VMT daily) * (1 MT / 1 x 10^6 g) = 58 MT of CO_2 daily
  - Percent CO_2emissions reduction= 1 – (58 tons/ 75 tons) = 23%

Preferred Literature:

- 7 – 12% reduction in CO_2 emissions

This study [1] examined traffic conditions in Southern California using energy and emissions modeling and calculated the impacts of 1) congestion mitigation strategies to smooth traffic flow, 2) speed management techniques to reduce high free-flow speeds, and 3) suppression techniques to eliminate acceleration/deceleration associated with stop-and-go traffic. Using typical conditions on Southern California freeways, the strategies could reduce emissions by 7 to 12 percent.

The table (in the mitigation method section) was calculated using the CO_2 emissions equation from the report:

$$\ln(y) = b_0 + b_1 * x + b_2 * x^2 + b_3 * x^3 + b_4 * x^4$$

where

y = CO_2 emission in grams / mile
x = average trip speed in miles per hour (mph)

The coefficients for b_i were based off of Table 1 of the report, which then provides an equation for both congested conditions (real-world) and free-flow (steady-state) conditions.

Alternative Literature:

- 4 - 13% reduction in fuel consumption

The FHWA study [2] looks at various case studies of traffic flow improvements. In Los Angeles, a new traffic control signal system was estimated to reduce signal delays by 44%, vehicle stops by 41%, and fuel consumption by 13%. In Virginia, a study of retiming signal systems estimated reductions of stops by 25%, travel time by 10%, and fuel consumption by 4%. In California, optimization of 3,172 traffic signals through 1988 (through California's Fuel Efficient Traffic Signal Management program) documented an average reduction in vehicle stops of 16% and in fuel use of 8.6%. The 4-13% reduction in fuel consumption applies only to that vehicular travel directly benefited by the traffic flow improvements, specifically the VMT within the corridor in which the ITS is implemented and only during the times of day that would otherwise be congested without ITS. For example, signal coordination along an arterial normally congested in peak commute hours would produce a 4-13% reduction in fuel consumption only for the VMT occurring along that arterial during weekday commute hours.

Alternate:

- Up to 0.02% *increase* in greenhouse gas (GHG) emissions

Moving Cooler [3] estimates that bottleneck relief will result in an increase in GHG emissions during the 40-year period, 2010 to 2050. In the short term, however, improved roadway conditions may improve congestion and delay, and thus reduce fuel consumption. VMT and GHG emissions are projected to increase after 2030 as induced demand begins to consume the roadway capacity. The study estimates a maximum increase of 0.02% in GHG emissions.

Alternative Literature References:

[2] FHWA, *Strategies to Reduce Greenhouse Gas Emissions from Transportation Sources*. http://www.fhwa.dot.gov/environment/glob_c5.pdf.

[3] Cambridge Systematics. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions.* Technical Appendices. Prepared for the Urban Land Institute. http://www.movingcooler.info/Library/Documents/Moving%20Cooler_Appendix%20B_Effectiveness_102209.pdf

Other Literature Reviewed:

None

3.6.3 Required Project Contributions to Transportation Infrastructure Improvement Projects

Range of Effectiveness: Grouped strategy. [See RPT-2 and TST-1 through 7]

Measure Description:

The project should contribute to traffic-flow improvements or other multi-modal infrastructure projects that reduce emissions and are not considered as substantially growth inducing. The local transportation agency should be consulted for specific needs.

Larger projects may be required to contribute a proportionate share to the development and/or continuation of a regional transit system. Contributions may consist of dedicated right-of-way, capital improvements, easements, etc. The local transportation agency should be consulted for specific needs.

Refer to Traffic Flow Improvements (RPT-2) or the Transit System Improvements (TST-1 through 7) strategies for a range of effectiveness in these categories. The benefits of Required Contributions may only be quantified when grouped with related improvements.

Measure Applicability:

- Urban, suburban, and rural context
- Appropriate for residential, retail, office, mixed use, and industrial projects

Alternative Literature:

Although no literature discusses project contributions as a standalone measure, this strategy is a supporting strategy for most operations and infrastructure projects listed in this report.

Other Literature Reviewed:

None

3.6.4 Install Park-and-Ride Lots

Range of Effectiveness: Grouped strategy. [See RPT-1, TRT-11, TRT-3, and TST-1 through 6]

Measure Description:

This project will install park-and-ride lots near transit stops and High Occupancy Vehicle (HOV) lanes. Park-and-ride lots also facilitate car- and vanpooling. Refer to Implement Area or Cordon Pricing (RPT-1), Employer-Sponsored Vanpool/Shuttle (TRT-11), Ride Share Program (TRT-3), or the Transit System Improvement strategies (TST-1 through 6) for ranges of effectiveness within these categories. The benefits of Park-and-Ride Lots are minimal as a stand-alone strategy and should be grouped with any or all of the above listed strategies to encourage carpooling, vanpooling, ride-sharing, and transit usage.

Measure Applicability:

- Suburban and rural context
- Appropriate for residential, retail, office, mixed use, and industrial projects

Alternative Literature:

Alternate:

- 0.1 – 0.5% vehicle miles traveled (VMT) reduction

A 2005 FHWA [1] study found that regional VMT in metropolitan areas may be reduced between 0.1 to 0.5% (citing Apogee Research, Inc., 1994). The reduction potential of this strategy may be limited because it reduces the trip length but not vehicle trips.

Alternate:

- 0.50% VMT reduction per day

Washington State Department of Transportation (WSDOT) [2] notes the above number applies to countywide interstates and arterials.

Alternative Literature References:

[1] FHWA. Transportation and Global Climate Change: A Review and Analysis of the Literature – Chapter 5: Strategies to Reduce Greenhouse Gas Emissions from Transportation Sources. http://www.fhwa.dot.gov/environment/glob_c5.pdf

[2] Washington State Department of Transportation. *Cost Effectiveness of Park-and-Ride Lots in the Puget Sound Area.* http://www.wsdot.wa.gov/research/reports/fullreports/094.1.pdf

Other Literature Reviewed:

None

3.7 Vehicles

3.7.1 Electrify Loading Docks and/or Require Idling-Reduction Systems

Range of Effectiveness: 26-71% reduction in TRU idling GHG emissions

Measure Description:

Heavy-duty trucks transporting produce or other refrigerated goods will idle at truck loading docks and during layovers or rest periods so that the truck engine can continue to power the cab cooling elements. Idling requires fuel use and results in GHG emissions.

The Project Applicant should implement an enforcement and education program that will ensure compliance with this measure. This includes posting signs regarding idling restrictions as well as recording engine meter times upon entering and exiting the facility.

Measure Applicability:

- Truck refrigeration units (TRU)

Inputs:

The following information needs to be provided by the Project Applicant:

- Electricity provider for the Project
- Horsepower of TRU
- Hours of operation

Baseline Method:

$$\text{GHG emission} = \frac{CO_2\ \text{Exhaust}}{\text{Activity} \times \text{AvgHP} \times \text{LF}} \times \text{Hp} \times \text{Hr} \times \text{C} \times \text{LF}$$

Where:

GHG emission = MT CO_2e

CO_2 Exhaust = Statewide daily CO_2 emission from TRU for the relevant horsepower tier (tons/day). Obtained from OFFROAD2007.

Activity = Statewide daily average TRU operating hours for the relevant horsepower tier (hours/day). Obtained from OFFROAD2007.

AvgHP = Average TRU horsepower for the relevant horsepower tier (HP). Obtained from OFFROAD2007.

Hp = Horsepower of TRU.

Hr = Hours of operation.

C = Unit conversion factor

LF = Load factor of TRU for the relevant horsepower tier (dimensionless). Obtained from OFFROAD 2007.

Note that this method assumes the load factor of the TRU is same as the default in OFFROAD2007.

Mitigation Method:

Electrify loading docks

TRUs will be plugged into electric loading dock instead of left idling. The indirect GHG emission from electricity generation is:

$$\text{GHG emission} = \text{Utility} \times \text{Hp} \times \text{LF} \times \text{Hr} \times \text{C}$$

Where:

GHG emissions = MT CO_2e
Utility = Carbon intensity of Local Utility (CO_2e/kWh)
Hp = Horsepower of TRU.
LF = Load factor of TRU for the relevant horsepower tier (dimensionless). Obtained from OFFROAD2007.
Hr = Hours of operation.
C = Unit conversion factor

$$\text{GHG Reduction \%}^{79} = 1 - \frac{\text{Utility} \times \text{C}}{\text{EF} \times 10^{-6}}$$

Idling Reduction

Emissions from reduced TRU idling periods are calculated using the same methodology for the baseline scenario, but with the shorter hours of operation.

$$\text{GHG Reduction \%} = 1 - \frac{\text{time}_{\text{mitigated}}}{\text{time}_{\text{baseline}}}$$

Electrify loading docks

Power Utility	TRU Horsepower (HP)	Idling Emission Reductions[80]
LADW&P	< 15	26.3%
	< 25	26.3%
	< 50	35.8%

[79] This assumes energy from engine losses are the same.
[80] This reduction percentage applies to all GHG and criteria pollutant idling emissions.

PG&E	< 15	72.9%
	< 25	72.9%
	< 50	76.3%
SCE	< 15	61.8%
	< 25	61.8%
	< 50	66.7%
SDGE	< 15	53.5%
	< 25	53.5%
	< 50	59.5%
SMUD	< 15	67.0%
	< 25	67.0%
	< 50	71.2%

Idling Reduction

Emission reduction from shorter idling period is same as the percentage reduction in idling time.

Discussion:

The output from OFFROAD2007 shows the same emissions within each horsepower tier regardless of the year modeled. Therefore, the emission reduction is dependent on the location of the Project and horsepower of the TRU only.

Assumptions:

Data based upon the following references:

- California Air Resources Board. Off-road Emissions Inventory. OFFROAD2007. Available online at: http://www.arb.ca.gov/msei/offroad/offroad.htm
- California Climate Action Registry Reporting Online Tool. 2006 PUP Reports. Available online at: https://www.climateregistry.org/CARROT/public/reports.aspx

Preferred Literature:

The electrification of truck loading docks can allow properly equipped trucks to take advantage of external power and completely eliminate the need for idling. Trucks would need to be equipped with internal wiring, inverter, system, and a heating, ventilation, and air conditioning (HVAC) system. Under this mitigation measure, the direct emissions from fuel combustion are completely displaced by indirect emissions from the CO_2 generated during electricity production. The amount of electricity required depends on the type of truck and refrigeration elements; this data could be determined from manufacturer specifications. The total kilowatt-hours required should be multiplied by the carbon-intensity factor of the local utility provider in order to calculate the amount of indirect CO_2 emissions. To take credit for this mitigation measure, the Project Applicant would need to provide detailed evidence supporting a calculation of the emissions reductions.

Alternative Literature:

None

Other Literature Reviewed:

1. USEPA. 2002. Green Transport Partnership, A Glance at Clean Freight Strategies: Idle Reduction. Available online at: http://nepis.epa.gov/Adobe/PDF/P1000S9K.PDF
2. ATRI. 2009. Research Results: Demonstration of Integrated Mobile Idle Reduction Solutions. Available online at: http://www.atri-online.org/research/results/ATRI1pagesummaryMIRTDemo.pdf

None

3.7.2 Utilize Alternative Fueled Vehicles

Range of Effectiveness: Reduction in GHG emissions varies depending on vehicle type, year, and associated fuel economy.

Measure Description:

When construction equipment is powered by alternative fuels such as biodiesel (B20), liquefied natural gas (LNG), or compressed natural gas (CNG) rather than conventional petroleum diesel or gasoline, GHG emissions from fuel combustion may be reduced.

Measure Applicability:

- Vehicles

Inputs:

The following information needs to be provided by the Project Applicant:

- Vehicle category
- Traveling speed (mph)
- Number of trips and trip length, or Vehicle Miles Traveled (VMT)
- Fuel economy (mpg) or Fuel consumption

Baseline Method:

$$\text{Baseline } CO_2 \text{ Emission} = EF \times \frac{1}{FE} \times VMT \times C$$

Where:

Baseline CO_2 Emission = MT of CO_2
EF = CO_2 emission factor, from CCAR General Reporting Protocol (g/gallon)
VMT = Vehicle miles traveled (VMT) = T x L
FE = Fuel economy (mpg)
C = Unit conversion factor

$$\text{Baseline } N_2O / CH_4 \text{ Emission} = EF \times VMT \times C$$

Where:

Baseline N_2O/CH_4 Emission = MT of N_2O or CH_4
EF = N_2O or CH_4 emission factor, from CCAR General Reporting Protocol (g/mile)
VMT = Vehicle miles traveled (VMT) = T x L
T = Number of one-way trips
L = One-way trip length
FC = Fuel consumption (gallon) = VMT/FE

FE = Fuel economy (mpg)
C = Unit conversion factor

The total baseline GHG emission is the sum of the emissions of CO_2, N_2O and CH_4, adjusted by their global warming potentials (GWP):

Baseline GHG Emission
= Baseline CO_2 Emission + Baseline N_2O Emission $\times$ 310 +Baseline CH_4 Emission $\times$ 21

Where:

Baseline GHG Emission = MT of CO_2e
310 = GWP of N_2O
21 = GWP of CH_4

Mitigation Method:

Mitigated emissions from using alternative fuel is calculated using the same methodology before, but using emission factors for the alternative fuel, and fuel consumption calculated as follows:

$$GHG emissions = \frac{1}{FE} \times ER \times VMT \times EF_{CO2} + VMT \times EF_{N20} + VMT \times EF_{CH4}$$

Where:

ER = Energy ratio from US Department of Energy (see table below)
EF = Emission Factor for pollutant
VMT = Vehicle miles traveled (VMT)
FE = Fuel economy (mpg)

Fuel	Energy Ratio: Amount of fuel needed to provide same energy as			
	1 gallon of Gasoline		1 gallon of Diesel	
Gasoline	1	gal	1.13	gal
#2 Diesel	0.88	gal	1	gal
B20	0.92	gal	1.01	gal
CNG	126.67	ft^3	143.14	ft^3
LNG	1.56	gal	1.77	gal
LPC	1.37	gal	1.55	gal

Emission reductions can be calculated as:

$$\text{Reduction} = 1 - \frac{\text{Mitigated Emission}}{\text{Running Emission}}$$

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	Range Not Quantified[81]
PM	Range Not Quantified
CO	Range Not Quantified
NOx	Range Not Quantified
SO_2	Range Not Quantified
ROG	Range Not Quantified

Discussion:

Using the methodology described above, only the running emission is considered. A hypothetical scenario for a gasoline fueled light duty automobile in 2015 is illustrated below. The CO_2 emission factor from motor gasoline in CCAR 2009 is 8.81 kg/gallon. Assuming the automobile makes two trips of 60 mile each per day, and using the current passenger car fuel economy of 27.5 mpg under the CAFE standards, then the annual baseline CO_2 emission from the automobile is:

$$8.81 \times \frac{2 \times 60 \times 365}{27.5} \times 10^{-3} = 14.0 \text{ MT/year}$$

Where 10^{-3} is the conversion factor from kilograms to MT.

Using the most recent N_2O emission factor of 0.0079 g/mile in CCAR 2009 for gasoline passenger cars, the annual baseline N_2O emission from the automobile is:

$$0.0079 \times 2 \times 365 \times 60 \times 10^{-6} = 0.000346 \text{ MT/year}$$

[81] The emissions reductions varies and depends on vehicle type, year, and the associated fuel economy. The methodology above describes how to calculate the expected GHG emissions reduction assuming the required input parameters are known.

Similarly, using the same formula with the most recent CH_4 emission factor of 0.0147 g/mile in CCAR 2009 for gasoline passenger cars, the annual baseline CH_4 emission from the automobile is calculated to be 0.000644 MT/year.

Thus, the total baseline GHG emission for the automobile is:

$$14.0 + 0.000346 \times 310 + 0.000644 \times 21 = 14.1 \text{ MT/year}$$

If compressed natural gas (CNG) is used as alternative fuel, the CNG consumption for the same VMT is:

$$\frac{2 \times 60 \times 365}{27.5} \times 126.67 = 201{,}751 \text{ ft}^3$$

Using the same formula as for the baseline scenario but with emission factors of CNG and the CNG consumption, the mitigated GHG emission can be calculated as shown in the table below

Pollutant	Emission (MT/yr)
CO_2	11.0
N_2O	0.0022
CH_4	0.0323
CO_2e	12.4

Therefore, the emission reduction is:

$$1 - \frac{12.4}{14.0} = 11.4\%$$

Notice that in the baseline scenario, N_2O and CH_4 only make up <1% of the total GHG emissions, but actually increase for the mitigated scenario and contribute to >10% of total GHG emissions.

Assumptions:

Data based upon the following references:

- California Climate Action Registry (CCAR). 2009. General Reporting Protocol. Version 3.1. Available online at: http://www.climateregistry.org/tools/protocols/general-reporting-protocol.html

- US Department of Energy. 2010. Alternative and Advanced Fuels – Fuel Properties. Available online at: http://www.afdc.energy.gov/afdc/fuels/properties.html

Preferred Literature:

The amount of emissions avoided from using alternative fuel vehicles can be calculated using emission factors from the California Climate Action Registry (CCAR) General Reporting Protocol [1]. Multiplying this factor by the fuel consumption or vehicle miles traveled (VMT) gives the direct emissions of CO_2 and N_2O /CH_4, respectively. Fuel consumption and VMT can be calculated interchangeably with the fuel economy (mpg). The total GHG emission is the sum of the emissions from the three chemicals multiplied by their respective global warming potential (GWP).

Assuming the same VMT, the amount of alternative fuel required to run the same vehicle fleet can be calculated by multiplying gasoline/diesel fuel consumption by the equivalent-energy ratio obtained from the US Department of Energy [2]. Using the alternative fuel consumption and the emission factors for the alternative fuel from CCAR, the mitigated GHG emissions can be calculated. The GHG emissions reduction associated with this mitigation measure is therefore the difference in emissions from these two scenarios.

Alternative Literature:

None

Notes:

[1] California Climate Action Registry (CCAR). 2009. General Reporting Protocol. Version 3.1. Available online at: http://www.climateregistry.org/tools/protocols/general-reporting-protocol.html
[2] US Department of Energy. 2010. Alternative and Advanced Fuels – Fuel Properties. Available online at: http://www.afdc.energy.gov/afdc/fuels/properties.html

Other Literature Reviewed:

None

3.7.3 Utilize Electric or Hybrid Vehicles

Range of Effectiveness: 0.4 - 20.3% reduction in GHG emissions

Measure Description:

When vehicles are powered by grid electricity rather than fossil fuel, direct GHG emissions from fuel combustion are replaced with indirect GHG emissions associated with the electricity used to power the vehicles. When vehicles are powered by hybrid-electric drives, GHG emissions from fuel combustion are reduced.

Measure Applicability:

- Vehicles

Inputs:

The following information needs to be provided by the Project Applicant:

- Vehicle category
- Traveling speed (mph)
- Number of trips and trip length, or Vehicle Miles Traveled (VMT)
- Fuel economy (mpg)

Baseline Method:

$$\text{Baseline Emission} = EF \times (1 - R) \times VMT \times C$$

Where:

Baseline Emission = MT of Pollutant
EF = Running emission factor for pollutant at traveling speed, from EMFAC.
VMT = Vehicle miles traveled (VMT)
R = Additional reduction in EF due to regulation (see Table 1)
C = Unit conversion factor

Mitigation Method:

<u>Fully Electric Vehicle</u>

Vehicle will run solely on electricity. The indirect GHG emission from electricity generation is:

$$\text{Mitigated Emission} = \text{Utility} \times \frac{1}{FE} \times VMT \times ER \times C$$

Where:

Mitigated Emission = MT of CO_2e
Utility = Carbon intensity of Local Utility (CO_2e/kWh)
VMT = Vehicle miles traveled (VMT)
ER = Energy Ratio = 33.4 kWh/gallon-gasoline or 37.7 kWh/gallon-diesel
FE = Fuel Economy (mpg)
C = Unit conversion factor

Power Utility	Carbon-Intensity ($lbs\ CO_2e/MWh$)
LADW&P	1,238
PG&E	456
SCE	641
SDGE	781
SMUD	555

Criteria pollutant emissions will be 100% reduced for equipment running solely on electricity.

Hybrid-Electric Vehicle

The Project Applicant has to determine the fuel consumption reduced from using the hybrid-electric vehicle. The emission reductions for all pollutants are the same as the fuel reduction.

Emission reductions can be calculated as:

$$\text{GHG Reduction\%} = 1 - \frac{\text{Mitigated Emission}}{\text{Running Emission}}$$

Emission Reduction Ranges and Variables:

See Table VT-3.1 below.

Discussion:

Using the methodology described above, only the running emission is considered. A hypothetical scenario for a gasoline fueled light duty automobile with catalytic converter in 2015 is illustrated below. The running CO_2 emission factor at 30 mph from an EMFAC run of the Sacramento county with temperature of 60F and relative humidity of 45% is 336.1 g/mile. From Table VT-3.1, there will be an additional reduction of 9.1% for the emission factor in 2015 due to Pavley standard. Assuming the automobile makes two trips of 60 mile each per day, then annual baseline emission from the automobile is:

$$336.1 \times (100\% - 9.1\%) \times 2 \times 365 \times 60 \times 10^{-6} = 13.4 \text{ MT/year}$$

Where 10^{-6} is the conversion factor from grams to MT. Assuming the current passenger car fuel economy of 27.5 mpg under the CAFE standards, and using the carbon-intensity factor for PG&E, the electric provider for the Sacramento region, the mitigated emission from replacing the automobile described above with electric vehicle would be:

$$\left(456 \times \frac{2 \times 365 \times 60}{27.5} \times 33.4 \times \frac{1}{2{,}204 \times 10^{3}}\right) = 11.0 \text{ MT/year}$$

Therefore, the emission reduction is:

$$1 - \frac{11.0}{13.4} = 17.9\%$$

Assumptions:

Data based upon the following references:

- California Air Resources Board. EMFAC2007. Available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm
- California Climate Action Registry (CCAR). 2009. General Reporting Protocol. Version 3.1. Available online at: http://www.climateregistry.org/tools/protocols/general-reporting-protocol.html
- California Climate Action Registry Reporting Online Tool. 2006 PUP Reports. Available online at: https://www.climateregistry.org/CARROT/public/reports.aspx
- US Department of Energy. 2010. Alternative and Advanced Fuels – Fuel Properties. Available online at: http://www.afdc.energy.gov/afdc/fuels/properties.html

Preferred Literature:

The amount of emissions avoided from using electric and hybrid vehicles can be calculated using CARB's EMFAC model, which provides state-wide and regional running emission factors for a variety of on-road vehicles in units of grams per mile [1]. Multiplying this factor by the vehicle miles traveled (VMT) gives the direct emissions. For criteria pollutant, emissions can be assumed to be 100% reduced from running on electricity. For GHG, assuming the same VMT, the electricity required to run the same vehicle fleet can be calculated by dividing by the fuel economy (mph) and multiplying the gasoline-electric energy ratio obtained from the US Department of Energy [2]. Multiplying this value by the carbon-intensity factor of the local utility gives the amount of indirect GHG emissions associated with electric vehicles. The GHG emissions reduction associated with this mitigation measure is therefore the difference in emissions from these two scenarios.

Alternative Literature:

None

Notes:

[1] California Air Resources Board. EMFAC2007. Available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm
[2] US Department of Energy. 2010. Alternative and Advanced Fuels – Fuel Properties. Available online at: http://www.afdc.energy.gov/afdc/fuels/properties.html

Other Literature Reviewed:

None

Table VT-3.1
Reduction in EMFAC Running Emission Factor from New Regulations

Year	Vehicle Class	Reduction	Pollutant	Regulation
2010	LDA/LDT/MDV	0.4%	CO_2	Pavley Standard
2011	LDA/LDT/MDV	1.6%	CO_2	Pavley Standard
2012	LDA/LDT/MDV	3.5%	CO_2	Pavley Standard
2013	LDA/LDT/MDV	5.3%	CO_2	Pavley Standard
2014	LDA/LDT/MDV	7.1%	CO_2	Pavley Standard
2015	LDA/LDT/MDV	9.1%	CO_2	Pavley Standard
2016	LDA/LDT/MDV	11.0%	CO_2	Pavley Standard
2017	LDA/LDT/MDV	13.1%	CO_2	Pavley Standard
2018	LDA/LDT/MDV	15.5%	CO_2	Pavley Standard
2019	LDA/LDT/MDV	17.9%	CO_2	Pavley Standard
2020	LDA/LDT/MDV	20.3%	CO_2	Pavley Standard
2011	Other Buses	21.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	School Bus	19.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	MHDDT Agriculture	17.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	MHDDT CA International Registration Plan	4.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	MHDDT Instate	6.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	MHDDT Out-of-state	4.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	HHDDT Agriculture	23.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	HHDDT CA International Registration Plan	1.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	HHDDT Non-neighboring Out-of-state	0.5%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	HHDDT Neighboring Out-of-state	2.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	HHDDT Singleunit	10.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	HHDDT Tractor	9.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	Other Buses	25.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	Power Take Off	28.4%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	School Bus	45.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	MHDDT Agriculture	20.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	MHDDT CA International Registration Plan	12.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	MHDDT Instate	11.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles

Year	Vehicle Class	Reduction	Pollutant	Regulation
				Regulation
2012	MHDDT Out-of-state	12.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	HHDDT Agriculture	29.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	HHDDT CA International Registration Plan	8.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	HHDDT Non-neighboring Out-of-state	15.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	HHDDT Neighboring Out-of-state	15.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	HHDDT Drayage at Other Facilities	9.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	HHDDT Drayage in Bay Area	9.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	HHDDT Drayage near South Coast	7.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	HHDDT Singleunit	14.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	HHDDT Tractor	13.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	Other Buses	45.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	Power Take Off	57.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	School Bus	68.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	MHDDT Agriculture	31.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	MHDDT CA International Registration Plan	55.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	MHDDT Instate	64.5%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	MHDDT Out-of-state	55.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	HHDDT Agriculture	48.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	HHDDT CA International Registration Plan	60.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	HHDDT Non-neighboring Out-of-state	50.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	HHDDT Neighboring Out-of-state	63.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	HHDDT Drayage at Other Facilities	67.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	HHDDT Drayage in Bay Area	65.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	HHDDT Drayage near South Coast	51.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation

Year	Vehicle Class	Reduction	Pollutant	Regulation
2013	HHDDT Singleunit	66.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	HHDDT Tractor	69.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	Other Buses	53.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	Power Take Off	63.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	School Bus	71.4%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	MHDDT Agriculture	33.4%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	MHDDT CA International Registration Plan	65.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	MHDDT Instate	77.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	MHDDT Out-of-state	65.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	MHDDT Utility	0.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	HHDDT Agriculture	52.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	HHDDT CA International Registration Plan	63.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	HHDDT Non-neighboring Out-of-state	46.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	HHDDT Neighboring Out-of-state	64.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	HHDDT Singleunit	79.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	HHDDT Tractor	79.4%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	HHDDT Utility	4.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	Other Buses	49.5%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	Power Take Off	61.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	School Bus	71.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	MHDDT Agriculture	34.5%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	MHDDT CA International Registration Plan	60.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	MHDDT Instate	74.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	MHDDT Out-of-state	60.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	MHDDT Utility	0.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation

Year	Vehicle Class	Reduction	Pollutant	Regulation
2015	HHDDT Agriculture	53.5%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	HHDDT CA International Registration Plan	55.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	HHDDT Non-neighboring Out-of-state	37.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	HHDDT Neighboring Out-of-state	55.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	HHDDT Singleunit	77.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	HHDDT Tractor	76.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	HHDDT Utility	4.4%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	Other Buses	43.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	Power Take Off	75.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	School Bus	70.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	MHDDT Agriculture	32.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	MHDDT CA International Registration Plan	56.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	MHDDT Instate	73.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	MHDDT Out-of-state	56.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	MHDDT Utility	0.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	HHDDT Agriculture	51.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	HHDDT CA International Registration Plan	45.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	HHDDT Non-neighboring Out-of-state	27.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	HHDDT Neighboring Out-of-state	46.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	HHDDT Singleunit	75.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	HHDDT Tractor	73.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	HHDDT Utility	4.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	Other Buses	36.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	Power Take Off	71.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	School Bus	67.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation

Year	Vehicle Class	Reduction	Pollutant	Regulation
2017	MHDDT Agriculture	55.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	MHDDT CA International Registration Plan	52.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	MHDDT Instate	70.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	MHDDT Out-of-state	52.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	MHDDT Utility	0.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	HHDDT Agriculture	58.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	HHDDT CA International Registration Plan	37.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	HHDDT Non-neighboring Out-of-state	18.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	HHDDT Neighboring Out-of-state	37.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	HHDDT Singleunit	73.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	HHDDT Tractor	70.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	HHDDT Utility	3.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	Other Buses	31.4%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	Power Take Off	67.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	School Bus	74.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	MHDDT Agriculture	53.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	MHDDT CA International Registration Plan	47.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	MHDDT Instate	68.5%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	MHDDT Out-of-state	47.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	MHDDT Utility	0.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	HHDDT Agriculture	55.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	HHDDT CA International Registration Plan	30.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	HHDDT Non-neighboring Out-of-state	11.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	HHDDT Neighboring Out-of-state	30.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	HHDDT Singleunit	72.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation

Year	Vehicle Class	Reduction	Pollutant	Regulation
2018	HHDDT Tractor	67.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	HHDDT Utility	3.5%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	Other Buses	27.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	Power Take Off	76.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	School Bus	73.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	MHDDT Agriculture	53.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	MHDDT CA International Registration Plan	42.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	MHDDT Instate	65.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	MHDDT Out-of-state	42.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	MHDDT Utility	0.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	HHDDT Agriculture	54.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	HHDDT CA International Registration Plan	24.5%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	HHDDT Non-neighboring Out-of-state	5.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	HHDDT Neighboring Out-of-state	24.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	HHDDT Singleunit	69.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	HHDDT Tractor	64.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	HHDDT Utility	3.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	Other Buses	23.5%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	Power Take Off	74.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	School Bus	71.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	MHDDT Agriculture	52.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	MHDDT CA International Registration Plan	37.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	MHDDT Instate	60.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	MHDDT Out-of-state	37.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	MHDDT Utility	0.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation

Year	Vehicle Class	Reduction	Pollutant	Regulation
2020	HHDDT Agriculture	52.4%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	HHDDT CA International Registration Plan	19.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	HHDDT Non-neighboring Out-of-state	3.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	HHDDT Neighboring Out-of-state	20.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	HHDDT Singleunit	66.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	HHDDT Tractor	61.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	HHDDT Utility	2.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	Other Buses	21.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	Power Take Off	79.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	School Bus	68.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	MHDDT Agriculture	51.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	MHDDT CA International Registration Plan	33.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	MHDDT Instate	57.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	MHDDT Out-of-state	33.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	MHDDT Utility	5.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Agriculture	50.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT CA International Registration Plan	16.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Non-neighboring Out-of-state	3.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Neighboring Out-of-state	16.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Drayage at Other Facilities	10.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Drayage in Bay Area	9.4%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Drayage near South Coast	9.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Singleunit	64.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Tractor	59.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Utility	5.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation

Year	Vehicle Class	Reduction	Pollutant	Regulation
2022	Other Buses	20.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	Power Take Off	79.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	School Bus	66.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	MHDDT Agriculture	50.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	MHDDT CA International Registration Plan	28.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	MHDDT Instate	53.5%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	MHDDT Out-of-state	28.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	MHDDT Utility	6.4%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Agriculture	49.4%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT CA International Registration Plan	13.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Non-neighboring Out-of-state	1.5%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Neighboring Out-of-state	14.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Drayage at Other Facilities	10.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Drayage in Bay Area	8.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Drayage near South Coast	8.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Singleunit	61.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Tractor	55.5%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Utility	5.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	Other Buses	18.5%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	Power Take Off	74.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	School Bus	64.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	MHDDT Agriculture	79.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	MHDDT CA International Registration Plan	23.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	MHDDT Instate	48.4%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	MHDDT Out-of-state	23.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation

Year	Vehicle Class	Reduction	Pollutant	Regulation
2023	MHDDT Utility	7.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Agriculture	68.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT CA International Registration Plan	11.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Non-neighboring Out-of-state	1.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Neighboring Out-of-state	11.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Drayage at Other Facilities	9.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Drayage in Bay Area	8.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Drayage near South Coast	8.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Singleunit	56.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Tractor	51.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Utility	4.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	Other Buses	15.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	Power Take Off	68.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	School Bus	61.4%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	MHDDT Agriculture	77.4%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	MHDDT CA International Registration Plan	20.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	MHDDT Instate	43.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	MHDDT Out-of-state	20.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	MHDDT Utility	5.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT Agriculture	65.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT CA International Registration Plan	9.1%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT Non-neighboring Out-of-state	0.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT Neighboring Out-of-state	9.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT Drayage at Other Facilities	9.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT Drayage in Bay Area	7.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation

Year	Vehicle Class	Reduction	Pollutant	Regulation
2024	HHDDT Drayage near South Coast	7.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT Singleunit	50.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT Tractor	46.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT Utility	3.4%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	Other Buses	13.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	Power Take Off	62.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	School Bus	58.2%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	MHDDT Agriculture	75.4%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	MHDDT CA International Registration Plan	15.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	MHDDT Instate	37.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	MHDDT Out-of-state	15.3%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	MHDDT Utility	3.4%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Agriculture	62.7%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT CA International Registration Plan	6.8%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Non-neighboring Out-of-state	0.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Neighboring Out-of-state	7.0%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Drayage at Other Facilities	8.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Drayage in Bay Area	7.5%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Drayage near South Coast	7.6%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Singleunit	44.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Tractor	42.9%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Utility	2.4%	PM2.5	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	MHDDT CA International Registration Plan	1.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	MHDDT Instate	2.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	MHDDT Out-of-state	1.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation

Year	Vehicle Class	Reduction	Pollutant	Regulation
2011	HHDDT CA International Registration Plan	0.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	HHDDT Non-neighboring Out-of-state	0.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	HHDDT Neighboring Out-of-state	1.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	HHDDT Singleunit	4.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2011	HHDDT Tractor	3.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	Power Take Off	13.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	School Bus	2.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	MHDDT CA International Registration Plan	1.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	MHDDT Instate	2.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	MHDDT Out-of-state	1.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	HHDDT CA International Registration Plan	0.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	HHDDT Non-neighboring Out-of-state	0.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	HHDDT Neighboring Out-of-state	0.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	HHDDT Singleunit	3.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2012	HHDDT Tractor	3.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	Other Buses	18.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	Power Take Off	34.0%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	School Bus	4.4%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	MHDDT Agriculture	5.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	MHDDT CA International Registration Plan	12.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	MHDDT Instate	25.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	MHDDT Out-of-state	12.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	HHDDT Agriculture	10.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	HHDDT CA International Registration Plan	8.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	HHDDT Non-neighboring Out-of-state	1.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation

Year	Vehicle Class	Reduction	Pollutant	Regulation
2013	HHDDT Neighboring Out-of-state	8.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	HHDDT Singleunit	33.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2013	HHDDT Tractor	28.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	Other Buses	40.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	Power Take Off	37.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	School Bus	6.4%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	MHDDT Agriculture	9.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	MHDDT CA International Registration Plan	22.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	MHDDT Instate	34.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	MHDDT Out-of-state	22.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	MHDDT Utility	0.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	HHDDT Agriculture	17.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	HHDDT CA International Registration Plan	13.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	HHDDT Non-neighboring Out-of-state	4.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	HHDDT Neighboring Out-of-state	14.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	HHDDT Singleunit	45.4%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	HHDDT Tractor	36.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2014	HHDDT Utility	1.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	Other Buses	52.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	Power Take Off	33.0%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	School Bus	6.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	MHDDT Agriculture	18.4%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	MHDDT CA International Registration Plan	20.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	MHDDT Instate	31.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	MHDDT Out-of-state	20.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation

Year	Vehicle Class	Reduction	Pollutant	Regulation
2015	MHDDT Utility	0.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	HHDDT Agriculture	27.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	HHDDT CA International Registration Plan	11.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	HHDDT Non-neighboring Out-of-state	2.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	HHDDT Neighboring Out-of-state	12.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	HHDDT Singleunit	42.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	HHDDT Tractor	34.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2015	HHDDT Utility	1.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	Other Buses	54.4%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	Power Take Off	43.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	School Bus	4.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	MHDDT Agriculture	19.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	MHDDT CA International Registration Plan	22.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	MHDDT Instate	32.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	MHDDT Out-of-state	22.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	MHDDT Utility	0.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	HHDDT Agriculture	29.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	HHDDT CA International Registration Plan	11.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	HHDDT Non-neighboring Out-of-state	3.4%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	HHDDT Neighboring Out-of-state	13.0%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	HHDDT Singleunit	43.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	HHDDT Tractor	35.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2016	HHDDT Utility	1.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	Other Buses	59.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	Power Take Off	38.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation

Year	Vehicle Class	Reduction	Pollutant	Regulation
2017	MHDDT Agriculture	43.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	MHDDT CA International Registration Plan	27.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	MHDDT Instate	35.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	MHDDT Out-of-state	27.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	MHDDT Utility	1.0%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	HHDDT Agriculture	45.0%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	HHDDT CA International Registration Plan	14.4%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	HHDDT Non-neighboring Out-of-state	7.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	HHDDT Neighboring Out-of-state	17.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	HHDDT Singleunit	46.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	HHDDT Tractor	38.0%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2017	HHDDT Utility	1.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	Other Buses	56.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	Power Take Off	32.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	School Bus	7.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	MHDDT Agriculture	41.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	MHDDT CA International Registration Plan	26.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	MHDDT Instate	41.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	MHDDT Out-of-state	26.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	MHDDT Utility	1.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	HHDDT Agriculture	42.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	HHDDT CA International Registration Plan	15.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	HHDDT Non-neighboring Out-of-state	4.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	HHDDT Neighboring Out-of-state	16.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	HHDDT Singleunit	51.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation

Year	Vehicle Class	Reduction	Pollutant	Regulation
2018	HHDDT Tractor	43.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2018	HHDDT Utility	1.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	Other Buses	52.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	Power Take Off	38.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	School Bus	6.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	MHDDT Agriculture	40.0%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	MHDDT CA International Registration Plan	22.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	MHDDT Instate	38.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	MHDDT Out-of-state	22.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	MHDDT Utility	1.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	HHDDT Agriculture	40.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	HHDDT CA International Registration Plan	12.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	HHDDT Non-neighboring Out-of-state	2.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	HHDDT Neighboring Out-of-state	13.0%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	HHDDT Singleunit	48.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	HHDDT Tractor	41.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2019	HHDDT Utility	1.4%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	Other Buses	49.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	Power Take Off	41.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	School Bus	5.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	MHDDT Agriculture	38.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	MHDDT CA International Registration Plan	19.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	MHDDT Instate	34.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	MHDDT Out-of-state	19.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	MHDDT Utility	1.4%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation

Year	Vehicle Class	Reduction	Pollutant	Regulation
2020	HHDDT Agriculture	38.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	HHDDT CA International Registration Plan	9.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	HHDDT Non-neighboring Out-of-state	1.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	HHDDT Neighboring Out-of-state	10.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	HHDDT Singleunit	45.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	HHDDT Tractor	39.0%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2020	HHDDT Utility	1.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	Other Buses	48.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	Power Take Off	51.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	School Bus	4.4%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	MHDDT Agriculture	38.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	MHDDT CA International Registration Plan	21.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	MHDDT Instate	41.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	MHDDT Out-of-state	21.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	MHDDT Utility	33.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Agriculture	37.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT CA International Registration Plan	9.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Non-neighboring Out-of-state	1.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Neighboring Out-of-state	9.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Drayage at Other Facilities	40.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Drayage in Bay Area	41.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Drayage near South Coast	39.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Singleunit	54.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Tractor	45.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2021	HHDDT Utility	21.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation

Year	Vehicle Class	Reduction	Pollutant	Regulation
2022	Other Buses	48.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	Power Take Off	60.0%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	School Bus	3.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	MHDDT Agriculture	40.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	MHDDT CA International Registration Plan	20.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	MHDDT Instate	41.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	MHDDT Out-of-state	20.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	MHDDT Utility	28.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Agriculture	40.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT CA International Registration Plan	8.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Non-neighboring Out-of-state	1.4%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Neighboring Out-of-state	9.0%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Drayage at Other Facilities	39.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Drayage in Bay Area	40.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Drayage near South Coast	39.0%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Singleunit	54.4%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Tractor	45.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2022	HHDDT Utility	18.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	Other Buses	47.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	Power Take Off	54.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	School Bus	2.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	MHDDT Agriculture	65.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	MHDDT CA International Registration Plan	18.4%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	MHDDT Instate	39.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	MHDDT Out-of-state	18.4%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation

Year	Vehicle Class	Reduction	Pollutant	Regulation
2023	MHDDT Utility	25.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Agriculture	59.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT CA International Registration Plan	7.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Non-neighboring Out-of-state	1.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Neighboring Out-of-state	8.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Drayage at Other Facilities	38.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Drayage in Bay Area	39.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Drayage near South Coast	38.4%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Singleunit	52.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Tractor	44.0%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2023	HHDDT Utility	16.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	Other Buses	43.4%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	Power Take Off	47.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	School Bus	1.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	MHDDT Agriculture	63.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	MHDDT CA International Registration Plan	15.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	MHDDT Instate	33.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	MHDDT Out-of-state	15.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	MHDDT Utility	19.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT Agriculture	56.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT CA International Registration Plan	6.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT Non-neighboring Out-of-state	0.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT Neighboring Out-of-state	6.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT Drayage at Other Facilities	38.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT Drayage in Bay Area	39.4%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation

Year	Vehicle Class	Reduction	Pollutant	Regulation
2024	HHDDT Drayage near South Coast	37.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT Singleunit	47.2%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT Tractor	39.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2024	HHDDT Utility	13.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	Other Buses	39.0%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	Power Take Off	39.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	School Bus	1.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	MHDDT Agriculture	61.1%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	MHDDT CA International Registration Plan	11.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	MHDDT Instate	28.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	MHDDT Out-of-state	11.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	MHDDT Utility	13.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Agriculture	53.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT CA International Registration Plan	4.6%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Non-neighboring Out-of-state	0.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Neighboring Out-of-state	4.8%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Drayage at Other Facilities	37.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Drayage in Bay Area	38.9%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Drayage near South Coast	37.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Singleunit	41.5%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Tractor	35.7%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation
2025	HHDDT Utility	10.3%	NOx	On-Road Heavy-Duty Diesel Vehicles Regulation

4.0 Water

4.1 Water Supply

4.1.1 Use Reclaimed Water

Range of Effectiveness: Up to 40% in Northern California and up to 81% in Southern California

Measure Description:

California water supplies come from ground water, surface water, and from reservoirs, typically fed from snow melt. Some sources of water are transported over long distances, and sometimes over terrain to reach the point of consumption. Transporting water can require a significant amount of electricity. In addition, treating water to potable standards can also require substantial amounts of energy. Reclaimed water is water reused after wastewater treatment for non-potable uses instead of returning the water to the environment. This is different than gray water, which has not been through wastewater treatment. Reclaimed non-potable water requires significantly less energy to collect, treat, and redistribute water to the point of local areas of non-potable water consumption. Since less energy is required to provide reclaimed water, fewer GHGs will be associated with reclaimed water use compared to the average California water supply use.

This measure describes how to calculate GHG savings from using reclaimed water instead of new potable water supplies for outdoor water uses or other non-potable water uses. The baseline scenario document outlines average Northern and Southern California electricity-use water factors, and assumes that all water is treated to potable standards.

Measure Applicability:

- Non-potable water use

Inputs:

The following information needs to be provided by the Project Applicant:

- Reclaimed water use (million gallons)
- Total non-potable water use (million gallons)

Baseline Method:

$$\text{GHG emissions} = \text{Water}_{\text{non-potable total}} \times \text{Electricity}_{\text{baseline}} \times \text{Utility}$$

Where:

GHG emissions = MT CO_2e
$Water_{non\text{-}potable\ total}$ = Total volume of non-potable water used (million gallons)
Provided by Applicant
$Electricity_{baseline}$ = Electricity required to supply, treat, and distribute water (kWh/million gallons)
Northern California Average: 3,500 kWh/million gallons
Southern California Average: 11,111 kWh/million gallons
Utility = Carbon intensity of Local Utility (CO_2e/kWh)

Mitigation Method:

A million gallons of reclaimed water would use an average of 2,100 kWh electricity per million gallons of water (range of 1,200 to 3,000 kWh). Therefore the percent reduction in GHG emissions associated with implementing reclaimed water usage is:

$$\text{GHG emission reduction} = \frac{Water_{reclaimed}}{Water_{non\text{-}potable\ total}} \times \frac{Electricity_{baseline} - Electricity_{reclaimed}}{Electricity_{baseline}}$$

Where:

GHG emission reduction = Percentage reduction in GHG emissions for non-potable water use.
$Water_{reclaimed}$ = Total volume of reclaimed water used (million gallons)
Provided by Applicant
$Water_{non\text{-}potable\ total}$ = Total volume of non-potable water used (million gallons)
Provided by Applicant
$Electricity_{reclaimed}$ = Electricity required to treat and distribute reclaimed water (2,100 kWh/million gallons)
$Electricity_{baseline}$ = Electricity required to supply and distribute water
Northern California Average: 3,500 kWh/million gallons
Southern California Average: 11,111 kWh/million gallons

Therefore, for projects in Northern California, the reduction in GHG emissions is:

$$\text{GHG emission reduction} = \frac{Water_{reclaimed}}{Water_{non\text{-}potable\ total}} \times \frac{(3{,}500 - 2{,}100)}{3{,}500} = \frac{Water_{reclaimed}}{Water_{non\text{-}potable\ total}} \times 0.40$$

And for projects in Southern California, the reduction in GHG emissions is:

$$\text{GHG emission reduction} = \frac{Water_{reclaimed}}{Water_{non\text{-}potable\ total}} \times \frac{(11{,}111 - 2{,}100)}{11{,}111} = \frac{Water_{reclaimed}}{Water_{non\text{-}potable\ total}} \times 0.81$$

As shown in these equations, the carbon intensity of the local utility does not play a role in determining the percentage reduction in GHG emissions.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	N. California: Up to 40% if assuming 100% reclaimed water S. California: Up to 81% if assuming 100% reclaimed water Percent reduction would scale down linearly as the percent reclaimed water decreases.
All other pollutants	Not quantified[82]

Discussion:

If the Project Applicant uses 100 million gallons of non-potable water for a project in Northern California, they would calculate baseline emissions as described in the baseline methodologies document. If the applicant then selects to mitigate water by committing to using 40 million gallons of reclaimed water in place of the usual water source, the applicant would reduce the amount of GHG emissions associated with outdoor water use by 16%

$$\text{GHG Emission Reduced} = \frac{40}{100} \times 0.40 = 0.16 \text{ or } 16\%$$

Assumptions:

Data based upon the following reference:

[1] CEC. 2006. Refining Estimates of Water-Related Energy Use in California. PIER Final Project Report. Prepared by Navigant Consulting, Inc. CEC-500-2006-118. Available online at: http://www.energy.ca.gov/2006publications/CEC-500-2006-118/CEC-500-2006-118.PDF

Preferred Literature:

GHG emissions from the mitigated scenario should be calculated based on the 2006 CEC report, which presents regional baseline electricity-use water factors and a factor of 1,200-3,000 kWh per million gallons for reclaimed water. GHG emissions are calculated by multiplying the amount of water (million gallons) by the electricity-use water factor (kWh per million gallons) by the carbon-intensity of the local utility (CO_2e per kWh). The GHG emissions reductions associated with this mitigation measure are

[82] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

associated with the difference between the baseline potable water electricity-use water factor and the mitigated scenario.

Alternative Literature:

None

Other Literature Reviewed:

None

4.1.2 Use Gray Water

Range of Effectiveness: Up to 100% of outdoor water GHG emissions if outdoor water use is replaced completely with graywater

Measure Description:

California water supplies come from ground water, surface water, and from reservoirs, typically fed from snow melt. Some sources of water are transported over long distances, and sometimes over terrain to reach the point of consumption. Transporting water can require a significant amount of electricity. In addition, treating water to potable standards can also require substantial amounts of energy. Untreated wastewater generated from bathtubs, showers, bathroom wash basins, and clothes washing machines is known as graywater and is collected and distributed onsite for irrigation of landscape and mulch. Since graywater does not require treatment or energy to redistribute it onsite, there are negligible GHG emissions associated with the use of graywater.

This measure describes how to calculate GHG savings from using graywater instead of new potable water supplies for landscape irrigation and other outdoor uses. The baseline scenario document outlines average Northern and Southern California electricity-use water factors, and assumes that all water is non-potable.

Measure Applicability:

- Outdoor water use

Inputs:

The following information needs to be provided by the Project Applicant:

- Graywater use[83] (million gallons), or:
    - Type of graywater system, which must be compliant with the California Plumbing Code, and
    - Number of residents in homes with compliant graywater systems
- Total outdoor water use (million gallons)

Baseline Method:

$$\text{GHG emissions} = \text{Water}_{\text{outdoor total}} \times \text{Electricity}_{\text{baseline}} \times \text{Utility}$$

[83] Note that this is the amount of graywater used, which may be less than the amount of graywater generated. A project may generate and collect more graywater than is needed for landscape irrigation. The Project Applicant should only take credit for the amount of potable water which is displaced by graywater. The amount of landscape irrigation water demand (graywater demand) is calculated according to the methodology described in WUW-3 and the baseline methodologies document.

Where:

GHG emissions = MT CO_2e

$Water_{outdoor\ total}$ = Total volume of outdoor water used (million gallons)
Provided by Applicant

$Electricity_{baseline}$ = Electricity required to supply, treat, and distribute water (kWh/million gallons)
Northern California Average: 3,500 kWh/million gallons
Southern California Average: 11,111 kWh/million gallons

Utility = Carbon intensity of Local Utility (CO_2e/kWh)

Mitigation Method:

If the Project Applicant cannot provide the total amount of graywater used, the graywater use can be calculated based on the following equation:

$Water_{graywater}$ =

$$\left[\left(25 \times Residents_{graywater\text{-}sbw}\right) + \left(15 \times Residents_{graywater\text{-}laundry}\right)\right] \frac{gallons}{day} \times \frac{365\ days}{year} \times \frac{1\ million\ gallons}{10^6\ gallons}$$

Where:

$Water_{graywater}$ = Total volume of graywater used (million gallons).

$Residents_{graywater\text{-}sbw}$ = Total number of residents in homes with graywater systems based on graywater generated from showers, bathtubs, and wash basins

25 = gallons per day per residential occupant from showers, bathtubs, and washbasins [1]

$Residents_{graywater\text{-}laundry}$ = Total number of residents in homes with graywater systems based on graywater generated from laundry machines

15 = gallons per day per residential occupant from laundry machines [1]

The percent reduction in GHG emissions associated with implementing graywater usage is therefore:

$$\text{GHG emission reduction} = \frac{Water_{graywater}}{Water_{oudoor\ total}} \times \frac{Electricity_{baseline} - Electricity_{graywater}}{Electricity_{baseline}}$$

Where:

GHG emission reduction = Percentage reduction in GHG emissions for outdoor water use.

$Water_{graywater}$ = Total volume of graywater used (million gallons)
Provided by Applicant or calculated using equation above

$Water_{outdoor\ total}$ = Total volume of outdoor water used (million gallons)
Provided by Applicant

$Electricity_{graywater}$	=	Electricity required to distribute graywater (0 kWh/million gallons)[84]
$Electricity_{baseline}$	=	Electricity required to supply, treat, and distribute water Northern California Average: 3,500 kWh/million gallons [2] Southern California Average: 11,111 kWh/million gallons [2]

Therefore, for projects in Northern California, the reduction in GHG emissions is:

$$\text{GHG emission reduction} = \frac{Water_{graywater}}{Water_{outdoor\ total}} \times \frac{(3{,}500-0)}{3{,}500} = \frac{Water_{graywater}}{Water_{outdoor\ total}}$$

And for projects in Southern California, the reduction in GHG emissions is:

$$\text{GHG emission reduction} = \frac{Water_{graywater}}{Water_{outdoor\ total}} \times \frac{(11{,}111-0)}{11{,}111} = \frac{Water_{graywater}}{Water_{outdoor\ total}}$$

As shown in these equations, the carbon intensity of the local utility does not play a role in determining the percentage reduction in GHG emissions.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	N. California: Up to 100% if assuming 100% graywater S. California: Up to 100% if assuming 100% graywater Percent reduction would scale down linearly as the percent reclaimed water decreases.
All other pollutants	Not Quantified[85]

Discussion:

If the Project Applicant uses 100 million gallons of water for outdoor uses in a project in Northern California, they would calculate baseline emissions as described above and in the baseline methodologies document. If the Project Applicant then selects to mitigate water by committing to establishing graywater systems based on graywater recovery from laundry machines in 500 homes with an average of 3 people in each home, the amount of graywater used is then:

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[84] In some cases the distribution of graywater will require some amount of electricity; for example, graywater generated at residences and pumped to a nearby park. In those cases, $Electricity_{graywater}$ will be non-zero.

[85] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

$Water_{graywater}$ =

$$[(25\times 0)+(15\times 500\times 3)]\frac{\text{gallons}}{\text{day}}\times\frac{365\,\text{days}}{\text{year}}\times\frac{1\,\text{million gallons}}{10^6\ \text{gallons}} = 8.2 \text{ million gallons}$$

Then the Project Applicant would reduce the amount of GHG emissions associated with outdoor water use by 8.2%

$$\text{GHG Emission Reduced} = \frac{8.2}{100} = 0.082 \text{ or } 8.2\%$$

Assumptions:

Data based upon the following references:

[1] 2007 CPC, Title 24, Part 5, Chapter 16A, Part I – Nonpotable Water Reuse Systems. Available online at: http://www.hcd.ca.gov/codes/shl/2007CPC_Graywater_Complete_2-2-10.pdf

[2] CEC. 2006. Refining Estimates of Water-Related Energy Use in California. PIER Final Project Report. Prepared by Navigant Consulting, Inc. CEC-500-2006-118. December. Available online at: http://www.energy.ca.gov/2006publications/CEC-500-2006-118/CEC-500-2006-118.PDF

Preferred Literature:

Assuming a compliant graywater system is installed, Part 1606A.0 of the California Plumbing Code (CPC) estimates 25 gallons per day per residential occupant of graywater generation from showers, bathtubs, and wash basins, and 15 gallons per day per residential occupant of graywater discharge from laundry machines. Electricity and CO_2 savings from using graywater are determined by comparing to the emissions that would have been associated with the water use if the graywater demand had instead been supplied by potable water. The baseline emissions should be calculated based on the 2006 CEC methodology. A development may generate and collect more graywater than is needed for landscape irrigation. A Project Applicant should only take credit for emissions reductions associated with the amount of potable water which is displaced by graywater. The amount of landscape irrigation water demand (graywater demand) is calculated according to the methodology described in the baseline methodologies document and WUW-3.

Alternative Literature:

None

Other Literature Reviewed:

[3] Arizona Department of Environmental Quality. 2009. Using Gray Water at Home Brochure. Available online at: http://www.azdeq.gov/environ/water/permits/download/graybro.pdf

[4] Arizona Department of Water Resources. Technologies – Irrigation, Rainwater Harvesting, Gray Water Reuse and Artificial Turf. Available online at: http://www.azwater.gov/AzDWR/StatewidePlanning/Conservation2/Technologies/Tech%20pages%20templates/LandscapeIrrigation.htm. Accessed February 2010.

[5] AAC, Title 18, Chapter 9, Article 7. Direct Reuse of Reclaimed Water. Available online at: http://www.azsos.gov/public_services/title_18/18-09.pdf

[6] Oasis Design. Graywater Information Central. Available online at: http://www.graywater.net/. Accessed February 2010.

4.1.3 Use Locally Sourced Water Supply

Range of Effectiveness: 0 – 60% for Northern and Central California, 11 – 75% for Southern California

Measure Description:

California water supplies come from ground water, surface water, and from reservoirs, typically fed from snow melt. Some sources of water are transported over long distances, and sometimes over terrain to reach the point of consumption. Transporting water can require a significant amount of electricity. Using locally-sourced water or water from less energy-intensive sources reduces the electricity and indirect CO_2 emissions associated with water supply and transport.

This measure describes how to calculate GHG savings from using local or less energy-intensive water sources instead of water from the typical mix of Northern and Southern California sources. According to the 2006 CEC report [1], water in Northern California (which also includes the Central Coast and San Joaquin Valley for this study) is primarily supplied by deliveries from the State Water Project and groundwater, and to a lesser extent is supplied by the gravity-dominated systems of Hetch Hetchy and the Mokelumne Aqueduct. In contrast, water imported from the State Water Project is Southern California's dominant water source. The baseline scenario uses average Northern and Southern California electricity intensity factors as reported in 2006 CEC and detailed in the Baseline Method below.

Measure Applicability:

- Indoor (potable) and outdoor (non-potable) water use

Inputs:

- Total potable and non-potable water use (million gallons)

Baseline Method:

$$\text{GHG emissions} = \text{Water}_{baseline} \times \text{Electricity}_{baseline} \times \text{Utility}$$

Where:

GHG emissions = MT CO_2e

$\text{Water}_{baseline}$ = Total volume of water used (million gallons)
Provided by Applicant

$\text{Electricity}_{baseline}$ = Electricity required to supply, treat, and distribute water (and for indoor uses, the electricity required to treat the resulting wastewater) (kWh/million gallons)
Indoor Uses:
Northern California Average: 5,411 kWh/million gallons [1]
Southern California Average: 13,022 kWh/million gallons [1]

Outdoor Uses:
Northern California Average: 3,500 kWh/million gallons [1]
Southern California Average: 11,111 kWh/million gallons [1]
Utility = Carbon intensity of Local Utility (CO_2e/kWh)

Mitigation Method:

Table WSW-3.1 shows that water from local or nearby groundwater basins, nearby surface water, and gravity-dominated systems have smaller energy-intensity factors than the average Northern and Southern California energy-intensity factors. The Project Applicant should use Table WSW-3.1 to identify the outdoor and indoor electricity intensity factors associated with the Project's water source(s). The GHG emission reduction is then calculated as follows:

$$\text{GHG emission reduction} = \frac{Water_{mitigated}}{Water_{baseline}} \times \frac{Electricity_{baseline} - Electricity_{mitigated}}{Electricity_{baseline}}$$

Where:

GHG emission reduction = Percentage reduction in GHG emissions for water use
$Water_{mitigated}$ = Volume of water to be supplied from the mitigated (local or less energy-intensive) source
Provided by Applicant
$Water_{baseline}$ = Total volume of water used (million gallons)
Provided by Applicant
$Electricity_{mitigated}$ = Electricity required to distribute water for Project from mitigated (local or less-energy intensive) source
$Electricity_{baseline}$ = Baseline electricity required to supply, treat, and distribute water (and for indoor uses, the electricity required to treat the resulting wastewater) (kWh/million gallons)
Indoor Uses:
Northern California Average: 5,411 kWh/million gallons [1]
Southern California Average: 13,022 kWh/million gallons [1]
Outdoor Uses:
Northern California Average: 3,500 kWh/million gallons [1]
Southern California Average: 11,111 kWh/million gallons [1]

As shown in these equations, the carbon intensity of the local utility does not play a role in determining the percentage reduction in GHG emissions.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	Assuming 100% of water is sourced locally: Indoor Uses: • 0-40% reduction for Northern and Central California • 11-64% reduction for Southern California Outdoor Uses: • 0-60% reduction for Northern and Central California • 12-75% reduction for Southern California
All other pollutants	Not Quantified[86]

Discussion:

Assume a Project is located in Southern California within the Chino Basin and has a total indoor water demand of 100 million gallons. Assume 70 million gallons will be sourced from a water district which obtains its water from the typical Southern California water sources. Therefore, for these 70 million gallons the baseline outdoor water electricity-intensity factor for Southern California is used. Assume that the Project Applicant chooses to mitigate the Project by sourcing the remaining 30 million gallons from the Chino Basin. The expected GHG emission reduction is then:

$$\text{GHG Emission Reduced} = \frac{30}{100} \times \frac{11{,}111 - 4{,}298}{11{,}111} = 0.18 \text{ or } 18\%$$

Assumptions:

Data based upon the following reference:

[1] CEC. 2006. Refining Estimates of Water-Related Energy Use in California. PIER Final Project Report. Prepared by Navigant Consulting, Inc. CEC-500-2006-118. December. Available online at: http://www.energy.ca.gov/2006publications/CEC-500-2006-118/CEC-500-2006-118.PDF

86 Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

[2]CEC. 2005. California's Water-Energy Relationship. Final Staff Report. CEC 700-2005-011-SF. Available online at: http://www.energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011-SF.PDF
[3]NRDC. 2004. Energy Down the Drain: The Hidden Costs of California's Water Supply. Prepared by NRDC and the Pacific Institute. Available online at: http://www.nrdc.org/water/conservation/edrain/edrain.pdf

Preferred Literature:

Electricity and CO_2 savings from using locally-sourced water or water from sources which require below-average electricity intensities for supply and conveyance (such as gravity-dominated systems or local groundwater basins that are not very deep) are determined by comparing to the emissions that would have occurred if the water had instead been conveyed from typical water sources for the region. According to the 2005 and 2006 CEC reports [1,2], the typical mix of water sources in Northern and Central California is the State Water Project, groundwater, and gravity-dominated systems such as Hetch Hetchy and the Mokelumne Aqueduct. The majority of water in Southern California is supplied by imports from the State Water Project and the Colorado River Aqueduct. Examples of mitigated electricity-intensity factors are shown in Table WSW-3.1 and are based on data provided in 2006 CEC [1], 2005 CEC [2], and 2004 NRDC [3]. GHG emissions are calculated by multiplying the amount of water (million gallons) by the electricity-use water factor (kWh per million gallons) by the carbon-intensity of the local utility (CO_2e per kWh). The GHG emissions reductions associated with this mitigation measure are associated with the difference between the baseline water electricity-intensity factor and the mitigated electricity-intensity factor.

Alternative Literature:

None

Other Literature Reviewed:

None

Table WSW-3.1

Energy Intensity of Water Use (kWh/MG) by Region

REGION	WATER USE SEGMENT						
	Supply & Conveyance[1]		Treatment[1]	Distribution[1]	*OUTDOOR TOTAL (NON-POTABLE)*[2]	Wastewater Treatment[1]	*INDOOR TOTAL (POTABLE)*[3]
Northern California	SWP to Bay Area *surface water*	3,150	111	1,272	***4,533***	1,911	***6,444***
	Hetch Hetchy to Bay Area *gravity dominated*	0	111	1,272	***1,383***	1,911	***3,294***
	Mokelumne Aqueduct to Bay Area *gravity dominated*	160	111	1,272	***1,543***	1,911	***3,454***
Central California	SWP to Central Coast *surface water*	3,150	111	1,272	***4,533***	1,911	***6,444***
	SWP to San Joaquin Valley *surface water*	1,510	111	1,272	***2,893***	1,911	***4,804***
	San Joaquin River Basin & Central Coast[4] *groundwater*	896	111	1,272	***2,279***	1,911	***4,190***
	Tulare Lake Basin[4] *groundwater*	537	111	1,272	***1,920***	1,911	***3,831***
	Fresno and Kings Counties (Westlands WD)[4] *groundwater*	2,271	111	1,272	***3,654***	1,911	***5,565***
Southern California	SWP to L.A. Basin *surface water*	8,325	111	1,272	***9,708***	1,911	***11,619***
	Colorado River Aqueduct to L.A. Basin *surface water*	6,140	111	1,272	***7,523***	1,911	***9,434***
	Chino Basin[5] *groundwater*	2,915	111	1,272	***4,298***	1,911	***6,209***
	Los Angeles[4] *groundwater*	1,780	111	1,272	***3,163***	1,911	***5,074***
	San Diego County (Sweetwater WD)[4] *groundwater*	1,433	111	1,272	***2,816***	1,911	***4,727***
	San Diego County (Yuima WD)[4]	2,029	111	1,272	***3,412***	1,911	***5,323***

REGION	WATER USE SEGMENT						
	Supply & Conveyance[1]		Treatment[1]	Distribution[1]	*OUTDOOR TOTAL (NON-POTABLE)*[2]	Wastewater Treatment[1]	*INDOOR TOTAL (POTABLE)*[3]
	groundwater						
State-wide	Local / Intrabasin	120	111	1,272	***1,503***	1,911	***3,414***
	Groundwater	4.45 kWh / MG / foot of well depth	111	1,272	***TBC***	1,911	***TBC***
	Ocean Desalination	13,800	111	1,272	***15,183***	1,911	***17,094***
	Brackish Water Desalination	3,230	111	1,272	***4,613***	1,911	***6,524***

Abbreviations:

CEC - California Energy Commission
kWh - kilowatt hour
MG - million gallons
NRDC - Natural Resources Defense Council
SWP - State Water Project
TBC - to be calculated based on well depth
WD - Water District

Notes:

1. Treatment, Distribution, and Wastewater Treatment electricity-intensity factors from 2006 CEC. Supply & Conveyance electricity-intensity factors from 2006 CEC unless otherwise noted.
2. Outdoor (Non-Potable) electricity-intensity factor is the sum of the Supply & Conveyance, Treatment, and Distribution electricity-intensity factors.
3. Indoor (Potable) electricity-intensity factor is the sum of the Supply & Conveyance, Treatment, Distribution, and Wastewater Treatment electricity-intensity factors.
4. Supply & Conveyance electricity-intensity factor from 2004 NRDC.
5. Supply & Conveyance electricity-intensity factor from 2005 CEC.

Sources:

CEC. 2006. Refining Estimates of Water-Related Energy Use in California. PIER Final Project Report. Prepared by Navigant Consulting, Inc. CEC-500-2006-118. December. Available at: http://www.energy.ca.gov/2006publications/CEC-500-2006-118/CEC-500-2006-118.PDF

CEC. 2005. California's Water-Energy Relationship. Final Staff Report. CEC 700-2005-011-SF. Available online at: http://www.energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011-SF.PDF

NRDC. 2004. Energy Down the Drain: The Hidden Costs of California's Water Supply. Prepared by NRDC and the Pacific Institute. Available online at: http://www.nrdc.org/water/conservation/edrain/edrain.pdf

4.2 Water Use

4.2.1 Install Low-Flow Water Fixtures

Range of Effectiveness: 20% of GHG emissions associated with indoor Residential water use; 17-31% of GHG emissions associated with Non-Residential indoor water use.

Measure Description:

Water use contributes to GHG emissions indirectly, via the production of the electricity that is used to pump, treat, and distribute the water. Installing low-flow or high-efficiency water fixtures in buildings reduces water demand, energy demand, and associated indirect GHG emissions.

This measure describes how to calculate GHG savings from installing low-flow water toilets, urinals, showerheads, or faucets, or high-efficiency clothes washers and dishwashers in residential and commercial buildings. To take credit for this mitigation measure, the Project Applicant must know the total expected indoor water demand before and after installation of low-flow or high-efficiency water fixtures. If expected water demand after implementation of the mitigation measure is not known, it can be calculated based on the information provided below. Water flow rates presented here in Tables WUW-1.1 and WUW-1.3 are based on technical specifications in the California Code of Regulations Title 20 (Appliance Efficiency Regulations) [2], Title 24 (California Green Building Standards Code) [1] and ENERGY STAR [5-8]. Indoor water end-uses for residential and commercial buildings presented here in Tables WUW-1.1 and WUW-1.2 are based on data provided in a 2003 report by the Pacific Institute for Studies in Development, Environment, and Security [3]. This report incorporates data from the most comprehensive end-use survey available to date, the 1999 Residential End Uses of Water survey published by the American Water Works Association [4], as well as California-specific population, water, and appliance data. California-specific data includes local utility water use and market penetration rates of low-flow and high-efficiency water fixtures.

The baseline scenario document describes the method to calculate baseline GHG emissions. It provides average Northern and Southern California electricity-use water factors and assumes that all water is treated to potable standards.

The percent reduction in GHG emissions is calculated based on the baseline scenario water use and the percent reduction in indoor water use achieved from a Project Applicant's commitment to installing low-flow and high-efficiency water fixtures. Table WUW-1.4 lists the estimated percent reductions in GHG emissions by water fixture and land use. The sum of all percent reductions applicable to the Project gives the overall percent reduction in GHG emissions expected from this mitigation measure. The details of these calculations are described below.

Measure Applicability:

- Indoor water use
- To meet CEQA enforcement requirements, the Project Applicant should only take credit for this mitigation measure if the clothes washers and dishwashers are supplied by the Project Applicant/builder.

Inputs:

The following information needs to be provided by the Project Applicant:

- Total expected indoor water demand, without installation of low-flow or high-efficiency fixtures (million gallons), AND
- Total expected indoor water demand, after installation of low-flow or high-efficiency fixtures (million gallons), OR
- Commitment to low-flow or high-efficiency water fixtures (toilets, showerheads, sink faucets, dishwashers, clothes washers, or all of the above)

Baseline Method:

$$\text{GHG emissions} = \text{Water}_{baseline} \times \text{Electricity} \times \text{Utility}$$

Where:

GHG emissions = MT CO_2e

$\text{Water}_{baseline}$ = Total expected indoor water demand, without installation of low-flow and high-efficiency fixtures (million gallons)
Provided by Applicant

Electricity = Electricity required to supply, treat, and distribute water and the resulting wastewater (kWh/million gallons)
Northern California Average: 5,411 kWh/million gallons
Southern California Average: 13,022 kWh/million gallons

Utility = Carbon intensity of Local Utility (CO_2e/kWh)

Mitigation Method:

Since this mitigation method does not change the electricity intensity factor (kWh/million gallons) associated with the supply, treatment, and distribution of the water, the percent reduction in GHG emissions is dependent only on the change in water consumption.

The Project Applicant can choose to compute the percent reduction in GHG emissions in one of three ways:

Method A

The Project Applicant can use Table WUW-1.4 to calculate the overall percent reduction in GHG emissions from committing to installing certain low-flow or high-efficiency water fixtures. The Project Applicant may commit to installing fixtures based on three standards: the California Green Building Standards Code (CGBSC) mandatory requirements, the CGBSC voluntary standards, or the ENERGY STAR standards. Table WUW-1.4 presents the percent reductions in GHG emissions for each of these three standards based on water fixture type (toilet, showerhead, clothes washer, etc) and land use type (residential, office, restaurant, etc). Note that in Table WUW-1.4, it is assumed that a Project Applicant commits to installing low-flow or high-efficiency fixtures for 100% of an end-use category (i.e. either 0% or 100% of toilets will be low-flow, either 0% or 100% of clothes washers will be high-efficiency, etc). The total percent reduction in GHG emissions expected from this mitigation measure is then simply the sum of all of the individual percent reductions:

$$\text{GHG emission reduction} = \sum \text{PercentReduction}_{\text{Fixture}}$$

Where:

GHG emission reduction	=	Percentage reduction in GHG emissions for indoor water use.
$\text{PercentReduction}_{\text{Fixture}}$	=	Percent reduction in GHG emissions from each individual water fixture (i.e. toilet, bathroom faucet, dishwasher, etc.) Provided in Table WUW-1.4

Method B

If the Project Applicant can provide detailed and substantial evidence to support a calculation of $\text{Water}_{\text{mitigated}}$, then that value can be used to calculate the percent GHG emission reduction using the following equation:

$$\text{GHG emission reduction} = \frac{\text{Water}_{\text{baseline}} - \text{Water}_{\text{mitigated}}}{\text{Water}_{\text{baseline}}}$$

Where:

GHG emission reduction	=	Percentage reduction in GHG emissions for indoor water use.
$\text{Water}_{\text{baseline}}$	=	Total expected indoor water demand, without installation of low-flow and high-efficiency fixtures (million gallons) Provided by Applicant
$\text{Water}_{\text{mitigated}}$	=	Total calculated indoor water demand, after installation of low-flow and high-efficiency fixtures (million gallons) Provided by Applicant or calculated using equations below

As shown in this equation, the carbon intensity of the local utility does not play a role in determining the percentage reduction in GHG emissions.

Method C

The Project Applicant may choose to install fixtures which exceed the requirements of the California Green Building Standards Code but have different flow rates than those specified in the Tables WUW-1.1 and WUW-1.3. To take credit for this mitigation measure, the Project Applicant would need to calculate the percent reduction in GHG emissions using the equations below. In these equations, it is assumed that a Project Applicant commits to installing low-flow or high-efficiency fixtures for 100% of an end-use category (i.e. either 0% or 100% of toilets will be low-flow, either 0% or 100% of clothes washers will be high-efficiency, etc). More complicated equations are necessary to account for less than 100% commitment in one or more end-use categories.

$$Water_{mitigated} = \sum EndUseWater_{mitigated}$$

End-Uses are toilets, urinals, showerheads, bathroom faucets, kitchen faucets, dishwashers, clothes washers, and leaks and other.

Where,

$$EndUseWater_{mitigated} = EndUse_{PercentIndoor} \times Water_{baseline} \times \frac{EndUseFlowRate_{mitigated}}{EndUseFlowRate_{unmitigated}}$$

$EndUse_{PercentIndoor}$ = % of Indoor Water Use for that end-use
  Provided in Table WUW-1.1 for Residential Buildings
  Provided in Table WUW-1.1 for Non-Residential Buildings

$Water_{baseline}$ = Total expected indoor water demand, without installation of low-flow and high-efficiency fixtures (million gallons)
  Provided by Applicant

$EndUseFlowRate_{baseline}$ = Baseline current California standard water flow rate for that end-use
  Provided in Table WUW-1.1 for Residential Buildings
  Provided in Table WUW-1.3 for Non-Residential Buildings

$EndUseFlowRate_{mitigated}$ = Mitigated water flow rate for that end use
  Provided by Applicant, supported by manufacturer specification or technical sheets

For the Leak, Other end use and all end-uses where the Project Applicant makes no commitment to installing low-flow or high-efficiency water fixtures, $EndUseFlowRate_{mitigated} = EndUseFlowRate_{unmitigated}$, so then $EndUseWater_{mitigated} = EndUse_{PercentIndoor} \times Water_{baseline}$.

Then the percent reduction in GHG emissions is calculated as follows:

$$\text{GHG emission reduction} = \frac{Water_{baseline} - Water_{mitigated}}{Water_{baseline}}$$

Where:

GHG emission reduction = Percentage reduction in GHG emissions for indoor water use.

$Water_{baseline}$ = Total expected indoor water demand, without installation of low-flow and high-efficiency fixtures (million gallons)
Provided by Applicant

$Water_{mitigated}$ = Total calculated indoor water demand, after installation of low-flow and high-efficiency fixtures (million gallons)
Calculated by Applicant using equation above

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	Estimated 20% reduction for residential buildings, assuming the Project Applicant commits to installing 100% of fixtures with the lowest flow rates presented in Table WUW-1.1. Estimated 17-31% reduction for non-residential buildings, assuming the Project Applicant commits to installing 100% of fixtures with the lowest flow rates presented in Table WUW-1.3.
All other pollutants	Not Quantified[87]

Discussion:

In this example, assume that a Project Applicant commits to installing the following:

For residences:

- 2010 CGBSC Mandatory Requirements for toilet, showerhead, bathroom faucet, and kitchen faucet
- ENERGY STAR residential standard dishwasher

For hotel:

- 2010 CGBSC Voluntary Standards for toilet, urinal, showerhead, bathroom faucet, and kitchen faucet
- ENERGY STAR top-loading clothes washer
- ENERGY STAR commercial dishwasher (high temp, under counter)

Using Method A, the following equation is employed:

$$\text{GHG emission reduction} = \sum PercentReduction_{Fixture}$$

[87] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

From Table WUW-1.4, the percent reduction in GHG emissions associated with indoor water use is then:

For residences:

6.6% + 4.4% + 5.7% + 3.3% + 0.2% = 20.2%

For hotel:

13.8% + 5.4% + 1.2% + 0.8% + 1.9% + 6.4% + 1.5% = 31.0%

Assumptions:

Data based upon the following references:

[1] CCR Title 24, Part 11. 2010. Draft California Green Building Standards Code. Available online at: http://www.documents.dgs.ca.gov/bsc/documents/2010/Draft-2010-CALGreenCode.pdf
[2] CCR Title 20, Division 2, Chapter 4, Article 4, Section 1605. Appliance Efficiency Regulations.
[3] Gleick, P.H.; Haasz, D.; Henges-Jeck, C.; Srinivasan, V.; Cushing, K.K.; Mann, A. 2003. Waste Not, Want Not: The Potential for Urban Water Conservation in California. Published by the Pacific Institute for Studies in Development, Environment, and Security. Full report available online at: http://www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf. Appendices available online at: http://www.pacinst.org/reports/urban_usage/appendices.htm
[4] Mayer, P.W.; DeOreo, W.B.; Opitz, E.M.; Kiefer, J.C.; Davis, W.Y.; Dziegielewski, B.; Nelson, J.O. 1999. Residential End Uses of Water. Published by the American Water Works Association Research Foundation.
[5] USEPA. ENERGY STAR: Clothes Washers Key Product Criteria. Available online at: http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers
[6] USEPA. ENERGY STAR: Commercial Clothes Washers for Consumers. Available online at: http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CCW
[7] USEPA. ENERGY STAR: Dishwashers Key Product Criteria. Available online at: http://www.energystar.gov/index.cfm?c=dishwash.pr_crit_dishwashers
[8] USEPA. ENERGY STAR Commercial Dishwashers Savings Calculator. Available online at: http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COH

Preferred Literature:

For the baseline scenario, the California Green Building Standards Code [1] specifies baseline water flow rates for toilets, showerheads, urinals, bathroom faucets, and kitchen faucets. The California Appliance Efficiency Regulation (Title 20) [2] specifies baseline water flow rates for residential and commercial dishwashers and clothes washers. For the mitigated scenario, the 2010 CGBSC also specifies water flow rates for toilets, showerheads, urinals, bathroom faucets, and kitchen faucets which become mandatory in 2011, additional voluntary flow rates for these same fixtures, and voluntary flow rates for commercial dishwashers and clothes washers. In addition, ENERGY STAR-certified residential and commercial dishwashers and clothes washers have mitigated water flow rates [5-8].

Alternative Literature:

None

Other Literature Reviewed:

[9] USEPA. Water Sense: Product Factsheets and Final Specifications. Available online at: http://www.epa.gov/watersense/products/index.html. Accessed February 2010.

USEPA WaterSense labeled products include toilets, bathroom sink faucets, and flushing urinals, and are certified to meet USEPA's standards for improved water efficiency. While WaterSense models do perform with greater water efficiency than federal standard models, they are not more efficient than the models required in California starting in 2011 due to the 2010 CGBSC. Furthermore, WaterSense models are compared to federal standard models and calculations would need to be adjusted to account for differences in California standards. USEPA reports that toilets, bathroom faucets, and showers account for 30%, 15%, and 17% of indoor household water use, respectively. USEPA reports that WaterSense toilets use 20% less water than the federal standard model, while WaterSense bathroom faucets use 30% less water. Federal standard showerheads use 2.5 gallons of water per minute while the WaterSense models use 2.0 gallons of water per minute, which is equivalent to the 2010 CGBSC Mandatory Requirement. Further, federal standard flushing urinal models use 1.0 gallons per flush, while WaterSense models uses 0.5 gallons per flush, which is equivalent to the 2010 CGBSC Mandatory Requirement.

Table WUW-1.1
Reduction in Water use from Low-flow or High-efficiency Residential Water Fixtures

Fixture	% of Indoor Water Use[1]	Water Flow Rate				
		Baseline Current California Standard[2]	Mitigated 2010 California Green Building Standards Code (Mandatory in 2011)[3]	Mitigated 2010 California Green Building Standards Code (Voluntary)[4]	Mitigated ENERGY STAR[5]	Unit
Toilet	33%	1.6	1.28	--	--	gallons/flush
Showerhead	22%	2.5	2.0	--	--	gallons/minute @ 60 psi
Bathroom Faucet	18%	2.2	1.5	--	--	gallons/minute @ 60 psi
Kitchen Faucet		2.2	1.8	--	--	gallons/minute @ 60 psi
Standard Dishwasher	1%	6.5	--	5.8	5.0	gallons/cycle
Compact Dishwasher		4.5	--	--	3.5	gallons/cycle
Top-loading Clothes Washer	14%	6.0	--	--	6.0	gallons/cycle/ cubic foot
Front-loading Clothes Washer		6.0	--	--	6.0	gallons/cycle/ cubic foot
Leaks, Other	12%	--	--	--	--	--

Notes:

1. Indoor household end use of water 2000 estimates from Figure 2-4c of the Pacific Institute report.
2. Baseline water flow rates for toilets, showerheads, bathroom faucets, and kitchen faucets are from the 2010 California Green Building Standards Code. Baseline water flow rates for dishwashers and clothes washers are from CCR Title 20, Division 2, Chapter 4, Article 4, Section 1605.2 (Appliance Efficiency Regulations for appliances sold in California).
3. Mitigated water flow rates for toilets, showerheads, bathroom faucets, and kitchen faucets are voluntary in 2010 and mandatory starting January 1, 2011.
4. Mitigated water flow rates for dishwashers and clothes washers are voluntary.
5. In some cases, the 2011 ENERGY STAR dishwasher and clothes washer models have lower flow rates than the 2010 California Green Building Standards Code. Using these ENERGY STAR models results in an additional mitigation beyond what is recommended by the 2010 California Green Building Standards Code.

Table WUW-1.2
Percent Indoor Water Use by End-Use in Non-Residential Buildings

End-Use	OFFICE		HOTEL		RESTAURANT		GROCERY STORE		NON-GROCERY RETAIL STORES		K-12 SCHOOL		OTHER SCHOOL	
	Total[1]	Indoor[2]	Total[1]	Indoor[2]	Total[1]	Indoor[2]	Total[1]	Indoor[2]	Total[1]	Indoor[2]	Total[1]	Indoor[2]	Total[1]	Indoor[2]
Restroom	26%	--	51%	--	34%	--	17%	--	26%	--	20%	--	20%	--
Toilets (72% of Restroom)	--	48%	--	46%	--	27%	--	26%	--	46%	--	51%	--	37%
Urinals (17% of Restroom)	--	11%	--	11%	--	6%	--	6%	--	11%	--	12%	--	9%
Faucets (4% of Restroom)	--	3%	--	3%	--	1%	--	1%	--	3%	--	3%	--	2%
Showers (7% of Restroom)	--	5%	--	4%	--	3%	--	2%	--	4%	--	5%	--	4%
Kitchen	3%	--	10%	--	46%	--	9%	--	4%	--	2%	--	1%	--
Faucets (57% of Kitchen)	--	4%	--	7%	--	29%	--	11%	--	6%	--	4%	--	1%
Dishwashers (24% of Kitchen)	--	2%	--	3%	--	12%	--	5%	--	2%	--	2%	--	1%
Ice Making (19% of Kitchen)	--	1%	--	2%	--	10%	--	4%	--	2%	--	1%	--	0%
Laundry	0%	0%	14%	18%	0%	0%	0%	0%	0%	0%	0%	0%	1%	3%
Other	10%	26%	5%	6%	12%	13%	22%	46%	11%	27%	6%	21%	17%	44%
Landscaping	38%	--	10%	--	6%	--	3%	--	38%	--	72%	--	61%	--
Cooling	23%	--	10%	--	2%	--	49%	--	21%	--	unknown	--	unknown	--
TOTAL	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Notes:

1. Water end-use data from Figures E-1, E-2, E-5, E-6, E-7, E-8, and E-9 of Appendix E of the Pacific Institute report.
2. Indoor end-use data calculated based on the total water use data for the relevant building category and Figure 4-3 and Figure 4-4 of the Pacific Institute report. Figure 4-3 shows the breakdown of restroom water use by end-use in the commercial & industry sector. Figure 4-4 shows the breakdown of kitchen water use by end-use in the commercial & industry sector; it was assumed that all end-uses except dishwashing and ice making are associated with faucet water use.

Table WUW-1.3
Reduction in Water use from Low-flow or High-efficiency Non-Residential Water Fixtures

Fixture	Water Flow Rate				
	Baseline Current California Standard[1]	Mitigated 2010 California Green Building Standards Code (Mandatory in 2011)[2]	Mitigated 2010 California Green Building Standards Code (Voluntary)[3]	Mitigated ENERGY STAR[4]	Unit
Toilet	1.6	1.28	1.12	--	gallons/flush
Urinal	1.0	0.5	0.5	--	gallons/flush
Showerhead	2.5	2.0	1.8	--	gallons/minute @ 60 psi
Bathroom Faucet	0.5	0.4	0.35	--	gallons/minute @ 60 psi
Kitchen Faucet	2.2	1.8	1.6	--	gallons/minute @ 60 psi
Dishwasher: High Temp, Under Counter	1.98	--	0.90	1.00	gallons/rack
Dishwasher: High Temp, Door	1.44	--	0.95	0.95	gallons/rack
Dishwasher: High Temp, Single Tank Conveyor	1.13	--	0.70	0.70	gallons/rack
Dishwasher: High Temp, Multi Tank Conveyor	1.10	--	0.70	0.54	gallons/rack
Dishwasher: Low Temp, Under Counter	1.95	--	0.98	1.70	gallons/rack
Dishwasher: Low Temp, Door	1.85	--	1.16	1.18	gallons/rack
Dishwasher: Low Temp, Single Tank Conveyor	1.23	--	0.62	0.79	gallons/rack
Dishwasher: Low Temp, Multi Tank Conveyor	0.99	--	0.62	0.54	gallons/rack
Top-loading Clothes Washer	9.5	--	8.6	6.0	gallons/cycle/ cubic foot
Front-loading Clothes Washer	9.5	--	8.6	6.0	gallons/cycle/ cubic foot

Notes:

1. Baseline water flow rates for toilets, showerheads, bathroom faucets, and kitchen faucets are from the 2010 California Green Building Standards Code. Baseline water flow rates for dishwashers are from the ENERGY STAR Commercial Dishwasher Calculator. Baseline water flow rates for clothes washers are from CCR Title 20, Division 2, Chapter 4, Article 4, Section 1605.2 (Appliance Efficiency Regulations for appliances sold in California).

2. These mitigated water flow rates for toilets, showerheads, bathroom faucets, and kitchen faucets are voluntary in 2010 and mandatory starting January 1, 2011.

3. These mitigated water flow rates for toilets, showerheads, bathroom faucets, and kitchen faucets are voluntary and represent the maximum recommended flow rate in order to achieve an overall 30% reduction in water use. Mitigated water flow rates for dishwashers and clothes washers are also voluntary. The range of values shown here represents different types of commercial dishwashers (high-temperature or chemical; conveyor, door, or undercounter models). See Appendix A5 of the 2010 California Green Building Standards Code for details.

4. In some cases, the ENERGY STAR dishwasher and clothes washer models have lower flow rates than the 2010 California Green Building Standards Code. Using these ENERGY STAR models results in an additional mitigation beyond what is recommended by the 2010 California Green Building Standards Code. See the following ENERGY STAR website for details: http://www.energystar.gov/index.cfm?c=comm_dishwashers.pr_crit_comm_dishwashers

Table WUW-1.4

Percent Reductions in GHG emissions from Installing Low-Flow or High-Efficiency Water Fixtures

FIXTURE	LAND USE							
	RESIDENTIAL	OFFICE	HOTEL	RESTAURANT	GROCERY STORE	NON-GROCERY RETAIL STORE	K-12 SCHOOL	OTHER SCHOOL
2010 California Green Building Standards Code (Mandatory Requirements starting in 2011):								
Toilet	6.6%	9.6%	9.2%	5.3%	5.1%	9.1%	10.3%	7.4%
Urinal	N/A	5.7%	5.4%	3.1%	3.0%	5.4%	6.1%	4.4%
Showerhead	4.4%	0.9%	0.9%	0.5%	0.5%	0.9%	1.0%	0.7%
Bathroom Faucet	5.7%	0.5%	0.5%	0.3%	0.3%	0.5%	0.6%	0.4%
Kitchen Faucet	3.3%	0.8%	1.3%	5.2%	1.9%	1.0%	0.7%	0.3%
2010 California Green Building Standards Code (Voluntary Standards):								
Toilet	N/A	14.4%	13.8%	8.0%	7.7%	13.7%	15.4%	11.1%
Urinal	N/A	5.7%	5.4%	3.1%	3.0%	5.4%	6.1%	4.4%
Showerhead	N/A	1.3%	1.2%	0.7%	0.7%	1.2%	1.4%	1.0%
Bathroom Faucet	N/A	0.8%	0.8%	0.4%	0.4%	0.8%	0.9%	0.6%
Kitchen Faucet	N/A	1.2%	1.9%	7.8%	2.9%	1.5%	1.1%	0.4%
Top-Loading Clothes Washer	N/A	N/A	1.8%	N/A	N/A	N/A	N/A	0.3%

FIXTURE	LAND USE							
	RESIDENTIAL	OFFICE	HOTEL	RESTAURANT	GROCERY STORE	NON-GROCERY RETAIL STORE	K-12 SCHOOL	OTHER SCHOOL
Front-Loading Clothes Washer	N/A	N/A	1.8%	N/A	N/A	N/A	N/A	0.3%
Residential Standard Dishwasher	0.1%	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Residential Compact Dishwasher	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Commercial Dishwasher: High Temp, Under Counter	N/A	1.0%	1.6%	6.5%	2.5%	1.3%	0.9%	0.3%
Commercial Dishwasher: High Temp, Door	N/A	0.6%	1.0%	4.1%	1.5%	0.8%	0.6%	0.2%
Commercial Dishwasher: High Temp, Single Tank Conveyor	N/A	0.7%	1.1%	4.6%	1.7%	0.9%	0.7%	0.2%
Commercial Dishwasher: High Temp, Multi Tank Conveyor	N/A	0.7%	1.1%	4.4%	1.6%	0.9%	0.6%	0.2%
Commercial Dishwasher: Low Temp, Under Counter	N/A	0.9%	1.5%	6.0%	2.2%	1.2%	0.9%	0.3%
Commercial Dishwasher: Low Temp, Door	N/A	0.7%	1.1%	4.5%	1.7%	0.9%	0.6%	0.2%
Commercial Dishwasher: Low Temp, Single Tank Conveyor	N/A	0.9%	1.5%	6.0%	2.2%	1.2%	0.9%	0.3%

FIXTURE	LAND USE							
	RESIDENTIAL	OFFICE	HOTEL	RESTAURANT	GROCERY STORE	NON-GROCERY RETAIL STORE	K-12 SCHOOL	OTHER SCHOOL
Commercial Dishwasher: Low Temp, Multi Tank Conveyor	N/A	0.7%	1.1%	4.5%	1.7%	0.9%	0.6%	0.2%
ENERGY STAR Standards:								
Top-Loading Clothes Washer	N/A	N/A	6.4%	N/A	N/A	N/A	N/A	0.9%
Front-Loading Clothes Washer	N/A	N/A	6.4%	N/A	N/A	N/A	N/A	0.9%
Residential Standard Dishwasher	0.2%	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Residential Compact Dishwasher	0.2%	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Commercial Dishwasher: High Temp, Under Counter	N/A	0.9%	1.5%	5.9%	2.2%	1.2%	0.8%	0.3%
Commercial Dishwasher: High Temp, Door	N/A	0.6%	1.0%	4.1%	1.5%	0.8%	0.6%	0.2%
Commercial Dishwasher: High Temp, Single Tank Conveyor	N/A	0.7%	1.1%	4.6%	1.7%	0.9%	0.7%	0.2%
Commercial Dishwasher: High Temp, Multi Tank Conveyor	N/A	0.9%	1.5%	6.1%	2.3%	1.2%	0.9%	0.3%
Commercial Dishwasher: Low Temp, Under Counter	N/A	0.2%	0.4%	1.5%	0.6%	0.3%	0.2%	0.1%

FIXTURE	LAND USE							
	RESIDENTIAL	OFFICE	HOTEL	RESTAURANT	GROCERY STORE	NON-GROCERY RETAIL STORE	K-12 SCHOOL	OTHER SCHOOL
Commercial Dishwasher: Low Temp, Door	N/A	0.7%	1.1%	4.3%	1.6%	0.8%	0.6%	0.2%
Commercial Dishwasher: Low Temp, Single Tank Conveyor	N/A	0.7%	1.1%	4.3%	1.6%	0.8%	0.6%	0.2%
Commercial Dishwasher: Low Temp, Multi Tank Conveyor	N/A	0.8%	1.4%	5.5%	2.0%	1.1%	0.8%	0.3%

Notes:

N/A indicates that either (a) an improved standard does not exist, or (b) the percent of indoor water use for that fixture and land use is typically zero. For example, (a) the ENERGY STAR standard for residential clothes washers is the same as the baseline current California standard, and (b) no water is expected to be used for laundry (clothes washers) in the Office land use.

4.2.2 Adopt a Water Conservation Strategy

Range of Effectiveness: Varies depending on Project Applicant and strategies selected. It is equal to the Percent Reduction in water commitment.

Measure Description:

Water use contributes to GHG emissions indirectly, via the production of the electricity that is used to pump, treat, and distribute the water. Reducing water use reduces energy demand and associated indirect GHG emissions.

This mitigation measure describes how to calculate GHG emissions reductions from a Water Conservation Strategy which achieves X% reduction in water use (where X% is the specific percentage reduction in water use committed to by the Project Applicant). The steps taken to achieve this X% reduction in water use can vary in nature and may incorporate technologies which have not yet been established at the time this document was written. In order to take credit for this mitigation measure, the Project Applicant would need to provide detailed and substantial evidence supporting the percent reduction in water use.

The expected percent reduction is applied to the baseline water use, calculated according to the baseline methodology document. The energy-intensity factor associated with water conveyance, treatment, and distribution is provided in the 2006 CEC report [1].

This measure may incorporate other mitigation measures (WUW-1 through 6) of this document. As such, if this measure is used, the other measures cannot be used. These measures can be consulted to assist in determining methods of quantification and typical ranges of effectiveness.

Measure Applicability:

- Indoor and/or Outdoor water use

Inputs:

The following information needs to be provided by the Project Applicant:

- Total expected water demand, without implementation of Water Conservation Strategy (million gallons)
- Percent reduction in water use after implementation of Water Conservation Strategy (%)

Baseline Method:

$$\text{GHG emissions} = \text{Water}_{baseline} \times \text{Electricity} \times \text{Utility}$$

Where:

GHG emissions = MT CO_2e

$Water_{baseline}$ = Total expected water demand, without implementation of Water Conservation Strategy (million gallons)
Provided by Applicant

Electricity = Electricity required to supply, treat, and distribute water (and for indoor uses, the electricity required to treat the wastewater) (kWh/million gallons)
Northern California Avg (outdoor uses): 3,500 kWh/million gallons [1]
Northern California Avg (indoor uses): 5,411 kWh/million gallons [1]
Southern California Avg (outdoor uses): 11,111 kWh/million gallons [1]
Southern California Avg (indoor uses): 13,022 kWh/million gallons [1]

Utility = Carbon intensity of Local Utility (CO_2e/kWh)

If there are percent reductions associated with both indoor and outdoor water use, the GHG emissions from indoor and outdoor water use should be calculated separately and then summed. Thus,

$$\text{Total GHG emissions} = \text{GHG emissions}_{indoor} + \text{GHG emissions}_{outdoor}$$

Mitigation Method:

Since this mitigation method does not change the electricity intensity factor (kWh/million gallons) associated with the supply and distribution of the water, the percent reduction in GHG emissions is dependent only on the change in water consumption:

$$\text{GHG emission reduction} = \text{PercentReduction}$$

Where:

GHG emission reduction = Percentage reduction in GHG emissions for water use.

PercentReduction = Expected percent reduction in water use after implementation of Water Conservation Strategy (%)
Provided by Applicant

As shown in these equations, the carbon intensity of the local utility does not play a role in determining the percentage reduction in GHG emissions.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	To be determined by Applicant

All other pollutants	Not Quantified[88]

Discussion:

The percent reduction in GHG emissions is equivalent to the percent reduction in indoor and outdoor water usage. Therefore, if a Project Applicant implements a Water Conservation Strategy which achieves a 10% reduction in water use, the GHG emissions associated with water use are reduced by 10%.

Assumptions:

Data based upon the following reference:

[1] CEC. 2006. Refining Estimates of Water-Related Energy Use in California. PIER Final Project Report. Prepared by Navigant Consulting, Inc. CEC-500-2006-118. Available online at: http://www.energy.ca.gov/2006publications/CEC-500-2006-118/CEC-500-2006-118.PDF

Preferred Literature:

2006 CEC report

Alternative Literature:

None

Other Literature Reviewed:

None

[88] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

4.2.3 Design Water-Efficient Landscapes

Range of Effectiveness: 0 – 70% reduction in GHG emissions from outdoor water use

Measure Description:

Water use contributes to GHG emissions indirectly, via the production of the electricity that is used to pump, treat, and distribute the water. Designing water-efficient landscapes for a project site reduces water consumption and the associated indirect GHG emissions. Examples of measures which a Project Applicant should consider when designing landscapes are reducing lawn sizes, planting vegetation with minimal water needs such as California native species, choosing vegetation appropriate for the climate of the project site, and choosing complimentary plants with similar water needs or which can provide each other with shade and/or water.

This measure describes how to calculate GHG savings from residential and commercial landscape plantings which have decreased watering demands compared to standard California landscape plantings. The methodology for calculating water demand presented here is based on the California Department of Water Resources (CDWR) 2009 Model Water Efficient Landscape Ordinance [1] and the CDWR 2000 report: "A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California: The Landscape Coefficient Method and WUCOLS III" ("WUCOLS") [2].

By January 1, 2010, all local water agencies were required to adopt the CDWR Model Water Efficient Landscape Ordinance or develop their own local ordinance which is at least as effective at conserving water as the Model Ordinance. Some local agencies have published or are in the process of developing local ordinances.[89] A Project Applicant may choose to use the methodology presented in a local ordinance to demonstrate a percent reduction in water use and GHG emissions; however, the calculations will be similar to the methodology presented in the CDWR Model Ordinance and re-described here.

Measure Applicability:

- Outdoor water use

Inputs:

The following information needs to be provided by the Project Applicant:

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[89] List of local water agencies and a description of their plans to either adopt the CDWR Model Ordinance or develop their own ordinance: ftp://ftp.water.ca.gov/Model-Water-Efficient-Landscape-Ordinance/Local-Ordinances/

- $Water_{baseline}$, to be calculated by the Project Applicant using the methodology described below
- $Water_{mitigated}$, to be calculated by the Project Applicant using the methodology described below

Baseline Method:

The Project's baseline water use is the Maximum Applied Water Allowance (MAWA) described in the Model Water Efficient Landscape Ordinance:

$$MAWA = ET_0 \times 0.62 \times [(0.7 \times LA) + (0.3 \times SLA)]$$

Where:

MAWA	=	Maximum Applied Water Allowance (gallons per year)
ET_0	=	Annual Reference Evapotranspiration[90] from Appendix A of the Model Water Efficient Landscape Ordinance (inches per year)
0.7	=	ET Adjustment Factor (ETAF)
LA	=	Landscape Area[91] includes Special Landscape Area[92] (square feet)
0.62	=	Conversion factor (to gallons per square foot)
SLA	=	Portion of the landscape area identified as Special Landscape Area (square feet)
0.3	=	the additional ET Adjustment Factor for Special Landscape Area

Then the baseline GHG emissions are calculated as follows:

$$GHG\ emissions = MAWA \times Electricity \times Utility$$

Where:

GHG emissions	=	MT CO_2e
Electricity	=	Electricity required to supply, treat, and distribute water (kWh/million gallons) Northern California Average (outdoor uses): 3,500 kWh/million gallons Southern California Average (outdoor uses): 11,111 kWh/million gallons

[90] Evapotranspiration is water lost to the atmosphere due to evaporation from soil and transpiration from plant leaves. For a more detailed definition, see this California Irrigation Management Information System (CIMIS) website: http://wwwcimis.water.ca.gov/cimis/infoEtoOverview.jsp;jsessionid=91682943559928B8A9A243D2A2665E19

[91] § 491 Definitions in Model Water Efficient Landscape Ordinance: "Landscape Area (LA) means all the planting areas, turf areas, and water features in a landscape design plan subject to the Maximum Applied Water Allowance calculation. The landscape area does not include footprints of buildings or structures, sidewalks, driveways, parking lots, decks, patios, gravel or stone walks, other pervious or non-pervious hardscapes, and other non-irrigated areas designed for non-development (e.g., open spaces and existing native vegetation)."

[92] § 491 Definitions in Model Water Efficient Landscape Ordinance: "Special Landscape Area (SLA) means an area of the landscape dedicated solely to edible plants, areas irrigated with recycled water, water features using recycled water and areas dedicated to active play such as parks, sports fields, golf courses, and where turf provides a playing surface."

Utility = Carbon intensity of Local Utility (CO_2e/kWh)

Mitigation Method:

Since this mitigation method does not change the electricity intensity factor (kWh/million gallons) associated with the supply, treatment, and distribution of the water, the percent reduction in GHG emissions is dependent only on the change in water consumption.

The Project's mitigated water use is the Estimated Total Water Use (ETWU) described in the Model Water Efficient Landscape Ordinance:

$$ETWU = ET0 \times 0.62 \times \left(\frac{PF \times HA}{IE} + SLA \right)$$

Where:

ETWU	=	Estimated total water use (gallons per year)
ET_0	=	Annual Reference Evapotranspiration from Appendix A of the Model Water Efficient Landscape Ordinance (inches per year)
PF	=	Plant Factor from WUCOLS[93] see Table WUW-3.1 for examples and WUCOLS for a complete list of values
HA	=	Hydrozone Area[94] (square feet)
SLA	=	Special Landscape Area (square feet)
0.62	=	Conversion factor (to gallons per square foot)
IE	=	Irrigation Efficiency[95] (minimum 0.71)

Then the percent reduction in GHG emissions is calculated as follows:

$$\text{GHG emission reduction} = \frac{MAWA - ETWU}{MAWA}$$

[93] § 491 Definitions in Model Water Efficient Landscape Ordinance: "Plant Factor (PF)" is a factor, when multiplied by ET_0, estimates the amount of water needed by plants." The Model Water Efficient Landscape Ordinance indicates that PF is 0-0.3 for low water use plants, 0.4-0.6 for moderate water use plants, and 0.7-1.0 for high water use plants. PF is equivalent to the "species factor" (k_s) in WUCOLS. See Table A above for examples of low, moderate, and high water use plants from WUCOLS. For a complete list of PF (k_s) values, see the species evaluation list in WUCOLS.

[94] § 491 Definitions in Model Water Efficient Landscape Ordinance: "Hydrozone means a portion of the landscaped area having plants with similar water needs. A hydrozone may be irrigated or non-irrigated."

[95] § 491 Definitions in Model Water Efficient Landscape Ordinance: "Irrigation Efficiency (IE) means the measurement of the amount of water beneficially used divided by the amount of water applied. Irrigation efficiency is derived from measurements and estimates of irrigation system characteristics and management practices. The minimum average irrigation efficiency for purposes of the ordinance is 0.71. Greater irrigation efficiency can be expected from well designed and maintained systems."

As shown in this equation, the regional electricity intensity factor and utility carbon intensity factor do not play a role in determining the percentage reduction in GHG emissions. Furthermore, since ET_0 is a multiplier in both MAWA and ETWU, it cancels out and therefore ET_0 does not play a role in determining the percentage reduction in GHG emissions either.

Table WUW-3.1: Example Plant Factor (PF) Values from WUCOLS

Water Needs	PF Range	Plant Type	Species Examples
Low	0 - 0.3	tree	Quercus agrifolia (coast live oak)
			Yucca
			Pinus halepensis (Aleppo pine)
		shrub	Quercus berberidifolia (California scrub oak)
			Lonicera subspicata (chaparral honeysuckle)
			Salvia apiana (white sage)
		vine	Macfadyena unguis-cati (cat's claw)
		groundcover	Arctostaphylos spp. (manzanita)
		perennial	Monardella villosa (coyote mint)
Moderate	0.4 - 0.6	tree	Acer negundo (California box elder)
			Acer paxii (evergreen maple)
		shrub	Buxus microphylla japonica (Japanese boxwood)
		vine	Wisteria
			Aristolochia durior (Dutchman's pipe)
		groundcover	Ceratostigma plumbaginoides (dwarf plumbago)
		perennial	Monarda didyma (bee balm)
	0.6	turf grasses (warm season)	Bermudagrass
			kikuyugrass
			seashore paspalum
			St. Augustinegrass
			zoysiagrass
High	0.7 - 1.0	tree	Betula pendula (European white birch)
			Betula nigra (river/red birch)
		shrub	Cyathea cooperii (Australian tree fern)
			Cornus stolonifera (red osier dogwood)
		groundcover	Soleirolia soleirolii (baby's tears)
		perennial	Mimulus spp., herbaceous (monkey flower)
			Woodwardia radicans (European chain fern)
			Acorus gramineus (sweet flag)
	0.8	turf grasses (cool season)	annual bluegrass
			annual ryegrass
			colonial bentgrass
			creeping bentgrass
			hard fescue
			highland bentgrass
			Kentucky bluegrass
			meadow fescue
			perennial ryegrass
			red fescue
			rough-stalked bluegrass
			tall fescue

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	Assuming an irrigation efficiency of 71% as specified in the Model Water Efficient Landscape Ordinance and no Special Landscape Area: • 0% reduction if 100% of vegetation is Moderate PF • 13% reduction if 40% of vegetation is Low PF, 40% is Moderate PF, and 20% is High PF • 35% reduction if 50% of vegetation is Low PF and 50% is Moderate PF • 70% reduction if 100% of vegetation is Low PF
All other pollutants	Not Quantified[96]

Discussion:

Example calculations of MAWA and ETWU are provided in the Model Water Efficient Landscape Ordinance. In this example, assume that the Project Applicant has used the equations to calculate MAWA = 100 million gallons and ETWU = 80 million gallons. Then the GHG emissions reduction is 20%:

$$\text{GHG Emission Reduced} = \frac{100-80}{100} = 0.2 \text{ or } 20\%$$

Assumptions:

Data based upon the following references:

[1] California Department of Water Resources. 2009. Model Water Efficient Landscape Ordinance. Available online at: http://www.water.ca.gov/wateruseefficiency/docs/MWELO09-10-09.pdf

[2] ("WUCOLS"): California Department of Water Resources. 2000. A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California: The Landscape Coefficient Method and WUCOLS III. Available online at: http://www.water.ca.gov/pubs/conservation/a_guide_to_estimating_irrigation_water_needs_of_landscape_plantings_in_california__wucols/wucols00.pdf

[3] CEC. 2006. Refining Estimates of Water-Related Energy Use in California. PIER Final Project Report. Prepared by Navigant Consulting, Inc. CEC-500-2006-118. December. Available online at: http://www.energy.ca.gov/2006publications/CEC-500-2006-118/CEC-500-2006-118.PDF

Preferred Literature:

The California Department of Water Resources Model Water Efficient Landscape Ordinance requires that the Estimated Total Water Use (ETWU) of certain landscape

[96] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

projects shall not exceed the Maximum Applied Water Allowance (MAWA) for that landscape area. The MAWA is calculated based on average irrigation efficiencies and plant factors, two major influences on the water demand of a landscape. The ETWU is calculated based on project-specific plant factors and irrigation efficiency.

Alternative Literature:

[4] ("WUCOLS"): California Department of Water Resources. 2000. A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California: The Landscape Coefficient Method and WUCOLS III. Available online at: http://www.water.ca.gov/pubs/conservation/a_guide_to_estimating_irrigation_water_needs_of_landscape_plantings_in_california__wucols/wucols00.pdf

[5] The Las Pilitas Nursery website has a user-friendly and searchable database of native California plants: http://www.laspilitas.com/shop/plant-products. As shown in WUCOLS, many California native plants have minimal or very low water needs.

The equation on page 9 of WUCOLS [4] shows that water demand for irrigation landscape plantings (ETL, landscape evapotranspiration) is calculated by multiplying two parameters: the landscape coefficient (KL) and the reference evapotranspiration (ETo). KL values are based on a species factor, density factor, and microclimate factor. The guidance provides detailed instructions on how to assign project-specific values for these three factors. KL can then be divided by the irrigation efficiency to obtain the Total Water Applied, as shown on page 31 of the guidance [4]. Total Water Applied is analogous to ETWU in the methodology shown above. Thus, the detailed WUCOLS methodology could be used to perform a more rigorous calculation of ETWU which incorporates microclimate effects (e.g. windy areas, areas shaded by buildings, etc) and vegetation density effects.

Other Literature Reviewed:

None

4.2.4 Use Water-Efficient Landscape Irrigation Systems

Range of Effectiveness: 6.1% reduction in GHG emissions from outdoor water

Measure Description:

Water use contributes to GHG emissions indirectly, via the production of the electricity that is used to pump, treat, and distribute the water. Using water-efficient landscape irrigation techniques such as "smart" irrigation technology reduces outdoor water demand, energy demand, and the associated GHG emissions.[97]

"Smart" irrigation control systems use weather, climate, and/or soil moisture data to automatically adjust watering schedules in response to environmental and climate changes, such as changes in temperature or precipitation levels. Thus, the appropriate amount of moisture for a certain vegetation type is maintained, and excessive watering is avoided. Many companies which design and install smart irrigation systems, such as Calsense, ET Water, and EPA-certified WaterSense Irrigation Partners, may be able to provide a site-specific estimate of the percent reduction in outdoor water use that can be expected from installing a smart irrigation system. Expected reductions are in the range of 1 – 30%, with the high end of the range associated with historically high water users. To take credit for the high end of the GHG emissions reductions based on these company quotes, the Project Applicant would need to provide detailed and substantial evidence supporting the proposed percent reduction in water use. Alternatively, the Project Applicant could apply the average percent reduction reported in a 2009 study conducted by Aquacraft, Inc. in cooperation with the California Department of Water Resources, the California Urban Water Conservation Council, and a consortium of California water utilities. This comprehensive study showed that smart irrigation systems of various brands achieve an average of 6.1% reduction in outdoor water use in California. This percent reduction is based on a two year study (one year pre and post installation of smart controllers) of over two thousand sites in seventeen different water utilities throughout northern and southern California. While the study also presents utility-specific percent reductions, variations in implementation and sample size between utilities renders these percent reductions insufficient for characterization in a mitigation measure at this time. The study also notes that for a sample of smart controllers where data was collected for three years after installation, the percent reduction in water use increased with time, with the greatest percent reduction achieved in year three.

[97] The installation of smart irrigation controllers will be required starting in 2011 as indicated in the 2010 Draft California Green Building Standards Code. As technology advances and newer generation smart irrigation controllers become available, the Project Applicant may choose to use this mitigation measure to quantify water use and associated GHG reductions beyond what would be achieved with the standards required by the California Green Building Standards Code.

The expected percent reduction is applied to the baseline water use, calculated according to the baseline methodology document. The energy-intensity factor associated with water conveyance and distribution is provided in the 2006 CEC report [2].

Measure Applicability:

- Outdoor water use

Inputs:

The following information needs to be provided by the Project Applicant:

- Total expected outdoor water demand, without installation of smart landscape irrigation controller (million gallons).
- (Optional) Project-specific percent reduction in outdoor water demand, after installation of smart landscape irrigation controller. Percent reduction must be verifiable. Otherwise, use the default value of 6.1%.

Baseline Method:

$$\text{GHG emissions} = \text{Water}_{\text{baseline}} \times \text{Electricity} \times \text{Utility}$$

Where:

GHG emissions = MT CO_2e

$\text{Water}_{\text{baseline}}$ = Total expected outdoor water demand, without installation of smart landscape irrigation controllers (million gallons)
Provided by Applicant

Electricity = Electricity required to supply, treat, and distribute water (kWh/million gallons)
Northern California Average: 3,500 kWh/million gallons
Southern California Average: 11,111 kWh/million gallons

Utility = Carbon intensity of Local Utility (CO_2e/kWh)

Mitigation Method:

Since this mitigation method does not change the electricity intensity factor (kWh/million gallons) associated with the supply and distribution of the water, the percent reduction in GHG emissions is dependent only on the change in water consumption:

$$\text{GHG emission reduction} = \text{PercentReduction} \times \text{Water}_{\text{baseline}}$$

Where:

GHG emission reduction = Percentage reduction in GHG emissions for outdoor water use.

$\text{Water}_{\text{baseline}}$ = Total expected outdoor water demand, without installation of smart landscape irrigation controllers (million gallons)

Provided by Applicant

PercentReduction = Expected percent reduction in water use after installation of smart landscape irrigation controllers (%)

Provided by Applicant or use default 6.1%

As shown in these equations, the carbon intensity of the local utility does not play a role in determining the percentage reduction in GHG emissions.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	6.1% unless project-specific data is provided
All other pollutants	Not Quantified[98]

Discussion:

The percent reduction in GHG emissions is equivalent to the percent reduction in outdoor water usage. Therefore, if a Project Applicant uses the default percent reduction in water usage associated with installing smart landscape irrigation control systems (6.1%), the resulting reduction in GHG emissions is also 6.1%.

Assumptions:

Data based upon the following references:

[1] "Evaluation of California Weather-Based "Smart" Irrigation Controller Programs." July 2009. Presented to the California Department of Water Resources by The Metropolitan Water District of Southern California and The East Bay Municipal Utility District. Facilitated by the California Urban Water Conservation Council. Prepared by Aquacraft Inc., National Research Center Inc., and Dr. Peter J. Bickel. Available online at: http://www.aquacraft.com/Download_Reports/Evaluation_of_California_Smart_Controller_Programs_-_Final_Report.pdf

[2] CEC. 2006. Refining Estimates of Water-Related Energy Use in California. PIER Final Project Report. Prepared by Navigant Consulting, Inc. CEC-500-2006-118. Available online at: http://www.energy.ca.gov/2006publications/CEC-500-2006-118/CEC-500-2006-118.PDF

Preferred Literature:

As described above, the 2009 study [1] conducted by Aquacraft, Inc. in cooperation with the California Department of Water Resources, the California Urban Water Conservation Council, and a consortium of California water utilities showed that smart

[98] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

irrigation systems of various brands achieve an average of 6.1% reduction in outdoor water use in California.

Alternative Literature:

When common watering systems such as in-ground sprinklers are used, much of the water applied to lawns and landscapes is not absorbed by the vegetation. Instead, it is lost through runoff or evaporation. The USEPA reports that a study by the American Water Works Association found that households with in-ground sprinkler systems used 35% more water outdoors than households without these systems, while households with drip irrigation systems used 16% more water [3]. The USEPA reports that hand-held hoses or sprinklers are often more water efficient than automatic irrigation systems.

However, "smart" automatic landscape irrigation systems do exist. Examples include systems which automatically adjust watering schedules in response to environmental and climate changes, such as changes in temperature or precipitation levels. A few references have quantified reductions from this type of irrigation strategy. The Southern Nevada Water Authority reports that smart irrigation systems can reduce outdoor water use by an average of 15 to 30 percent, depending on the system, landscape type, and location [4]. One study conducted in 40 households with historically high water use in Irvine, California showed an average reduction in outdoor water use of 16% [5,6]. Another study conducted in Santa Barbara, California households with historically high water use showed an average water savings of 26% [5,7]. A Project Applicant could also hire an EPA-certified WaterSense Irrigation Partner to design and install a new irrigation system or audit an existing system in an effort to minimize the amount of water consumed [6].

[3] USEPA. 2002. Water-Efficient Landscaping: Preventing Pollution & Using Resources Wisely. Available online at: http://www.epa.gov/npdes/pubs/waterefficiency.pdf
[4] Southern Nevada Water Authority. Smart Irrigation Controllers. Available online at: http://www.snwa.com/html/land_irrig_smartclocks.html. Accessed March 2010.
[5] Irrigation Association. Smart Controller Efficiency Testing. Available online at: http://www.irrigation.org/SWAT/Industry/case-studies.asp. Accessed March 2010.
[6] Irvine Ranch Water District, et al. 2001. Residential Weather-Based Irrigation Scheduling: Evidence from the Irvine "ET Controller" Study. Available online at: http://www.irrigation.org/swat/images/irvine.pdf
[7] Santa Barbara County Water Agency, et al. 2003. Santa Barbara County ET Controller Distribution and Installation Program Final Report. Available online at: http://www.irrigation.org/swat/images/santa_barbara.pdf
[8] USEPA. WaterSense: Landscape Irrigation. Available online at: http://www.epa.gov/WaterSense/services/landscape_irrigation.html

4.2.5 Reduce Turf in Landscapes and Lawns

Range of Effectiveness: Varies and is equal to the percent commitment to turf reduction, assuming no other outdoor water uses

Measure Description:

Water use contributes to GHG emissions indirectly, via the production of the electricity that is used to pump, treat, and distribute the water. Turf grass (i.e. lawn grass) has relatively high water needs compared to most other types of vegetation. For example, trees planted in turf generally do not need additional watering besides what is required for the turf. Water agencies in Southern California have instituted turf removal programs which provide rebates for resident who reduce the turf area in their lawns. Reducing the turf size of landscapes and lawns reduces water consumption and the associated indirect GHG emissions.[99]

This measure describes how to calculate GHG savings from reducing the turf area of an existing lawn by X square feet, or designing a lawn to have X square feet less than the turf area of a standard lawn at the project location.[100]

Additional GHG emissions reductions may occur due to a reduction in fertilizer usage. Since this will vary based on individual occupant behavior, this reduction in GHG emissions from decreased fertilizer usage is not quantified.

Measure Applicability:

- Outdoor water use

Inputs:

The following information needs to be provided by the Project Applicant:

- Turf area of existing lawn or standard lawn at the project location (square feet)
- Turf area reduction commitment (square feet reduced or percent of baseline reduced)

Baseline Method:

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[99] See the SoCal WaterSmart Residential Turf Program description at http://socalwatersmart.com/index.php?option=com_content&view=article&id=77&Itemid=10. Accessed March 2010.

[100] The Project Applicant would need to provide a value for and evidence supporting this "standard-sized lawn." This value is likely to vary greatly depending on the type of building (single-family, condo, apartment complex, commercial space) as well as location (region in California, urban or suburban).

The methodology for calculating water demand presented here is based on the California Department of Water Resources (CDWR) 2009 Model Water Efficient Landscape Ordinance [1] and the CDWR 2000 report: "A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California: The Landscape Coefficient Method and WUCOLS III" [2].

The Project Applicant should first calculate the amount of water required to support the existing turf or standard-sized turf ($Water_{baseline}$).[101] In the equations below, "crop" also represents "turf grass," or lawn grasses.

$$ET_C = K_c \times ET_0$$

Where:

ET_C = Crop Evapotranspiration, the total amount of water the baseline turf loses during a specific time period due to evapotranspiration[102] (inches water/day)

K_C = Crop Coefficient, factor determined from field research, which compares the amount of water lost by the crop (e.g. turf) to the amount of water lost by a reference crop (unitless)
Species-specific; provided in Table WUW-5.1 below

ET_0 = Reference Evapotransporation, the amount of water lost by a reference crop (inches water/day)
Region-specific; provided in Appendix A of the CDWR Model Water Efficient Landscape Ordinance [1]

101 Page 10 of the CDWR report explains that the objective of landscape management is to maintain the "health, appearance, and reasonable growth" of plants, and not necessarily to replenish all of the water lost at maximum evapotranspiration rates. Thus, the CDWR methodology presented here calculates only the amount of water required to sustain the health, appearance, and growth of the plants.

102 Evapotranspiration is water lost to the atmosphere due to evaporation from soil and transpiration from plant leaves. For a more detailed definition, see this California Irrigation Management Information System (CIMIS) website: http://wwwcimis.water.ca.gov/cimis/infoEtoOverview.jsp;jsessionid=91682943559928B8A9A243D2A2665E19

Table WUW-5.1: Crop Coefficient for Turf Grasses

Category	Kc	Species
cool season grasses	0.8	annual bluegrass annual ryegrass colonial bentgrass creeping bentgrass hard fescue highland bentgrass Kentucky bluegrass meadow fescue perennial ryegrass red fescue rough-stalked bluegrass tall fescue
warm season grasses	0.6	Bermudagrass kikuyugrass seashore paspalum St. Augustinegrass zoysiagrass

Reference: p. 6 and p. 137 of CDWS report

Then: $Water_{baseline} = ETC \times Area_{baseline} \times 0.62 \times 365$

Where:

$Water_{baseline}$ = Volume of water required to support the baseline turf (gallons/year)
$Area_{baseline}$ = Area of existing or standard turf (square feet)
Provided by the Applicant
0.62 = conversion factor (gallons/squarefoot·inches water)
365 = conversion factor (days/year)
ETC = Crop evapotranspiration
Calculated using the equation on page 280

Then the baseline GHG emissions are calculated as follows:

$$GHG\ emissions = Water_{baseline} \times Electricity \times Utility$$

Where:

GHG emissions = MT CO_2e
Electricity = Electricity required to supply, treat, and distribute water (kWh/million gallons)

Northern California Average (outdoor uses): 3,500 kWh/million gallons
Southern California Average (outdoor uses): 11,111 kWh/million gallons
Utility = Carbon intensity of Local Utility (CO_2e/kWh)

Mitigation Method:

The equations above show that the GHG emissions are directly proportional to the water demand, which is in turn directly proportional to the area of the turf. Therefore, only the area of the existing or standard turf and the commitment to turf area reduction (square feet reduced or percent of baseline reduced) are needed to calculate the percent reduction in GHG emissions:

$$\text{GHG emission reduction} = \frac{Area_{reduction}}{Area_{baseline}} = AreaPercentReduction$$

Where:

$Area_{reduction}$ = Area of turf to be reduced (square feet)
Provided by the Applicant
$Area_{baseline}$ = Area of existing or standard turf (square feet)
Provided by the Applicant
AreaPercentReduction = Percent reduction in turf area (%)
Provided by the Applicant

As shown in this equation, the regional electricity intensity factor for water and the utility carbon intensity factor do not play a role in determining the percentage reduction in GHG emissions.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	Up to 100%, assuming 100% reduction in turf grass area. This would be the case for rock-lawns, for example.
All other pollutants	Not Quantified[103]

Discussion:

In this example, assume that the Project Applicant has provided detailed evidence to show that the turf area of a standard lawn at the project location is 8,000 square feet. If the Project Applicant then commits to reducing the turf area of lawns by 3,000 square feet, then the GHG emissions reduction is 37.5%.

[103] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

$$\text{GHG Emission Reduced} = \frac{3{,}000}{8{,}000} = 0.375 \text{ or } 37.5\%$$

Assumptions:

Data based upon the following references:

[1] California Department of Water Resources. 2009. Model Water Efficient Landscape Ordinance. Available online at: http://www.water.ca.gov/wateruseefficiency/docs/MWELO09-10-09.pdf

[2] California Department of Water Resources. 2000. A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California: The Landscape Coefficient Method and WUCOLS III. Available online at: http://www.water.ca.gov/pubs/conservation/a_guide_to_estimating_irrigation_water_needs_of_landscape_plantings_in_california__wucols/wucols00.pdf

[3] CEC. 2006. Refining Estimates of Water-Related Energy Use in California. PIER Final Project Report. Prepared by Navigant Consulting, Inc. CEC-500-2006-118. December. Available online at: http://www.energy.ca.gov/2006publications/CEC-500-2006-118/CEC-500-2006-118.PDF

Preferred Literature:

See above

Alternative Literature:

None

Other Literature Reviewed:

None

4.2.6 Plant Native or Drought-Resistant Trees and Vegetation

Range of Effectiveness: Best Management Practice; may be quantified if substantial evidence is available.

Measure Description:

California native plants within their natural climate zone and ecotype need minimal watering beyond normal rainfall, so less water is needed for irrigating native plants than non-native species. Drought-resistant vegetation needs even less watering. Water use contributes to GHG emissions indirectly, via the production of the electricity that is used to pump, treat, and distribute the water. Thus, planting native and drought-resistant vegetation reduces water use and the associated GHGs. Designing landscapes with native plants can provide many other benefits, including reducing the need for fertilization and pesticide use, and providing a more natural habitat for native wildlife. Although there is much anecdotal evidence for the benefits of planting native vegetation, few scientific studies have quantified the actual water savings. Therefore, this mitigation measure would most likely be employed as a Best Management Practice. Future studies may quantify the water-saving benefits of planting native or drought-resistant vegetation. In order to take quantitative credit for this mitigation measure, the Project Applicant would need to provide detailed and substantial evidence supporting a percent reduction in water use. The percent reduction would be applied to the baseline water use, calculated according to the baseline methodology described in WUW-3 (Design water efficient landscapes) and the baseline methodology document.

Measure Applicability:

- Outdoor water use

Inputs:

The following information needs to be provided by the Project Applicant:

- Percent reduction in water use, calculated using detailed and substantial evidence
- $Water_{baseline}$, to be calculated by the Project Applicant using the baseline methodology described in WUW-3 (Design water efficient landscapes) and the baseline methodology document

Baseline Method

See WUW-3 (Design water efficient landscapes)

Mitigation Method

Since this mitigation method does not change the electricity intensity factor (kWh/million gallons) associated with the supply, treatment, and distribution of the water, the percent reduction in GHG emissions is dependent only on the change in water consumption:

$$\text{GHG emission reduction} = \text{PercentReduction} \times \text{Water}_{baseline}$$

Where:

GHG emission reduction = Percentage reduction in GHG emissions for outdoor water use.

$Water_{baseline}$ = Baseline water demand, without planting native or drought-resistant vegetation
Provided by Applicant, calculated using baseline methodology of Mitigation Measure WUW-3

PercentReduction = Expected percent reduction in water use resulting from planting native or drought-resistant vegetation
Provided by Applicant

As shown in these equations, the carbon intensity of the local utility does not play a role in determining the percentage reduction in GHG emissions.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	To be determined by Applicant
All other pollutants	Not Quantified[104]

Discussion:

Currently there is not sufficient substantial evidence supporting a generalized reduction in emissions due to planting native or drought tolerant species. However, if the project applicant is able to provide sufficient substantial evidence supporting a reduction in water usage associated with native or drought tolerant species, the percent reduction in GHG emissions is equivalent to the percent reduction in outdoor water usage. Therefore, if a Project Applicant can support a 10% reduction in water use by native and drought tolerant species, the GHG emissions associated with water use are reduced by 10%.

Assumptions:

None

[104] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

Alternative Literature:

The EPA reports that while there is anecdotal evidence for the water-saving benefits of planting native and drought-resistant vegetation, there are very few scientific studies available which quantify the benefits. There are several good resources available which describe the qualitative benefits. The California Native Plant Society provides many resources for designing a native plant garden, including how to identify native plants and where to buy them. The Las Pilitas Nursery provides similar resources and also lists species of drought-resistant plants that are best for specific California regions. The EPA also provides tips for designing landscapes with native plants.

USEPA. "Exploring the Environmental, Social and Economic Benefits Conference," December 6-7, 2004. USEPA. Greenacres: Landscaping with Native Plants Research Needs. Available online at: http://www.epa.gov/greenacres/conf12_04/conf_A.html. Accessed March 2010.
California Native Plant Society. Homepage. Available online at: http://www.cnps.org/. Accessed March 2010.
Las Pilitas Nursery. Drought Tolerant or Resistant Native Plants. Available online at: http://www.laspilitas.com/garden/Drought_resistant_plants_for_a_California_garden.html. Accessed March 2010.
USEPA. Greenacres: Native Plants Brochure. Available online at: http://www.epa.gov/greenacres/navland.html#Introduction. Accessed March 2010.

Alternative Literature:

None.

Other Literature Reviewed:

None

5.0 Landscaping Equipment

5.1 Landscaping Equipment

5.1.1 Prohibit Gas Powered Landscape Equipment.

Measure Description:

Electric lawn equipment including lawn mowers, leaf blowers and vacuums, shredders, trimmers, and chain saws are available. When electric landscape equipment is used in place of a conventional gas-powered equipment, direct GHG emissions from natural gas combustion are replaced with indirect GHG emissions associated with the electricity used to power the equipment.

Measure Applicability:

[1] Landscaping equipment

Inputs:

The following information needs to be provided by the Project Applicant:

- Electricity provider for the Project
- Horsepower of landscaping equipment
- Hours of operation

Baseline Method:

Look up landscape equipment emission factor based on type of fuel used:

Landscaping Equipment Horsepower	CO_2 Emission Factor from Gasoline (g/hp-hr)
< 25	429.44
25 – 50	783.30
50 – 120	774.50
120 –175	753.25
> 175	732.00

$$\text{GHG emission} = EF \times Hp \times LF \times Hr \times 10^{-6}$$

Where:

GHG emission = MT CO_2e per year

EF = CO_2 emission factor for the relevant horsepower tier show in table above (g/hp-hr). Obtained from OFFROAD2007.

Hp = Horsepower of landscaping equipment
LF = Load factor of equipment for the relevant horsepower tier (dimensionless). Obtained from OFFROAD2007.
Hr = Hours of operation per year
10^{-6} = Unit conversion from grams to MT

Mitigation Method:

Landscaping equipment will run on electricity instead of gasoline. The indirect GHG emission from electricity generation is:

$$\text{GHG emission} = Utility \times Hp \times LF \times Hr \times C$$

Where:

GHG emissions = MT CO_2e
Utility = Carbon intensity of Local Utility (CO_2e/kWh). See table below.
Hp = Horsepower of landscaping equipment.
LF = Load factor of equipment for the relevant horsepower tier (dimensionless). Obtained from OFFROAD2007.
Hr = Hours of operation.
C = Unit conversion factor

Power Utility	Carbon-Intensity (lb CO_2e/kWh)
LADWP	1,238
PG&E	456
SCE	641
SDGE	781
SMUD	555

GHG Reduction %[105] $= 1 - \dfrac{Utility \times C}{EF \times 10^{-6}}$

EF = Emission Factor for the relevant fuel horsepower tier (g/hp-hr) Obtained from OFFROAD2007. See accompanying tables.

Emission Reduction Ranges and Variables:

Power Utility	Equipment Horsepower	Project GHG Emission Reductions
LADWP	< 25	2.5%
	25 – 50	46.5%

[105] This assumes energy from engine losses are the same.

Power Utility	Equipment Horsepower	Project GHG Emission Reductions
	50 – 120	45.9%
	120 –175	44.4%
	> 175	42.8%
PG&E	< 25	64.1%
	25 – 50	80.3%
	50 – 120	80.1%
	120 –175	79.5%
	> 175	78.9%
SCE	< 25	49.5%
	25 – 50	72.3%
	50 – 120	72.0%
	120 –175	71.2%
	> 175	70.4%
SDGE	< 25	38.5%
	25 – 50	66.3%
	50 – 120	65.9%
	120 –175	64.9%
	> 175	63.9%
SMUD	< 25	56.3%
	25 – 50	76.0%
	50 – 120	75.8%
	120 –175	75.1%
	> 175	74.3%

Criteria pollutants will be reduced by reduction in combustion. They will also increase through the increase in energy use. However, the increase may not be in the same air basin.

Discussion:

The output from OFFROAD2007 shows the same emissions within each horsepower tier regardless of the year modeled. Therefore, the emission reduction is dependent on the location of the Project and horsepower of the landscaping equipment only.

Assumptions:

Data based upon the following references:

California Air Resources Board. Off-road Emissions Inventory. OFFROAD2007. Available online at: http://www.arb.ca.gov/msei/offroad/offroad.htm

California Climate Action Registry Reporting Online Tool. 2006 PUP Reports. Available online at: https://www.climateregistry.org/CARROT/public/reports.aspx

Preferred Literature:

The amount of direct GHG emissions avoided can be calculated using CARB's OFFROAD model, which provides state-wide and regional emission factors for different types of landscaping equipment that can be converted to grams per horsepower-hour [1]. Multiplying this factor by the typical horsepower and load factor of the equipment and number of hours of operation gives the direct GHG emissions. Assuming the same number of operating hours and power output as the gas-powered equipment, the same amount of energy consumption multiplied by the carbon-intensity factor of the local utility gives the amount of indirect GHG emissions associated with using the electric landscape equipment. The GHG emissions reduction associated with this mitigation measure is therefore the difference in emissions from these two scenarios.

Companion Strategy:

In order to take credit for Mitigation Measure 80, a Project Applicant must also commit to providing electrical outlets on the exterior of all buildings (Mitigation Measure 60) so that electrical lawn equipment is compatible with built facilities.

Alternative Literature:

None

Notes:

1. CARB. OFFROAD 2007 Model. Available online at: http://www.arb.ca.gov/msei/offroad/offroad.htm. Accessed February 2010.

Other Literature Reviewed:

A. USEPA. Lawn Mower Exchange Program Calculator. Available online at: http://www.epa.gov/air/community/mowerexchange_calculator.html. Accessed February 2010.
B. USEPA. Improving Air Quality in Your Community: Outdoor Air – Transportation: Lawn Equipment. Available online at: http://www.epa.gov/air/community/details/yardequip.html. Accessed February 2010.
C. CARB. AB118 Lawn and Garden Equipment Replacement Project. Available online at: http://www.arb.ca.gov/msprog/aqip/lger.htm. Accessed February 2010.
D. SCAQMD. Mow Down Air Pollution Electric Lawn Mower Exchange. Available online at: http://www.aqmd.gov/tao/lawnmower2009.html. Accessed February 2010.
E. VCAPD. Lawn Mower Trade-In Program for Ventura County Residents. Available online at: http://www.vcapcd.org/LawnMower_EN.htm. Accessed February 2010.

F. SMAQMD. Mow Down Air Pollution. Available online at: http://www.airquality.org/mobile/mowdown/index.shtml. Accessed February 2010.

5.1.2 Implement Lawnmower Exchange Program

Range of Effectiveness: Best Management Practice, influences Area GHG emissions from landscape equipment

Measure Description:
When electric and rechargeable battery-powered lawnmowers are used in place of conventional gas-powered lawnmowers, direct GHG emissions from fuel combustion are displaced by indirect GHG emissions associated with the electricity used to power the equipment. The indirect GHG emissions from electricity generation are expected to be significantly less than the direct GHG emissions from gasoline or diesel fuel combustion. Since the magnitude of the GHG emissions reduction depends on the equipment model (including electric power efficiency and battery recharge time), hours of operation, fuel displaced, and number of lawnmowers replaced, the exact GHG emissions reduction is not quantifiable at this time. Therefore, this mitigation measure should be incorporated as a Best Management Practice to allow for educated residents and commercial tenants to reduce their contribution to GHG emissions from landscaping. Many California Air Districts, including eight air districts supported by the CARB Lawn and Garden Equipment Replacement (LGER) Project, already have lawnmower exchange programs in place. This Best Management Practice could involve participating in these established lawnmower exchange programs, supplementing the established programs, or implementing a new program for the Project. The Project Applicant should check with the local air district regarding participating in established programs. The Project Applicant could take quantitative credit for this mitigation measure if detailed and substantial evidence were provided.

Measure Applicability:
- GHG emissions from landscaping

Assumptions:
Data based upon the following references:

- CARB. AB118 Lawn and Garden Equipment Replacement Project. Available online at: http://www.arb.ca.gov/msprog/aqip/lger.htm. Accessed February 2010.
- SCAQMD. Mow Down Air Pollution Electric Lawn Mower Exchange. Available online at: http://www.aqmd.gov/tao/lawnmower2009.html. Accessed February 2010.
- VCAPD. Lawn Mower Trade-In Program for Ventura County Residents. Available online at: http://www.vcapcd.org/LawnMower_EN.htm. Accessed February 2010.
- SMAQMD. Mow Down Air Pollution. Available online at: http://www.airquality.org/mobile/mowdown/index.shtml. Accessed February 2010.

Emission Reduction Ranges and Variables:
This is a Best Management Practice and therefore there is no quantifiable reduction at this time. Check with local agencies for guidance on any allowed reductions associated with implementation of best management practices.

Preferred Literature:
CARB's Lawn and Garden Equipment Replacement (LGER) Project was established to encourage the use of cordless zero-emission lawn and garden equipment and to help bring more electric equipment to the market. The LGER Project provides vouchers for electric cordless residential lawn mowers valued up to $250 for each gas-powered lawnmower turned in. The LGER Project provides grants to eight air districts with existing lawnmower exchange programs, including AVAQMD, MDAQMD, SCAQMD, SDAPCD, SJVAPCD, SMAQMD, VCAPCD, and YSAQMD. Individual air districts may offer vouchers of different values.

Alternative Literature:

None

Other Literature Reviewed:

- USEPA. Lawn Mower Exchange Program Calculator. Available online at: http://www.epa.gov/air/community/mowerexchange_calculator.html. Accessed February 2010.
- USEPA. Improving Air Quality in Your Community: Outdoor Air – Transportation: Lawn Equipment. Available online at: http://www.epa.gov/air/community/details/yardequip.html. Accessed February 2010.

5.1.3 Electric Yard Equipment Compatibility

Range of Effectiveness: Best Management Practice, influences Area GHG emissions from landscape equipment. Not applicable on its own. This measure enhances effectiveness of A-1 and A-2.

Measure Description:

This measure is required to be grouped with measures A-1 “Prohibit Gas Powered Landscape Equipment” and A-2 “Implement a Lawnmower Exchange Program.” In order for measures A-1 and A-2 to be feasible, electrical outlets on the exterior of buildings must be accessible so that the electric landscaping equipment can be charged. In this mitigation measure, the Project Applicant commits to providing electrical outlets on the exterior of Project buildings as necessary for sufficient powering of electric lawnmowers and other landscaping equipment.

Measure Applicability:

- This measure is part of a grouped measure
- This measure contributes to reductions in GHG emissions from landscaping

Emission Reduction Ranges and Variables:

This measure is a Best Management Practice grouped with other measures and therefore there is no quantifiable reduction at this time. Check with local agencies for guidance on any allowed reductions associated with implementation of Best Management Practices.

Preferred Literature:

None

6.0 Solid Waste

6.1 Sold Waste

6.1.1 Institute or Extend Recycling and Composting Services

Range of Effectiveness: Varies depending on Project Applicant and strategies selected. Best Management Practice.

Measure Description:
The transport and decomposition of landfill waste and the flaring of landfill gas all produce GHG emissions. Decomposition of waste produces methane, a GHG which has a global warming potential over 20 times that of CO_2. The transport of waste from the site of generation to the landfill produces GHG emissions from the combustion of the fuel used to power the vehicle. Choosing waste management practices which reduce the amount of waste sent to landfills will reduce GHG emissions. Strategies to reduce landfill waste include increasing recycling, reuse, and composting, and encouraging lifestyle choices and office practices which reduce waste generation.

Current protocols for quantifying emissions reductions from diverted landfill waste developed by the USEPA and the California Center for Integrated Waste Management Board (CIWMB) are based on life-cycle approaches, which reflect emissions and reductions in both the upstream and downstream processes around waste management. The Project Applicant should seek local agency guidance on comparing and/or combining operational emissions inventories and life cycle emissions inventories.

Furthermore, while tools are available to quantify the avoided landfill GHG emissions from a specified amount of diverted or recycled waste, taking credit for this mitigation measure also requires the determination of the effects of instituting or extending recycling and composting services. Since both government and privately-sponsored recycling and composting programs vary dramatically in scope, waste materials accepted, and outreach efforts, no literature references exist which provide default values for percent of waste diverted. To take credit for this measure, the Project Applicant would need to provide detailed and substantial evidence supporting the amount of waste reduced or diverted to recycling and composting due to the institution of extended recycling and composting services.

Measure Applicability:

[2] Solid waste disposed to landfill

Inputs:
The following information needs to be provided by the Project Applicant:

- For residential buildings: number of residents
- For shopping malls and office buildings: building square footage
- For public venues: annual number of visitors
- For all other commercial buildings: number of employees
- Waste disposal method
- Amount of waste reduced or diverted to recycling and composting due to the institution of extended recycling and composting services.

Baseline Method:
The Project Applicant must first calculate the total amount of waste generated at the project.

For residential buildings and all commercial buildings except shopping malls and offices:

$$Waste_{baseline\ total} = People \times DisposalRate$$

For shopping malls and office buildings:

$$Waste_{baseline\ total} = SF \times DisposalRate$$

Where:

People = Number of residents, employees, or visitors (for public venues)
Provided by Applicant

SF = Square feet of building
Provided by Applicant

DisposalRate = Annual disposal rate of waste (tons/resident/year, tons/employee/year, or tons/visitor/year)
From Tables SW-1.1 and SW-1.2

The total waste stream is then portioned into material-specific streams (paper, glass, metal, plastic, etc.) using the percentages listed in Table SW-1.3.

USEPA's Waste Reduction Model (WARM) is used to quantify baseline emissions and emissions reductions from diverting landfill waste to composting or recycling. This web-based tool is available online at http://www.epa.gov/climatechange/wycd/waste/calculators/Warm_Form.html. The required inputs are the tons of waste associated with one of three waste management practices: landfill (baseline scenario), recycled (mitigated scenario), combusted (not applicable in California), and composted (mitigated scenario). The amount of each type of waste in tons is entered into the "Tons Landfilled" column in the Baseline Scenario of

WARM to calculate the baseline GHG emissions in metric MT carbon equivalent (MTCE). Other input variables include landfill type (presence of landfill gas control system or not) and distance of waste transport; however, default values can be used.

Mitigation Method:
In WARM, the project applicant specifies the amount of waste associated with each of the three alternative scenarios: waste reduced (e.g. reduced waste generation), waste recycled, and waste composted. WARM then calculates the GHG savings associated with the alternative scenarios as compared with the baseline scenario.

Assumptions:
Data based upon the following reference:

- USEPA. 2009. Waste Reduction Model. Available online at: http://www.epa.gov/climatechange/wycd/waste/calculators/Warm_home.html
- CIWMB. 1999. Statewide Waste Characterization Study: Final Results and Report. Available online at: http://www.calrecycle.ca.gov/publications/LocalAsst/34000009.pdf
- CIWMB. 2006. Targeted Statewide Waste Characterization Study: Waste Disposal and Diversion Findings for Selected Industry Groups. Available online at: http://www.ciwmb.ca.gov/WasteChar/WasteStudies.htm#2006Industry

Preferred Literature:
USEPA's WARM was developed to track GHG emission reductions from various waste management options. This tool calculates the GHG emissions associated with a baseline waste management strategy, as well as those associated with an alternative strategy that may include source reduction, recycling, composting, combusting, or landfilling. WARM then calculates the GHG savings associated with the alternative strategy as compared with the baseline strategy. WARM requires input of the estimated tons of waste per material type per disposal strategy. There are 34 different material types (e.g., aluminum cans, mixed paper, yard trimmings, carpet). Other input variables include landfill type (presence of landfill gas control system or not) and distance of waste transport; however, default values can be used. Note that WARM was developed based on a life-cycle approach, which reflects emissions and reductions in both the upstream and downstream processes around waste management. USEPA notes that emission factors developed based on this life cycle approach are not appropriate for use in GHG inventories.

Alternative Literature:
None

Other Literature Reviewed:

- HF&H Consultants. 2008. 5-Year Audit Program Assessment and Final Report. Prepared for StopWaste.Org. Available online at: http://www.stopwaste.org/docs/revised_assessment_report-final_1-08.pdf
- StopWaste.Org. 2008. Multifamily Dwelling Recycling Evaluation Report. Available online at: http://www.stopwaste.org/docs/mfd_evaluation_rpt.pdf

Table SW-1.1
Residential Waste Disposal Rates

Multi-family Homes		
All Counties	All Regions	**Annual Disposal Rate (tons/resident/year)**
		0.46

Single-family Homes		
County	**Region**	**Annual Disposal Rate (tons/resident/year)**
Alameda	Bay Area	0.42
Alpine	Mountain	0.25
Amador	Mountain	0.25
Butte	Central Valley	0.36
Calaveras	Mountain	0.25
Colusa	Central Valley	0.36
Contra Costa	Bay Area	0.42
Del Norte	Coastal	0.44
El Dorado	Mountain	0.25
Fresno	Central Valley	0.36
Glenn	Central Valley	0.36
Humbolt	Coastal	0.44
Imperial	Southern	0.41
Inyo	Mountain	0.25
Kern	Southern	0.41
Kings	Central Valley	0.36
Lake	Central Valley	0.36
Lassen	Mountain	0.25
Los Angeles	Southern	0.41
Madera	Central Valley	0.36
Marin	Bay Area	0.42
Mariposa	Mountain	0.25
Mendocino	Coastal	0.44
Merced	Central Valley	0.36
Modoc	Mountain	0.25
Mono	Mountain	0.25

Single-family Homes		
County	**Region**	**Annual Disposal Rate (tons/resident/year)**
Monterey	Coastal	0.44
Napa	Bay Area	0.42
Nevada	Mountain	0.25
Orange	Southern	0.41
Placer	Central Valley	0.36
Plumas	Mountain	0.25
Riverside	Southern	0.41
Sacramento	Central Valley	0.36
San Benito	Coastal	0.44
San Bernardino	Southern	0.41
San Diego	Southern	0.41
San Francisco	Bay Area	0.42
San Joaquin	Central Valley	0.36
San Luis Obispo	Southern	0.41
San Mateo	Bay Area	0.42
Santa Barbara	Southern	0.41
Santa Clara	Bay Area	0.42
Santa Cruz	Coastal	0.44
Shasta	Mountain	0.25
Sierra	Mountain	0.25
Siskiyou	Mountain	0.25
Solano	Bay Area	0.42
Sonoma	Coastal	0.44
Stanislaus	Central Valley	0.36
Sutter	Central Valley	0.36
Tehama	Central Valley	0.36
Trinity	Mountain	0.25
Tulare	Central Valley	0.36
Tuolumne	Mountain	0.25
Ventura	Southern	0.41
Yolo	Central Valley	0.36
Yuba	Central Valley	0.36

Source:

Single-family Homes		
County	**Region**	**Annual Disposal Rate (tons/resident/year)**

CalRecycle. Solid Waste Characterization Database: Residential Waste Disposal Rates. Available online at: http://www.calrecycle.ca.gov/wastechar/Resdisp.htm

CIWMB. 1999. Statewide Waste Characterization Study: Final Results and Report. Available online at: http://www.calrecycle.ca.gov/publications/LocalAsst/34000009.pdf.

Table SW-1.2
Commercial Waste Disposal Rates

Commercial Industry	Annual Disposal Rate	
Fast-Food Restaurants	2.1	tons/employee/year
Full-Service Restaurants	2.2	tons/employee/year
Food Stores	2.4	tons/employee/year
Durable Wholesale Distributors	1.2	tons/employee/year
Non-Durable Wholesale Distributors	1.4	tons/employee/year
Large Hotels	2.0	tons/employee/year
Building Material & Gardening, Big-Box Stores	3.2	tons/employee/year
Building Material & Gardening, Other Stores	1.7	tons/employee/year
Retail, Big-Box Stores	1.4	tons/employee/year
Retail, Other Stores	0.9	tons/employee/year
Shopping Malls, Anchor Stores	1.1	tons/1,000 sqft/year
Shopping Malls, Other	1.0	tons/1,000 sqft/year
Public Venues and Events	0.1	tons/100 visitors/year
Large Office Buildings	0.9	tons/1,000 sqft/year

Abbreviations:
lb - pound
sqft - square feet

Source:

CIWMB. 2006. Targeted Statewide Waste Characterization Study: Waste Disposal and Diversion Findings for Selected Industry Groups. Table 2. Available online at: http://www.ciwmb.ca.gov/WasteChar/WasteStudies.htm#2006Industry

Table SW-1.3
Waste Streams and Percent of Disposed Waste

Building Category	Disposed Waste Streams							
	Paper [Mixed Paper, Broad Definition]	Glass [Glass]	Metal [Mixed Metals]	Plastic [Mixed Plastics]	Electronics [Personal Computers]	Organics [Mixed Organics]	Construction & Demolition [Clay Bricks, Concrete]	Household Hazardous, Special, and Mixed Residue [Mixed MSW]
Residential	27.4%	4.0%	4.6%	8.8%	n/a	45.0%	4.5%	5.5%
Fast-Food Restaurants	33.0%	0.6%	1.6%	11.6%	0.0%	52.5%	0.6%	0.0%
Full-Service Restaurants	17.3%	2.7%	2.8%	7.3%	0.1%	66.5%	1.8%	1.5%
Food Stores	18.5%	0.5%	1.4%	9.5%	0.0%	65.0%	5.0%	0.0%
Durable Wholesale Distributors	26.3%	0.7%	11.4%	9.9%	0.5%	5.4%	43.5%	2.4%
Non-Durable Wholesale Distributors	26.5%	0.5%	3.3%	16.0%	2.6%	32.7%	18.4%	0.1%
Large Hotels	32.3%	4.7%	3.8%	9.7%	0.4%	44.2%	4.8%	0.1%
Building Material & Gardening, Big-Box Stores	12.2%	1.9%	8.3%	7.1%	1.2%	8.0%	60.1%	1.2%
Building Material & Gardening, Other Stores	13.4%	5.3%	3.9%	7.1%	1.9%	18.6%	47.4%	2.3%
Retail, Big-Box Stores	21.7%	1.1%	5.3%	16.0%	0.8%	23.6%	27.1%	4.4%
Retail, Other Stores	31.8%	6.2%	8.7%	14.4%	0.7%	17.5%	15.0%	5.7%
Shopping Malls, Anchor Stores	37.9%	5.0%	3.0%	28.8%	0.1%	15.5%	9.1%	0.5%
Shopping Malls, Other	32.7%	1.8%	2.3%	19.6%	0.2%	35.9%	5.3%	2.0%
Public Venues and Events	42.0%	5.5%	1.8%	14.8%	0.0%	34.0%	0.7%	1.2%
Large Office Buildings	50.3%	1.8%	1.6%	12.5%	0.1%	24.4%	8.3%	1.1%

Abbreviations:
MSW - municipal solid waste

Notes:
The USEPA report identifies waste streams with slightly different names than the CIWMB report. The CIWMB and USEPA waste stream categories were paired; USEPA categories are shown in brackets [ ] above.

Sources:
CIWMB. 1999. Statewide Waste Characterization Study: Final Results and Report. Available online at: http://www.calrecycle.ca.gov/publications/LocalAsst/34000009.pdf
CIWMB. 2006. Targeted Statewide Waste Characterization Study: Waste Disposal and Diversion Findings for Selected Industry Groups. Available online at: http://www.ciwmb.ca.gov/WasteChar/WasteStudies.htm#2006Industry
USEPA. 2006. Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks. Available online at: http://www.epa.gov/climatechange/wycd/waste/SWMGHGreport.html

6.1.2 Recycle Demolished Construction Material

Range of Effectiveness: Varies depending on Project Applicant and strategies selected. Best Management Practice.

Measure Description:
Recycling demolished construction material can contribute to GHG reductions in multiple ways. First, it displaces new construction materials, thereby reducing the need for new raw material acquisition and manufacturing of those new construction materials. Harvesting of raw materials and manufacturing new materials requires energy in the form of fuel combustion and electricity, both of which are associated with GHG emissions. If the process of recycling construction materials is less carbon-intensive than the processes required to harvest and produce new construction materials, recycling these construction materials results in a net reduction in GHG emissions. Second, using local recycled construction material reduces the emissions associated with the transportation of new construction materials, which are typically manufactured farther away from a project site. Third, recycling construction material avoids sending this material to landfills. Wood-based materials decompose in landfills and contribute to methane emissions.

Unlike measures which reduce GHG emissions during the operational lifetime of a project, such as reducing building electricity and water usage, this mitigation effort is realized prior to the actual operational lifetime of a project. Therefore, these GHG emissions reductions are best quantified in terms of a life-cycle analysis. Life cycle analyses examine all stages of the life of a product, including raw material acquisition, manufacture, transportation, installation, use, and disposal or recycling. The Project Applicant should seek local agency guidance on comparing and/or combining operational emissions inventories and life cycle emissions inventories.

Measure Applicability:
- Life cycle emissions from construction materials

Preferred Literature:
The California Integrated Waste Management Board (CIWMB) cites decreases in greenhouse gas emissions as a benefit of construction waste management and recycling in its document "Construction Waste Management" which is used as part of California Sustainable Design Training. The document is available online at: www.calrecycle.ca.gov/greenbuilding/training/statemanual/waste.doc

Alternative Literature:
None

Other Literature Reviewed:
None

7.0 Vegetation

7.1 Vegetation

7.1.1 Urban Tree Planting

Range of Effectiveness: CO_2 reduction varies by the number of trees. VOC emissions may increase.

Measure Description:

Planting trees sequesters CO_2 while the trees are actively growing. The amount of CO_2 sequestered depends on the type of tree. IPCC indicates that in most cases, the active growing period of a tree is 20 years and after this time the amount of carbon in biomass slows and will be completely offset by losses from clipping, pruning, and occasional death [1]. Therefore, the emissions only occur for a 20 year period and are summed over all years to give a net one-time GHG benefit.

If large areas of trees will be planted, the lead agency may want to ensure enforceability by requiring submission of annual inventory consistent with the Urban Forest Protocol [2]. This is a comprehensive protocol that requires maintenance and replacement of trees. If the Project Applicant desires to use this approach, calculation methodologies and assumptions presented in the protocol should be used. The information required to implement this protocol is often not available at the time of the CEQA process.

The type of tree species planted will result in varying degrees of carbon sequestration. In addition, trees emit volatile organic compounds (VOCs), which are criteria pollutant precursors. Therefore the Project Applicant may want to consider these issues when selecting the type of tree to plant. See [3] for details on low-VOC trees.

Measure Applicability:

- New trees

Inputs:

The following information needs to be provided by the Project Applicant:

- Species classes of trees planted, if known
- Number of net new trees in each species class, if known
- Total number of net new trees

Baseline Method:

In the baseline case, there are no net new trees planted.

Mitigation Method:

Look up default annual CO_2 sequestration rates on a per tree basis:

Broad species class	Default annual CO_2 accumulation per tree[1] (MT CO_2/ year)
Aspen	0.0352
Soft maple	0.0433
Mixed hardwood	0.0367
Hardwood maple	0.0521
Juniper	0.0121
Cedar/larch	0.0264
Douglas fir	0.0447
True fir/Hemlock	0.0381
Pine	0.0319
Spruce	0.0337
Miscellaneous[2]	0.0354

1. IPCC's carbon (C) values converted to carbon dioxide (CO_2) using ratio of molecular weights (44/12).
2. Average of all other broad species classes. To be assumed if tree type is not known.

Therefore, the reduction in GHG emissions associated with planting new trees is:

$$\text{GHG emission reduction} = (\text{Growing Period} \times \sum_{i=1}^{n} [\text{Sequestration } i \times \text{Trees } i\,]\,) \div \text{Total GHG emissions}$$

Where:

GHG emission reduction = Percentage reduction in GHG emissions as compared to total GHG emissions.
Growing Period = Growing period for all trees, expressed in years (20).
n = Number of broad species classes. Provided by Applicant.
Sequestration *i* = Default annual CO_2 accumulation per tree for broad species class *i*. Lookup in table above.
Trees *i* = Number of net new trees of broad species class *i*.
Total GHG emissions = Total GHG emissions. Provided by Applicant.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	Varies based on number of trees
VOC	May increase
All other pollutants	Not Quantified

Discussion:

If the applicant has baseline total project emissions of 5,000 MT CO_2e per year, and if the applicant elects to mitigate GHG emissions by committing to planting 500 net new "miscellaneous" trees, the applicant would reduce the amount of GHG emissions associated with the project by 7%.

$$\text{GHG Emission Reduced} = \frac{20 \times 0.0354 \times 500}{5{,}000} = 0.07 \text{ or } 7\%$$

Assumptions:

Data based upon the following reference:

[1] IPCC. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Table 8.2. Available online at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_08_Ch8_Settlements.pdf

Preferred Literature:

The IPCC Guidelines [1] provide a method for estimating the amount of carbon sequestered by trees. IPCC default annual CO_2 sequestration rates on a per tree basis are used. Table 8.2 of the IPCC Guidelines provides species class-specific sequestration values. For species that do not appear or if the species is unknown, the average value from Table 8.2 (0.035 MT CO_2 per year per tree) can be assumed to be representative of trees planted. Urban trees are only net carbon sinks when they are actively growing. The IPCC assumes an active growing period of 20 years (see p. 8.9). Thereafter, the accumulation of carbon in biomass slows with age, and will be completely offset by losses from clipping, pruning, and occasional death. Actual active growing periods are subject to, among other things, species, climate regime, and planting density. Additional credit may be taken for planting native trees. See WUW-3 for details on the design of water-efficient landscaping.

Alternative Literature:

The Center for Urban Forest Research Tree Carbon Calculator is based on a small set of data and extrapolates annual tree girth increases for various tree species [1]. Furthermore, it extrapolates the amount of carbon associated with a given girth for each tree species. This method is based on extrapolation of a limited dataset. In addition it requires considerably more input requirements that may not be available for CEQA projects. These inputs include knowledge of specific tree species that will be planted and assumptions regarding anticipated growth rates. Considering the order of magnitude of mitigation from this option, the additional complexity of this method would not generally be warranted for most CEQA projects.

The CAR Urban Forest Sector Protocol [2] provides guidelines for estimating the amount of CO_2 sequestered by common California tree species. This methodology would require Project Applicants to know the tree species to be planted at the time the CEQA analysis is prepared. Furthermore, this methodology would require Project Applicants to estimate the expected diameter of trees, which is dependent on climate and tree sub-species, among other things.

Alternative Literature References:

[2] CAR. 2010. Urban Forest Project Protocol Version 1.1. Available online at: http://www.climateactionreserve.org/how/protocols/adopted/urban-forest/current-urban-forest-project-protocol/

[3] The Center for Urban Forest Research Tree Carbon Calculator. Available online at: http://www.fs.fed.us/ccrc/topics/urban-forests/

Other Literature Reviewed:

None

7.1.2 Create New Vegetated Open Space

Range of Effectiveness: varies based on amount and type of land vegetated

Measure Description:

A development which re-vegetates or creates vegetated land from previously settled land sequesters CO_2 from the atmosphere which would not have been captured had there been no land-type change. There is no reduction in GHG emissions associated with preservation of a land.

Measure Applicability:

- Open space

Inputs:

The following information needs to be provided by the Project Applicant:

- Types of land uses created
- Acres of each land use created

Baseline Method:

In the baseline case, there is no preserved or created open space.

Mitigation Method:

Lookup carbon dioxide sequestered per acre for each land use that will be preserved or created:

Land Use	Sub-Category	Default annual CO_2 accumulation per acre[1] (MT CO_2/ acre)
Forest Land	Scrub	14.3
	Trees	111
Cropland	--	6.9
Grassland	--	4.31
Wetlands	--	0

1. Calculated by multiplying total biomass (MT dry matter/acre) from IPCC data by the carbon fraction in plant material (0.47), then using the ratio of molecular weights (44/12) to convert from MT of carbon (C) to MT of carbon dioxide (CO_2).

Land uses are defined by IPCC as follows:

(i) Forest Land

This category includes all land with woody vegetation consistent with thresholds used to define Forest Land in the national greenhouse gas inventory. It also includes systems with a vegetation structure that currently fall below, but *in situ* could potentially reach the threshold values used by a country to define the Forest Land category.

(ii) Cropland

This category includes cropped land, including rice fields, and agro-forestry systems where the vegetation structure falls below the thresholds used for the Forest Land category.

(iii) Grassland

This category includes rangelands and pasture land that are not considered Cropland. It also includes systems with woody vegetation and other non-grass vegetation such as herbs and brushes that fall below the threshold values used in the Forest Land category. The category also includes all grassland from wild lands to recreational areas as well as agricultural and silvi-pastural systems, consistent with national definitions.

(iv) Wetlands

This category includes areas of peat extraction and land that is covered or saturated by water for all or part of the year (e.g., peatlands) and that does not fall into the Forest Land, Cropland, Grassland or Settlements categories. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions.

$$\text{GHG emission reduction} = \left(\sum_{i=1}^{n} [\text{ Sequestration } i \text{ x Acres } i\ ] \right) \div \text{Total GHG emissions}$$

Where:

GHG emission reduction = Percentage reduction in GHG emissions as compared to total GHG emissions.

n = Number of land uses. Provided by Applicant.

Sequestration *i* = Default annual CO_2 accumulation per acre for land use *i.* Look up in table above.

Acres *i* = Number of acres of land use *i.*

Total GHG emissions = Total one-time GHG emissions. Provided by Applicant.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	Varies
All other pollutants	Not Quantified

Discussion:

If the applicant has baseline one-time emissions of 5,000 MT CO_2e per year, and if the applicant elects to mitigate GHG emissions by committing to creating 50 acres of forest land (scrub) and 20 acres of grassland, the applicant would reduce the amount of one-time GHG emissions by 16%.

$$\text{GHG Emission Reduced} = \frac{14.3 \times 50 + 4.31 \times 20}{5{,}000} = 0.16 \text{ or } 16\%$$

Assumptions:

Data based upon the following references:

[1] IPCC. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4. Available online at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

Preferred Literature:

The IPCC Guidelines provide a method for calculating changes in CO_2 sequestration due to land-type conversions. While other methods exist, notably the CCAR Forest Protocol [2], the IPCC Guidelines [1] have more general default values available that will be applicable to all areas of California without requiring detailed site-specific information. A general knowledge of the proposed change in land type is sufficient to quantify reductions in greenhouse gas emissions. IPCC designates four general vegetation types: forest land, cropland, grassland, and wetland. The amount of sequestered CO_2 is calculated based on the amount of carbon stock in each type of biomass (MT carbon / hectare vegetation). IPCC defaults for the carbon stock in each vegetation type are summarized in Table 8.4. (Note that this table represents the amount of carbon removed due to land conversion to settlements; it can also be used to calculate the amount of carbon sequestered due to conversion from settlement to vegetated land. Note also that a conversion to wetlands is not relevant for California). In addition to general default values, the IPCC Guidelines have climate and species-specific data available which can be used if details of the proposed development are known. To calculate the final mass of CO_2, the mass of carbon is then multiplied by 3.67, which is the ratio of molecular mass of CO_2 to the molecular mass of carbon. This method assumes that all of the carbon is converted into CO_2, which is appropriate for most CEQA projects.

Alternative Literature:

The CAR Forest Sector Protocol provides guidelines for estimating the amount of CO_2 sequestered by vegetated land [1]. The Protocol is specific to forest land only, and is not appropriate for estimating land-type conversions to or from cropland or grassland. Additionally, the methodology is limited to conversions from vegetated land to settlement or settlement to vegetated land, but is not appropriate for changes from one vegetated land type to another vegetated land type. The Protocol recommends accounting for changes in the organic carbon content of soil, which requires soil sampling and testing. While testing of existing soil is feasible, the protocol does not provide adequate methods for predicting the future soil organic carbon content after a land-type conversion has taken places. Furthermore, soil testing may be a burdensome task for a Project Applicant. Methodologies which provide default values, such as the IPCC Guidelines, are preferable.

Alternative Literature References:

[2] CAR. 2010. Urban Forest Project Protocol Version 1.1. Available online at: http://www.climateactionreserve.org/how/protocols/adopted/urban-forest/current-urban-forest-project-protocol/

Other Literature Reviewed:

None

8.0 Construction

8.1 Construction

8.1.1 Use Alternative Fuels for Construction Equipment

Range of Effectiveness: 0 – 22% reduction in GHG emissions

Measure Description:

When construction equipment is powered by alternative fuels such as compressed natural gas rather than conventional petroleum diesel or gasoline, GHG emissions from fuel combustion may be reduced.

Measure Applicability:

[3] Construction vehicles

Inputs:

The following information needs to be provided by the Project Applicant:

- Fuel type and Horsepower of Construction Equipment
- Hours of operation

Baseline Method:

For all pollutants besides ROG emissions from gasoline-fueled equipment, total emission is equivalent to exhaust emission and is calculated as follows:

$$\text{Exhaust Emission} = \frac{\text{Exhaust}}{\text{Activity} \times \text{AvgHP}} \times Hp \times Hr \times C$$

Where:

Exhaust Emission= MT or tons of pollutant per year
Exhaust = Statewide daily emission from equipment for the relevant horsepower tier of diesel or gasoline fuel (tons/day). Obtained from OFFROAD2007.
Activity = Statewide daily average operating hours for the relevant horsepower tier (hours/day). Obtained from OFFROAD2007.
AvgHP = Average horsepower for the relevant horsepower tier (HP). Obtained from OFFROAD2007.
Hp = Horsepower of equipment.
Hr = Hours of operation.
C = Unit conversion factor

Note that this method assumes the load factor of the equipment is same as the default in OFFROAD2007.

Total GHG emission is calculated as follows:

$$\text{GHG Emission} = CO_2\ \text{Emission} + CH_4\ \text{Emission} \times 21 + N_2O\ \text{Emission} \times 310$$

Where:

GHG Emission = MT CO_2e
CO_2 Emission = CO_2 emission calculated as described above with data from OFFROAD2007.
CH_4 Emission = CH_4 emission calculated as described above with data from OFFROAD2007.
N_2O Emission = N_2O emission calculated as described above with data from OFFROAD2007.
21 = Global warming potential of CH_4 following CCAR GPR 2009.
310 = Global warming potential of N_2O following CCAR GPR 2009.

Total ROG emission from gasoline-fueled equipment is calculated as follows:

$$\text{Total ROG Emission} = \text{Exhaust ROG Emission} + \frac{\text{Resting} + \text{Diurnal} + \text{Hot Soak} + \text{Evaporative}}{\text{Activity} \times \text{AvgHP}} \times Hp \times Hr \times C$$

Where:

Total ROG Emission = Tons of ROG emission per year
Exhaust ROG Emission = ROG emission from exhaust calculated as described above (tons/year)
Resting = Statewide daily resting losses from equipment for the relevant horsepower tier (tons/day). Obtained from OFFROAD2007.
Diurnal = Statewide daily diurnal losses from equipment for the relevant horsepower tier (tons/day). Obtained from OFFROAD2007.
Hot Soak = Statewide daily hot soak losses from equipment for the relevant horsepower tier (tons/day). Obtained from OFFROAD2007.
Evaporative = Statewide daily evaporative losses from equipment for the relevant horsepower tier (tons/day). Obtained from OFFROAD2007.
Activity = Statewide daily average operating hours for the relevant horsepower tier (hours/day). Obtained from OFFROAD2007.
AvgHP = Average horsepower for the relevant horsepower tier (HP). Obtained from OFFROAD2007.
Hp = Horsepower of TRU.
Hr = Hours of operation.
C = Unit conversion factor

Mitigation Method:

Mitigated emissions for this measure are calculated using the same method as baseline method, but with emission factors from compressed natural gas in OFFROAD2007.

Emission Reduction Ranges and Variables:

GHG and criteria pollutant emission reductions from switching diesel or gasoline fuel to compressed natural gas fuel for different years are listed in accompanying tables. Only equipment with emission data for compressed natural gas and either diesel or gasoline fuel in OFFROAD2007 are included.

Discussion:

The emission changes vary over a large range for different pollutants and equipment and between diesel and gasoline. In fact, GHG emissions for several types of equipment running on gasoline and all equipment running on diesel would increase from switching to compressed natural gas, as reflected by the negative reductions in the tables. On the other hand, SO_2 emissions are 100% reduced as there is no SO_2 emissions from equipment running on compressed natural gas according to OFFROAD2007. Other trends include no significant change in PM emissions for most gasoline equipment, considerable decrease in CO emissions from gasoline equipment but significant increase in CO emissions from diesel equipment. Therefore, the Project Applicant has to weigh the costs and benefits from switching to compressed natural gas on a case-by-case basis.

Assumptions:

Data based upon the following references:

- California Air Resources Board. Off-road Emissions Inventory. OFFROAD2007. Available online at: http://www.arb.ca.gov/msei/offroad/offroad.htm
- California Climate Action Registry (CCAR). 2009. General Reporting Protocol. Version 3.1. Available online at: http://www.climateregistry.org/tools/protocols/general-reporting-protocol.html
  California Climate Action Registry Reporting Online Tool. 2006 PUP Reports. Available online at: https://www.climateregistry.org/CARROT/public/reports.aspx

Preferred Literature:

GHG emissions from the combustion of conventional petroleum diesel and gasoline fuel can be calculated using CARB's OFFROAD model emission factors [1]. The model provides state-wide and regional emission factors that can be converted to grams per horsepower-hour. Multiplying this factor by the typical horsepower of the equipment and the estimated number of hours of operation gives the total GHG emissions. In this mitigation measure, compressed natural gas was chosen as the alternative fuel. Emission factors for compressed natural gas can also be obtained from OFFROAD The

GHG emissions reduction associated with this mitigation measure is therefore the difference in emissions from using petroleum diesel or gasoline versus using compressed natural gas. Other types of alternative fuels besides compressed natural gas exist. In order to take credit for this mitigation measure, the Project Applicant would need to provide detailed and substantial documentation showing expected reductions in GHG emissions as a result of running construction equipment on these alternative fuels rather than petroleum diesel or gasoline. One potential issue with quantifying this mitigation measure is the difference in fuel economy between petroleum diesel and alternative fuels.

Alternative Literature:

Many USDOE, NREL, and USEPA reports exist which present data on exhaust emissions from engines operating with alternative fuels. The majority of these reports focuses on oxides of nitrogen (NOx) and particulate matter (PM) emissions and have limited CO_2 emissions and fuel economy data. One NREL report shows CO_2 emissions and fuel economy for three ethanol/diesel blends (7.7%, 10%, and 15%) in three off-road engines (6.8, 8.1, and 12.5 L) and compares the results to engine performance using conventional diesel fuel [5]. However, this report presented engine-specific data from a small study size. Issues with other reports include the study's focus on on-road engines rather than off-road engines which would be used in construction equipment. It would be difficult to generalize the data contained in these reports for a Project Applicant's ease of use.

Notes:

[1] CARB. OFFROAD 2007 Model. Available online at: http://www.arb.ca.gov/msei/offroad/offroad.htm. Accessed February 2010.

Other Literature Reviewed:

[2] USEPA. 2002. A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions. Available online at: http://www.epa.gov/otaq/models/analysis/biodsl/p02001.pdf
[3] USDOE. NREL: ReFUEL Laboratory: Data and Resources. Available online at: http://www.nrel.gov/vehiclesandfuels/refuellab/data_resources.html. Accessed March 2010.
[4] USDOE. 2006. NREL: Effects of Biodiesel Blends on Vehicle Emissions. Available online at: http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/40554.pdf
[5] USDOE. 2003. NREL: The Effect of Biodiesel Composition on Engine Emissions from a DDC Series 60 Diesel Engine. Available online at: http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/31461.pdf

Table C-1.1
Emission Reduction Due to Fuel Switch from Gasoline to Compressed Natural Gas

Equipment	Horsepower	2004					
		CO	CO_2e	NOx	PM	ROG	SO_2
Aerial Lifts	<15	59%	-27%	36%	91%	98%	100%
	15 - 25	61%	-40%	7%	90%	97%	100%
Air Conditioner	< 175	24%	14%	19%	0%	97%	100%
Baggage Tug	< 120	46%	15%	-4%	0%	93%	100%
Belt Loader	< 120	52%	18%	3%	0%	95%	100%
Bobtail	< 120	55%	17%	19%	0%	95%	100%
Cargo Loader	< 120	41%	16%	2%	0%	93%	100%
Catering Truck	< 250	31%	12%	25%	0%	94%	100%
Forklifts	< 25	53%	-46%	23%	-85%	92%	100%
	25 - 50	94%	22%	-33%	0%	97%	100%
	50 - 120	58%	19%	18%	0%	96%	100%
	120 - 175	24%	17%	24%	0%	94%	100%
Fuel Truck	<175	3%	18%	17%	0%	99%	100%
Generator Sets	<120	52%	18%	14%	0%	96%	100%
	120 - 175	22%	14%	21%	0%	95%	100%
Lav Truck	<175	32%	18%	17%	0%	94%	100%
Lift	<120	53%	17%	14%	0%	96%	100%
Passenger Stand	<175	27%	15%	22%	0%	96%	100%
Service Truck	<250	13%	16%	26%	0%	95%	100%

Equipment	Horsepower	2010					
		CO	CO_2e	NOx	PM	ROG	SO_2
Aerial Lifts	<15	58%	-27%	39%	91%	96%	100%
	15 - 25	58%	-37%	32%	90%	95%	100%
Air Conditioner	< 175	29%	14%	19%	0%	98%	100%
Baggage Tug	< 120	13%	13%	-114%	0%	84%	100%
Belt Loader	< 120	27%	15%	-82%	0%	91%	100%
Bobtail	< 120	29%	16%	11%	0%	96%	100%
Cargo Loader	< 120	15%	14%	-70%	0%	89%	100%
Catering Truck	< 250	35%	12%	29%	0%	95%	100%
Forklifts	< 25	53%	-51%	3%	-85%	85%	100%
	25 - 50	95%	22%	18%	0%	98%	100%
	50 - 120	52%	18%	5%	0%	95%	100%
	120 - 175	27%	14%	23%	0%	94%	100%
Fuel Truck	<175	9%	16%	15%	0%	100%	100%
Generator Sets	<120	40%	17%	16%	0%	97%	100%
	120 - 175	26%	14%	23%	0%	95%	100%
Lav Truck	<175	36%	15%	-18%	0%	94%	100%
Lift	<120	44%	17%	16%	0%	96%	100%

Passenger Stand	<175	32%	15%	25%	0%	97%	100%
Service Truck	<250	19%	14%	40%	0%	95%	100%

Equipment	Horsepower	2015					
		CO	CO_2e	NOx	PM	ROG	SO_2
Aerial Lifts	<15	58%	-27%	39%	91%	96%	100%
	15 - 25	58%	-37%	32%	90%	94%	100%
Air Conditioner	< 175	31%	13%	23%	0%	99%	100%
Baggage Tug	< 120	8%	14%	-93%	0%	85%	100%
Belt Loader	< 120	22%	16%	-69%	0%	92%	100%
Bobtail	< 120	25%	16%	13%	0%	96%	100%
Cargo Loader	< 120	5%	14%	-91%	0%	88%	100%
Catering Truck	< 250	38%	11%	33%	0%	95%	100%
Forklifts	< 25	53%	-51%	3%	-85%	84%	100%
	25 - 50	95%	22%	34%	0%	98%	100%
	50 - 120	52%	18%	6%	0%	95%	100%
	120 - 175	27%	14%	25%	0%	95%	100%
Fuel Truck	<175	12%	15%	13%	0%	100%	100%
Generator Sets	<120	21%	16%	17%	0%	97%	100%
	120 - 175	29%	13%	24%	0%	96%	100%
Lav Truck	<175	36%	15%	-24%	0%	95%	100%
Lift	<120	37%	16%	16%	0%	96%	100%
Passenger Stand	<175	34%	14%	28%	0%	98%	100%
Service Truck	<250	22%	13%	46%	0%	96%	100%

Equipment	Horsepower	2020					
		CO	CO_2e	NOx	PM	ROG	SO_2
Aerial Lifts	<15	58%	-27%	39%	91%	96%	100%
	15 - 25	58%	-37%	32%	90%	94%	100%
Air Conditioner	< 175	32%	13%	24%	0%	99%	100%
Baggage Tug	< 120	7%	15%	-49%	0%	89%	100%
Belt Loader	< 120	21%	16%	-27%	0%	94%	100%
Bobtail	< 120	26%	16%	13%	0%	96%	100%
Cargo Loader	< 120	3%	15%	-62%	0%	91%	100%
Catering Truck	< 250	39%	11%	36%	0%	96%	100%
Forklifts	< 25	53%	-51%	3%	-85%	84%	100%
	25 - 50	95%	22%	36%	0%	98%	100%
	50 - 120	52%	18%	8%	0%	95%	100%
	120 - 175	27%	14%	26%	0%	95%	100%
Fuel Truck	<175	12%	14%	9%	0%	100%	100%
Generator Sets	<120	-5%	16%	17%	0%	98%	100%
	120 - 175	30%	13%	25%	0%	97%	100%
Lav Truck	<175	36%	15%	3%	0%	96%	100%

Lift	<120	30%	16%	15%	0%	97%	100%
Passenger Stand	<175	35%	14%	30%	0%	98%	100%
Service Truck	<250	23%	13%	42%	0%	96%	100%

Equipment	Horsepower	2025					
		CO	CO_2e	NOx	PM	ROG	SO_2
Aerial Lifts	<15	58%	-27%	39%	91%	96%	100%
	15 - 25	58%	-37%	32%	90%	94%	100%
Air Conditioner	< 175	32%	13%	27%	0%	99%	100%
Baggage Tug	< 120	8%	15%	-27%	0%	92%	100%
Belt Loader	< 120	21%	17%	-7%	0%	96%	100%
Bobtail	< 120	25%	16%	13%	0%	96%	100%
Cargo Loader	< 120	3%	16%	-40%	0%	93%	100%
Catering Truck	< 250	39%	11%	36%	0%	96%	100%
Forklifts	< 25	53%	-51%	3%	-85%	84%	100%
	25 - 50	95%	21%	36%	0%	98%	100%
	50 - 120	52%	18%	8%	0%	95%	100%
	120 - 175	27%	14%	26%	0%	95%	100%
Fuel Truck	<175	13%	14%	13%	0%	100%	100%
Generator Sets	<120	-15%	16%	18%	0%	98%	100%
	120 - 175	30%	13%	26%	0%	98%	100%
Lav Truck	<175	36%	15%	22%	0%	97%	100%
Lift	<120	27%	16%	15%	0%	97%	100%
Passenger Stand	<175	35%	13%	30%	0%	99%	100%
Service Truck	<250	24%	12%	34%	0%	96%	100%

Table C-1.2
Emission Reduction Due to Fuel Switch from Diesel to Compressed Natural Gas

Equipment	Horsepower	2004					
		CO	CO_2e	NOx	PM	ROG	SO_2
Aerial Lifts	<15	-2749%	-27%	55%	36%	73%	100%
	15 - 25	-2912%	-31%	46%	26%	74%	100%
Air Conditioner	<175	-451%	-21%	-30%	84%	87%	100%
Baggage Tug	<120	-507%	-24%	10%	94%	88%	100%
Belt Loader	<120	-469%	-23%	6%	93%	89%	100%
Bobtail	<120	-441%	-22%	23%	93%	91%	100%
Cargo Loader	<120	-625%	-25%	-4%	93%	84%	100%
Catering Truck	<250	-1152%	-22%	-44%	70%	78%	100%
Forklifts	<50	-21%	-23%	-51%	93%	95%	100%
	50 - 120	-594%	-25%	5%	93%	87%	100%
	120 - 175	-581%	-22%	-2%	88%	89%	100%
Generator Sets	<120	-397%	-12%	-2%	92%	91%	100%
	<175	-415%	-12%	-11%	85%	89%	100%
Lav Truck	<175	-457%	-22%	-11%	88%	89%	100%
Lift	<120	-465%	-23%	-5%	92%	89%	100%

Equipment	Horsepower	2010					
		CO	CO_2e	NOx	PM	ROG	SO_2
Aerial Lifts	<15	-3037%	-27%	31%	-29%	59%	100%
	15 - 25	-3755%	-32%	40%	-3%	60%	100%
Air Conditioner	<175	-450%	-20%	-36%	73%	85%	100%
Baggage Tug	<120	-556%	-22%	22%	92%	88%	100%
Belt Loader	<120	-513%	-22%	21%	92%	90%	100%
Bobtail	<120	-480%	-19%	64%	91%	96%	100%
Cargo Loader	<120	-678%	-24%	6%	91%	84%	100%
Catering Truck	<250	-1732%	-21%	-38%	53%	73%	100%
Forklifts	<50	-54%	-21%	26%	90%	96%	100%
	50 - 120	-647%	-22%	32%	90%	90%	100%
	120 - 175	-598%	-21%	38%	82%	90%	100%
Generator Sets	<120	-430%	-11%	11%	89%	91%	100%
	<175	-436%	-11%	0%	81%	89%	100%
Lav Truck	<175	-477%	-21%	1%	84%	90%	100%
Lift	<120	-503%	-22%	9%	90%	89%	100%

Equipment	Horsepower	2015					
		CO	CO_2e	NOx	PM	ROG	SO_2
Aerial Lifts	<15	-3040%	-27%	28%	-86%	57%	100%
	15 - 25	-4465%	-32%	32%	-48%	46%	100%
Air Conditioner	<175	-450%	-19%	-41%	47%	85%	100%
Baggage Tug	<120	-590%	-21%	30%	91%	89%	100%
Belt Loader	<120	-541%	-21%	31%	90%	91%	100%
Bobtail	<120	-505%	-19%	65%	89%	96%	100%
Cargo Loader	<120	-720%	-22%	4%	88%	83%	100%
Catering Truck	<250	-1899%	-20%	-54%	16%	72%	100%
Forklifts	<50	-85%	-20%	41%	83%	94%	100%
	50 - 120	-682%	-21%	23%	81%	89%	100%
	120 - 175	-596%	-20%	36%	68%	91%	100%
Generator Sets	<120	-456%	-11%	22%	84%	91%	100%
	<175	-444%	-10%	12%	71%	90%	100%
Lav Truck	<175	-483%	-20%	10%	76%	91%	100%
Lift	<120	-531%	-21%	17%	85%	89%	100%

Equipment	Horsepower	2020					
		CO	CO_2e	NOx	PM	ROG	SO_2
Aerial Lifts	<15	-3040%	-27%	28%	-91%	57%	100%
	15 - 25	-4722%	-32%	29%	-91%	39%	100%
Air Conditioner	<175	-449%	-19%	-104%	-81%	88%	100%
Baggage Tug	<120	-621%	-20%	31%	87%	90%	100%
Belt Loader	<120	-569%	-20%	31%	85%	91%	100%
Bobtail	<120	-526%	-19%	53%	84%	95%	100%
Cargo Loader	<120	-757%	-21%	-9%	78%	81%	100%
Catering Truck	<250	-1946%	-20%	-120%	-75%	73%	100%
Forklifts	<50	-100%	-20%	32%	60%	91%	100%
	50 - 120	-696%	-21%	-17%	55%	84%	100%
	120 - 175	-596%	-20%	-12%	31%	89%	100%
Generator Sets	<120	-476%	-10%	25%	69%	91%	100%
	<175	-446%	-10%	5%	48%	90%	100%
Lav Truck	<175	-485%	-19%	-3%	56%	91%	100%
Lift	<120	-553%	-20%	13%	72%	89%	100%

Equipment	Horsepower	2025					
		CO	CO_2e	NOx	PM	ROG	SO_2
Aerial Lifts	<15	-3040%	-27%	28%	-91%	57%	100%
	15 - 25	-4803%	-32%	27%	-109%	37%	100%
Air Conditioner	<175	-450%	-19%	-346%	-331%	88%	100%
Baggage Tug	<120	-640%	-19%	17%	79%	89%	100%
Belt Loader	<120	-587%	-20%	16%	72%	90%	100%
Bobtail	<120	-548%	-19%	32%	72%	93%	100%
Cargo Loader	<120	-763%	-20%	-40%	56%	78%	100%
Catering Truck	<250	-1936%	-20%	-330%	-294%	72%	100%
Forklifts	<50	-106%	-20%	19%	-26%	89%	100%
	50 - 120	-703%	-21%	-69%	-48%	79%	100%
	120 - 175	-597%	-20%	-172%	-110%	83%	100%
Generator Sets	<120	-483%	-10%	13%	37%	90%	100%
	<175	-446%	-10%	-37%	-3%	90%	100%
Lav Truck	<175	-486%	-19%	-57%	5%	90%	100%
Lift	<120	-560%	-20%	-8%	37%	87%	100%

8.1.2 Use Electric and Hybrid Construction Equipment

Range of Effectiveness: 2.5 – 80% of GHG emissions from equipment that is electric or hybrid if used 100% of the time

Measure Description:

When construction equipment is powered by grid electricity rather than fossil fuel, direct GHG emissions from fuel combustion are replaced with indirect GHG emissions associated with the electricity used to power the equipment. When construction equipment is powered by hybrid-electric drives, GHG emissions from fuel combustion are reduced.

Measure Applicability:

- Construction vehicles

Inputs:

The following information needs to be provided by the Project Applicant:

- Electricity provider for the Project
- Fuel type and Horsepower of Construction Equipment
- Hours of operation

Baseline Method:

$$\text{Baseline Emission} = EF \times Hp \times LF \times Hr \times C$$

Where:

Emission = MT CO_2e or MT Criteria Pollutant
EF = Emission factor for the relevant fuel horsepower tier (g/hp-hr). Obtained from OFFROAD2007. See accompanying tables
Hp = Horsepower of equipment.
LF = Load factor of equipment for the relevant horsepower tier (dimensionless). Obtained from OFFROAD2007.
Hr = Hours of operation.
C = Unit conversion factor

Mitigation Method:

Fully Electric Vehicle

Construction vehicles will run solely on electricity. The indirect GHG emission from electricity generation is:

$$\text{Mitigated GHG Emission} = Utility \times Hp \times LF \times Hr \times C$$

Where:

GHG emissions = MT CO_2e
Utility = Carbon intensity of Local Utility (CO_2e/kWh)
Hp = Horsepower of equipment.
LF = Load factor of equipment for the relevant horsepower tier (dimensionless). Obtained from OFFROAD2007.
Hr = Hours of operation.
C = Unit conversion factor

Criteria pollutant emissions will be 100% reduced for equipment running solely on electricity.

$$\text{GHG Reduction }\%^{106} = 1 - \frac{\text{Utility} \times C}{EF \times 10^{-6}}$$

Hybrid-Electric Vehicle

GHG Reduction % = Percent Reduction in Fuel Consumption

Emission Reduction Ranges and Variables:

Fully Electric Vehicle

GHG

Utility	Diesel	Compressed Natural Gas 4-strokes	Gasoline 2-strokes	Gasoline 4-strokes				
				<25 HP	25-50 HP	50-120 HP	120-175 HP	175-500 HP
LADW&P	26.3%	37.9%	2.5%	2.5%	46.5%	45.9%	44.4%	42.8%
PG&E	72.9%	77.1%	64.1%	64.1%	80.3%	80.1%	79.5%	78.9%
SCE	61.8%	67.9%	49.5%	49.5%	72.3%	72.0%	71.2%	70.4%
SDGE	53.5%	60.9%	38.5%	38.5%	66.3%	65.9%	64.9%	63.9%
SMUD	67.0%	72.2%	56.3%	56.3%	76.0%	75.8%	75.1%	74.3%

Criteria pollutant

Emissions will be 100% reduced for equipment running on electricity.

Hybrid-Electric Vehicle

GHG

The Project Applicant has to determine the fuel consumption reduced from using the hybrid-electric vehicle. The emission reductions for all pollutants are the same as the fuel reduction.

[106] This assumes energy from engine losses are the same.

Discussion:

The CO_2 emission factor show in the accompanying tables obtained from OFFROAD2007 [1] shows the same emissions within each horsepower tier regardless of the scenario year or equipment model year. The contributions of CH_4 and N_2O to overall GHG emissions is likely small (< 1% of total CO_2e) from diesel construction equipment [2] and were therefore not included. Therefore, the CO_2e emission reduction is dependent on the electricity provider for the Project, horsepower and fuel of the construction equipment only.

On the other hand, the criteria pollutant emission factors from OFFROAD2007 vary for different scenario and equipment model years. The criteria pollutant emission factors presented in the accompanying tables correspond to those of new equipment in the respective scenario years, i.e., model year is the same as scenario year. Since older equipment have higher emission factors due to deterioration and less regulation, the emission reduction calculated from this methodology is likely to be an underestimate.

Assumptions:

Data based upon the following references:

[1] California Air Resources Board. Off-road Emissions Inventory. OFFROAD2007. Available online at: http://www.arb.ca.gov/msei/offroad/offroad.htm

[2] California Climate Action Registry (CCAR). 2009. General Reporting Protocol. Version 3.1. Available online at: http://www.climateregistry.org/tools/protocols/general-reporting-protocol.html

[3] California Climate Action Registry Reporting Online Tool. 2006 PUP Reports. Available online at: https://www.climateregistry.org/CARROT/public/reports.aspx

Preferred Literature:

Electric construction equipment is available commercially from companies such as Peterson Pacific Corporation and Komptech USA, which specialize in the mechanical processing equipment like grinders and shredders [4,5]. The amount of direct GHG emissions avoided can be calculated using CARB's OFFROAD2007 model, which provides state-wide and regional emission factors for a variety of construction equipment that can be converted to grams per horsepower-hour [6]. Multiplying this factor by the number of hours of operation gives the direct GHG emissions. Assuming the same number of operating hours as the diesel-powered equipment, the electricity required to run a piece of electric construction equipment can be calculated by multiplying the operating hours by the amperage required to run the equipment and the voltage rating (obtained from manufacturer technical specifications) to obtain total kWh required. Multiplying this value by the carbon-intensity factor of the local utility gives the amount of indirect GHG emissions associated with using the electric equipment. The

GHG emissions reduction associated with this mitigation measure is therefore the difference in emissions from these two scenarios.

Construction equipment powered by hybrid-electric drives is also commercially available from companies such as Caterpillar [7]. For example, Caterpillar reports that during an 8-hour shift, its D7E hybrid dozer burns 19.5% fewer gallons of fuel than a conventional dozer while achieving a 10.3% increase in productivity. The D7E model burns 6.2 gallons per hour compared to a conventional dozer which burns 7.7 gallons per hour. The percent reduction in fuel use is directly proportional to the percent reduction in GHG emissions. Assuming complete combustion to CO_2 and a carbon content of 87%, the CO_2 emissions reductions can be calculated. Fuel usage and savings are dependent on the make and model of the construction equipment used. The Project Applicant should calculate project-specific savings and provide manufacturer specifications indicating fuel burned per hour.

Alternative Literature:

None

Notes:

[4] Peterson Pacific Corp. Product Brochure Downloads. Available online at: http://www.petersonpacific.com/content/MediaGallery_56_v. Accessed March 2010.
[5] Komptech USA. Products. Available online at: http://www.komptech.com/usa/products.htm. Accessed March 2010.
[6] CARB. OFFROAD 2007 Model. Available online at: http://www.arb.ca.gov/msei/offroad/offroad.htm. Accessed February 2010.
[7] Caterpillar. D7E Efficiency. Accessed February 2010. Available online at: http://www.cat.com/D7E

Other Literature Reviewed:

None

Table C-2.1
Emissions Factors from Different Fuels

Fuel	HP	CO_2 Emission Factor (g/hp-hr)
		All Years
Compressed Natural Gas 4-stroke	All	674.66
Diesel	All	568.30
Gasoline 2-stroke	All	429.44
Gasoline 4-stroke	<25	429.44
	25-50	783.30
	50-120	774.50
	120-175	753.25
	175-500	732.00

Fuel	HP	ROG Emission Factor (g/hp-hr)		
		2004	2010	2015+
Compressed Natural Gas 4-strokes	<15	0.14	0.14	0.14
	15-25	0.14	0.14	0.14
	25-50	0.06	0.01	0.01
	50-120	0.07	0.01	0.01
	120-175	0.06	0.01	0.01
	175-250	0.06	0.01	0.01
	250-500	0.06	0.01	0.01
Diesel	<15	0.57	0.41	0.41
	15-25	0.54	0.48	0.48
	25-50	0.54	0.20	0.08
	50-120	0.38	0.16	0.08
	120-175	0.18	0.13	0.08
	175-250	0.12	0.08	0.06
	250-500	0.10	0.08	0.06
	500-750	0.12	0.08	0.06
	750-1000	0.57	0.08	0.06
	>1000	0.57	0.08	0.08
Gasoline 2-stroke	<2	6.70	5.52	5.52
	2-15	4.19	3.59	3.59
	15-25	4.07	3.79	3.79
Gasoline 4-stroke	<5	6.70	5.52	5.52
	5-15	4.19	3.59	3.59
	15-25	4.07	3.79	3.79

Fuel	HP	ROG Emission Factor (g/hp-hr)		
		2004	2010	2015+
	25-50	1.49	0.65	0.65
	50-120	0.91	0.24	0.24
	120-175	0.72	0.15	0.15
	175-250	0.72	0.15	0.15
	250-500	0.72	0.15	0.15

Fuel	HP	CO Emission Factor (g/hp-hr)		
		2004	2010	2015+
Compressed Natural Gas 4-strokes	<15	300	300	300
	15-25	300	300	300
	25-50	7.02	7.02	7.02
	50-120	20	20	20
	120-175	16	16	16
	175-250	16	16	16
	250-500	16	16	16
Diesel	<15	3.47	3.47	3.47
	15-25	2.34	2.34	2.34
	25-50	3.27	2.86	2.72
	50-120	3.23	3.09	3.05
	120-175	2.70	2.70	2.70
	175-250	0.92	0.92	0.92
	250-500	0.92	0.92	0.92
	500-750	0.92	0.92	0.92
	750-1000	2.70	0.92	0.92
	>1000	2.70	0.92	0.92
Gasoline 2-stroke	<2	318	236	236
	2-15	274	225	225
	15-25	284	238	238
Gasoline 4-stroke	<5	318	236	236
	5-15	274	225	225
	15-25	284	238	238
	25-50	71	38	38
	50-120	38	8.76	8.76
	120-175	21	21	21
	175-250	21	21	21
	250-500	21	21	21

Fuel	HP	NOx Emission Factor (g/hp-hr)		
		2004	2010	2015+
Compressed Natural Gas 4-strokes	<15	8.44	8.44	8.44
	15-25	8.44	8.44	8.44
	25-50	5.19	1.95	1.95
	50-120	4.57	1.58	1.58
	120-175	4.56	1.58	1.58
	175-250	4.56	1.58	1.58
	250-500	4.56	1.58	1.58
Diesel	<15	6.08	4.37	4.37
	15-25	5.79	4.57	4.57
	25-50	5.10	4.88	4.80
	50-120	5.64	5.01	2.53
	120-175	4.72	4.44	2.27
	175-250	4.58	2.45	1.36
	250-500	4.29	2.45	1.36
	500-750	4.51	2.45	1.36
	750-1000	8.17	4.08	2.36
	>1000	8.17	4.08	2.36
Gasoline 2-stroke	<2	2.32	2.70	2.70
	2-15	2.84	2.90	2.90
	15-25	2.32	2.68	2.68
Gasoline 4-stroke	<5	2.32	2.70	2.70
	5-15	2.84	2.90	2.90
	15-25	2.32	2.68	2.68
	25-50	4.52	1.33	1.33
	50-120	5.06	1.78	1.78
	120-175	4.98	1.94	1.94
	175-250	4.98	1.94	1.94
	250-500	4.98	1.94	1.94

Fuel	HP	PM Emission Factor (g/hp-hr)		
		2004	2010	2015+
Compressed Natural Gas 4-strokes	<15	0.90	0.90	0.90
	15-25	0.90	0.90	0.90
	25-50	0.06	0.06	0.06
	50-120	0.06	0.06	0.06
	120-175	0.06	0.06	0.06
	175-250	0.06	0.06	0.06
	250-500	0.06	0.06	0.06
Diesel	<15	0.47	0.38	0.38
	15-25	0.38	0.38	0.38
	25-50	0.43	0.35	0.16
	50-120	0.39	0.24	0.01
	120-175	0.19	0.16	0.01
	175-250	0.11	0.11	0.01
	250-500	0.11	0.11	0.01
	500-750	0.11	0.11	0.01
	750-1000	0.38	0.11	0.06
	>1000	0.38	0.11	0.06
Gasoline 2-stroke	<2	0.74	0.74	0.74
	2-15	0.14	0.14	0.14
	15-25	0.14	0.14	0.14
Gasoline 4-stroke	<5	0.74	0.74	0.74
	5-15	0.14	0.14	0.14
	15-25	0.14	0.14	0.14
	25-50	0.06	0.06	0.06
	50-120	0.06	0.06	0.06
	120-175	0.06	0.06	0.06
	175-250	0.06	0.06	0.06
	250-500	0.06	0.06	0.06

8.1.3 Limit Construction Equipment Idling beyond Regulation Requirements

Range of Effectiveness: Varies with the amount of Project Idling occurring and the amount reduced.

Measure Description:

Heavy duty vehicles will idle during loading/unloading and during layovers or rest periods with the engine still on. Idling requires fuel use and results in emissions. The California Air Resources Board (CARB) Heavy-Duty Vehicle Idling Emission Reduction Program limits diesel-fueled commercial motor vehicles idling time to 5 minutes. There are some exceptions to the regulation such as positioning or providing a power source for equipment or operations such as lift, crane, pump, drill, hoist or other auxiliary equipment. Reduction in idling time beyond required under the regulation would further reduce fuel consumption and thus emissions. The project applicant should develop an enforceable mechanism that monitors the idling time to ensure compliance with this mitigation measure.

Measure Applicability:

- Heavy Duty Commercial Vehicles

Inputs:

The following information needs to be provided by the Project Applicant:

- Idling time of vehicle

Baseline Method:

For all pollutants, the idling emission from each idling period is calculated as follows:

$$\text{Emission} = EF \times t \times C$$

Where:

Emission = grams of pollutant per idling period
EF = Idling emission factor for diesel-fueled heavy duty vehicles obtained from EMFAC (g/idling-hour).
t = Baseline idling period (minute). This is 5 minutes for all vehicles which do not have auxiliary equipment powered by the primary engine exempted from the regulation. For exempted vehicles, the Project applicant shall determine the baseline idling period.
C = Time conversion factor = 1/60

Mitigation Method:

Mitigated emissions for this measure are calculated using the same method as baseline method, but with mitigated idling period.

Emission Reduction Ranges and Variables:

Emission reduction is calculated as follows:

$$\text{Reduction} = 1 - \frac{t_M}{t_B}$$

Where:

t_M = mitigated idling period
t_B = baseline idling period

Discussion:

If a heavy duty truck is regulated under the CARB Idling Emission Reduction Program, and the Project Applicant has committed to enforce a reduced idling period to 3 minutes, then the emissions for all pollutants from idling emissions would be reduced by:

$$1 - \frac{3}{5} = 0.4 = 40\%$$

If the Project Applicant determines that the average idling period for a heavy duty vehicle with a hoist powered by the primary engine is 20 minutes, and has committed to enforce a reduced idling time to 15 minutes, then the emissions for all pollutants would be reduced by:

$$1 - \frac{15}{20} = 0.25 = 25\%$$

Assumptions:

Data based upon the following references:

- California Air Resources Board (CARB) 2009. Heavy-Duty Vehicle Idling Emission Reduction Program. Available at: http://www.arb.ca.gov/msprog/truck-idling/truck-idling.htm
- CARB 2010. EMFAC2007 Model. Available at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Preferred Literature:

Idling of heavy duty commercial vehicles requires fuel use and results in emissions. Project Applicant can obtain the average idling emission factor for diesel-fueled heavy duty trucks in the county where the Project would be located from EMFAC. The total idling emissions can be determined by multiplying this emission factor by the total idling period. The California Air Resources Board (CARB) Heavy-Duty Vehicle Idling Emission Reduction Program limits diesel-fueled commercial motor vehicles idling time to 5 minutes, with exceptions for some vehicles with auxiliary equipment powered by the primary engine [1]. The Project Applicant has to determine the appropriate baseline idling periods for such exempted vehicles. A plan should also be developed to ensure enforcement of the reduced idling period that the Project Applicant has committed to.

Alternative Literature:

None

Notes:

[1] California Air Resources Board (CARB) 2009. Heavy-Duty Vehicle Idling Emission Reduction Program. Available at: http://www.arb.ca.gov/msprog/truck-idling/truck-idling.htm

Other Literature Reviewed:

None

8.1.4 Institute a Heavy-Duty Off-Road Vehicle Plan

Range of Effectiveness:

Not applicable on its own. This measure ensures compliances with other mitigation measures.

Measure Description:

The Project Applicant should provide a detailed plan that discusses a construction vehicle inventory tracking system to ensure compliances with construction mitigation measures. The system should include strategies such as requiring hour meters on equipment, documenting the serial number, horsepower, manufacture age, fuel, etc. of all onsite equipment and daily logging of the operating hours of the equipment.

Measure Applicability:

- This measure ensures compliances with other mitigation measures.
- Construction vehicles.

Preferred Literature:

None

Alternative Literature:

None

Literature References:

None

8.1.5 Implement a Construction Vehicle Inventory Tracking System

Range of Effectiveness:

Not applicable on its own. This measure ensures compliances with other mitigation measures.

Measure Description:

The Project Applicant should provide a detailed plan that discusses a construction vehicle inventory tracking system to ensure compliances with construction mitigation measures. The system should include strategies such as requiring engine run time meters on equipment, documenting the serial number, horsepower, manufacture age, fuel, etc. of all onsite equipment and daily logging of the operating hours of the equipment.

Measure Applicability:

- This measure ensures compliance with other mitigation measures.
- Construction vehicles.

Preferred Literature:

None

Alternative Literature:

None

Literature References:

None

9.0 Miscellaneous

9.1 Miscellaneous

9.1.1 Establish a Carbon Sequestration Project

Range of Effectiveness: Varies depending on Project Applicant and projects selected. The GHG emissions reduction is subtracted from the overall baseline project emissions inventory.

Measure Description:
The Project Applicant would establish a carbon sequestration project. This might include (a) geologic sequestration or carbon capture and storage techniques in which CO_2 from point sources such as power plants and fuel processing plants is captured and injected underground, (b) terrestrial sequestration in which ecosystems such as wetlands and forestlands are established or preserved to serve as CO_2 sinks, (c) novel techniques involving advanced chemical or biological pathways, or (d) technologies yet to be discovered. The Project Applicant would commit to a desired amount of carbon sequestration in MT per year. This amount would be subtracted from the overall baseline project emissions inventory. In order to take credit for this measure, the Project Applicant should be required to establish a reporting and verification mechanism to quantify the amount of carbon sequestered. Furthermore, the Project Applicant should be required to prove additionality.[107]

Measure Applicability:
- Overall baseline project GHG emissions inventory

Inputs:
- Amount of CO_2e sequestered (MT/year)

Baseline Method:
The Project Applicant should calculate the baseline project emissions inventory ($CO_2e_{baseline}$, the total baseline CO_2e emissions in MT per year) using the methods described in the baseline methodology document.

Mitigation Method:
The amount of CO_2e sequestered is subtracted from the overall project emissions inventory. Therefore, the percent GHG reduction is

[107] Additionality is the reduction in emissions by sources or enhancement of removals by sinks that is additional to any that would occur in the absence of the Project. In other words, the Project should not subsidize or take credit for emissions reductions which would have occurred regardless of the Project.

GHG emission reduction $= \frac{CO_2e_{sequestered}}{CO_2e_{baseline}}$

Where:

GHG emission reduction	=	Percentage reduction in overall GHG emissions from carbon sequestration project
$CO_2e_{sequestered}$	=	Amount of CO_2e sequestered (MT/year) Provided by Applicant
$CO_2e_{baseline}$	=	Total baseline CO_2e emissions (MT/year)

Assumptions:
Data based upon the following references:

- USDOE. Fossil Energy: Carbon Sequestration. Available online at: http://www.fossil.energy.gov/programs/sequestration/

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	To be determined by Applicant
All other pollutants	None

Preferred Literature:
The DOE Fossil Energy – Carbon Sequestration website describes the four core carbon sequestration technologies: geologic, carbon capture and storage, terrestrial, and novel biological and chemical pathways. The DOE website discusses current challenges and research projects associated with each of the carbon sequestration technologies, as well as the trade-offs between local environmental impacts and global environmental benefits.

Alternative Literature:
None

Other Literature Reviewed:
None

9.1.2 Establish Off-Site Mitigation

Range of Effectiveness: Varies depending on Project Applicant and projects selected. The GHG emissions reduction is subtracted from the overall baseline project emissions inventory.

Measure Description:
The Project Applicant may decide to establish GHG reduction measures similar to any of the measures discussed in this report. These reductions would take place outside of the Project Site. In order to take credit for this measure, the Project Applicant should be required to establish a method for registering and verifying the GHG emissions reduction. Furthermore, the Project Applicant should be required to prove additionality.[108]

Measure Applicability:

- Overall baseline project GHG emissions inventory

Inputs:

- Amount of CO_2e reduced off-site (MT/year)

Baseline Method:
The Project Applicant should calculate the baseline project emissions inventory ($CO_2e_{baseline}$, the total baseline CO_2e emissions in MT per year) using the methods described in the baseline methodology document.

Mitigation Method:
The amount of CO_2e reduced off-site is subtracted from the overall project emissions inventory. Therefore, the percent GHG reduction is:

$$\text{GHG emission reduction} = \frac{CO_2e_{\text{reduced off-site}}}{CO_2e_{\text{baseline}}}$$

Where:

GHG emission reduction	=	Percentage reduction in overall GHG emissions from off-site mitigation
$CO_2e_{\text{reduced off-site}}$	=	Amount of CO_2e reduced off-site (MT/year) Provided by Applicant
CO_2e_{baseline}	=	Total baseline CO_2e emissions (MT/year)

[108] Additionality is the reduction in emissions by sources or enhancement of removals by sinks that is additional to any that would occur in the absence of the Project. In other words, the Project should not subsidize or take credit for emissions reductions which would have occurred regardless of the Project.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	To be determined by Applicant
All other pollutants	To be determined by Applicant. Reductions in criteria pollutant emissions may be achieved if the off-site mitigation involves removing or retrofitting combustion sources or reducing electricity use.[109]

Preferred Literature:

None

[109] Note that the reduction in criteria pollutant emissions may not occur in the same air basin as the project.

9.1.3 Use Local and Sustainable Building Materials

Range of Effectiveness: Varies depending on Project Applicant and strategies selected. Best Management Practice.

Measure Description:
Using building materials which are sourced and processed locally (i.e. close to the project site, as opposed to in another state or country) reduces transportation distances and therefore reduces GHG emissions from fuel combustion. Using sustainable building materials, such as recycled concrete or sustainably harvested wood, also contributes to GHG emissions reductions due to the less carbon-intensive nature of the production and harvesting of these materials. Unlike measures which reduce GHG emissions during the operational lifetime of a project, such as reducing building electricity and water usage, these mitigation efforts are realized prior to the actual operational lifetime of a project. Therefore, these GHG emissions are best quantified in terms of a life-cycle analysis. Life cycle analyses examine all stages of the life of a product, including raw material acquisition, manufacture, transportation, installation, use, and disposal or recycling. The Project Applicant should seek local agency guidance on comparing and/or combining operational emissions inventories and life cycle emissions inventories.

Measure Applicability:
- Life cycle emissions from building materials

Inputs:
The following information needs to be provided by the Project Applicant:
- Project location
- Material transport distance
- Material type
- Building assembly type and square footage

Preferred Literature:
Several software packages and web-based tools are available which can be used to quantify the life cycle emissions from building materials.

The Building for Environmental and Economic Sustainability (BEES) software developed by the National Institute of Standards and Technology (NIST) can calculate global warming potential (in terms of CO_2 emissions in grams per product) for a variety of building products, including a multitude of cement varieties, fabrics, tiles, glass, wood, and shelving materials. Required inputs are the type of building material (e.g. generic 100% Portland cement, generic 20% limestone cement), and transportation distance. The user can compare between different types of materials and associated transportation distances.

The BEES software and user manual is available for public download here:
http://www.bfrl.nist.gov/oae/software/bees/bees.html

The Athena EcoCalculator for Assemblies software developed by the Athena Institute analyzes the environmental impacts of whole buildings in terms of global warming potential (in terms of CO_2e) from raw material extraction, final material manufacturing, transportation, on-site construction, maintenance, and demolition and disposal. Required inputs include the project location, assembly type (columns and beams, floor, exterior wall, interior wall, window, or roof), type of material, and square footage of material. The Athena EcoCalculator compares CO_2e emissions from the project-specific assembly to default assemblies of similar material and size. The Athena EcoCalculator is based on the more rigorous Athena Impact Estimator software, which requires detailed information about the building design including the number of columns and beams, supported span, wall height, and type of material used for all aspects. In contrast, the Athena EcoCalculator assumes default values for many of the architectural details.

A free public version of the Athena EcoCalculator is available for download here:
http://www.athenasmi.org/tools/ecoCalculator/index.html

Alternative Literature:
None

Other Literature Reviewed:
None

9.1.4 Require Best Management Practices in Agriculture and Animal Operations

9.1.5 Require Environmentally Responsible Purchasing

Range of Effectiveness: Varies depending on Project Applicant and strategies selected. Best Management Practice.

Measure Description:
Requiring environmentally responsible purchasing has the potential to have a net effect of reducing GHG emissions by reducing the life cycle emissions, operating emissions, and/or transportation emissions associated with a product. Examples of environmentally responsible purchases which reduce life cycle emissions include but are not limited to: purchasing products with sustainable packaging; purchasing post-consumer recycled copier paper, paper towels, and stationary; purchasing and stocking communal kitchens with reusable dishes and utensils; choosing sustainable cleaning supplies; and leasing equipment from manufacturers who will recycle the components at their “end of life.” Examples of environmentally responsible purchases which reduce a Project’s operating emissions include choosing ENERGY STAR appliances and Water Sense-certified water fixtures; choosing electronic appliances with built in sleep-mode timers; and purchasing “green power” (e.g. electricity generated from renewables or hydropower) from the utility. Choosing locally-made and distributed products reduces the transportation distances required to move the product from the distribution or manufacturing center to the Project, and therefore reduce GHG emissions associated with the transportation vehicles.

Since the magnitude of the energy and GHG reduction depends on the purchasing strategies implemented, the expected GHG reduction is not quantifiable at this time. Therefore, this mitigation measure should be incorporated as a Best Management Practice to encourage homeowners, commercial space tenants, and builders to make sustainable purchases and therefore reduce their contribution to GHG emissions. The Project Applicant could take quantitative credit for this mitigation measure if detailed and substantial evidence were provided.

Measure Applicability:

- Purchase of consumer and business goods and appliances

Assumptions:
Data based upon the following references:

- City of Chicago and ICLEI. Chicago Green Office Challenge: Waste. Available online at: http://www.chicagogreenofficechallenge.org/pages/waste/50.php
- Cool California.org. Small Business Money Saving Actions: Recycle and Cut Waste. Available online at: http://www.coolcalifornia.org/article/recycle-and-cut-waste

- Flex Your Power.org. Commercial Overview Energy Saving Tips: Office Equipment Tips. Available online at: http://www.fypower.org/com/tools/energy_tips_results.html?tips=office
- ENERGY STAR. 2007. Putting Energy into Profits: ENERGY STAR Guide for Small Businesses. Available online at: http://www.energystar.gov/ia/business/small_business/sb_guidebook/smallbizguide.pdf

Emission Reduction Ranges and Variables:
This is a Best Management Practice and therefore at this time there is no quantifiable reduction. Check with local agencies for guidance on any allowed reductions associated with implementation of best management practices.

Preferred Literature:
The Chicago Green Office Challenge, Cool California.org, and Flex Your Power.org website resources provide many examples of office and small business purchasing strategies which reduce waste and energy use. The ENERGY STAR Guide provides more details about energy-efficient appliance choices and the option to purchase renewable or clean energy from the utility for a higher cost.

Alternative Literature:
None

Other Literature Reviewed:
None

9.1.6 Implement an Innovative Strategy for GHG Mitigation

Range of Effectiveness: Varies depending on Project Applicant and strategies selected. The GHG emissions reduction may be quantifiable. If not quantifiable, this mitigation measure should be implemented as a Best Management Practice.

Measure Description:
The Project Applicant may develop a novel strategy to reduce GHG emissions at the project site or off-site. This strategy may incorporate technologies which have yet to be developed at the time of the publication of this report. In order to take quantifiable credit for this measure, the Project Applicant must provide detailed and substantial evidence showing the quantification and verification of the GHG emissions reduction. If the GHG emissions reduction is not quantifiable, it should be implemented as a Best Management Practice.

Measure Applicability:
- To be determined by Project Applicant

Inputs:
- Amount of CO_2e reduced due to Innovative Strategy
- Baseline CO_2e for applicable inventory sector

Baseline Method:
The Project Applicant should calculate the baseline CO_2e emissions associated with the applicable GHG emissions inventory sector ($CO_2e_{baseline\text{-}sector}$, the baseline CO_2e emissions in MT per year for the applicable sector) using the methods described in the baseline methodology document. For example, if the Innovative Strategy achieves GHG reductions by reducing building energy use, $CO_2e_{baseline\text{-}sector}$ is the total CO_2e emissions associated with baseline building energy use.

Mitigation Method:
The amount of CO_2e reduced due to the Innovative Strategy is subtracted from applicable emissions inventory sector. Therefore, the percent GHG reduction is:

$$\text{GHG emission reduction} = \frac{CO_2e_{reduced\text{-}sector}}{CO_2e_{baseline\text{-}sector}}$$

Where:

GHG emission reduction	=	Percentage reduction in sector GHG emissions due to Innovative Strategy
$CO_2e_{reduced\text{-}sector}$	=	Amount of CO_2e reduced due to Innovative Strategy (MT/year) Provided by Applicant
$CO_2e_{baseline\text{-}sector}$	=	Baseline sector CO_2e emissions (MT/year)

If the GHG emissions reduction cannot be quantified and/or verified, check with local agencies for guidance on any allowed reductions associated with implementation of Best Management Practices.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	To be determined by Applicant
All other pollutants	None

Preferred Literature:
None

10.0 General Plans

In addition to fact sheets and BMPs, this document includes measures that are more applicable for General Plans. The following measures have substantial evidence of reductions when implemented at a General Plan level rather than a project level.

10.1 General Plans

10.1.1 Fund Incentives for Energy Efficiency

Range of Effectiveness: Varies depending on Project Applicant and strategies selected. Best Management Practice.

Measure Description:
By funding incentives for energy-efficient choices in equipment, fixtures in buildings, or energy sources, a Project Applicant can promote reductions in GHG emissions associated with fuel combustion and electricity use. The Project Applicant may choose to contribute to an existing municipal energy fund or establish a new energy fund for the Project. The Project Applicant should check with the local air district regarding participating in established programs. These energy funds may provide financial incentives or grants for any number of energy efficiency measures including but not limited to: retrofitting or designing new buildings, parking lots, streets, and public areas with energy-efficient lighting; retrofitting or designing new buildings with low-flow water fixtures and high-efficiency appliances; retrofitting or purchasing new low-emissions equipment; purchasing electric or hybrid vehicles; and investing in renewable energy systems such as photovoltaics or wind turbines. Recipients of energy fund grants could include neighborhood developers, home and commercial space builders, homeowners, and utilities. Energy funds allow recipients flexibility in choosing efficiency strategies while still achieving the desired effects of reduced energy use and associated GHG emissions.

Since the magnitude of the energy and GHG reduction depends on the strategies selected by the energy fund recipients, the expected GHG reduction is not quantifiable at this time. Therefore, this mitigation measure should be incorporated as a Best Management Practice to encourage utilities, builders, residents, and commercial tenants to reduce their energy use and/or choose cleaner energy, and therefore reduce their contribution to GHG emissions. The Project Applicant could take quantitative credit for this mitigation measure if detailed and substantial evidence were provided.

Measure Applicability:
- GHG emissions from energy use (fuel combustion and electricity use)

Assumptions:
Data based upon the following references:

- City of Ann Arbor. Energy Office: Energy Fund. Available online at: http://www.a2gov.org/government/publicservices/systems_planning/energy/Pages/EnergyFund.aspx
- Go Solar California. California Solar Initiative. Available online at: http://www.gosolarcalifornia.org/csi/index.html
- USDOE. Database of State Initiatives for Renewables and Efficiency: California. Available online at: http://www.dsireusa.org/incentives/index.cfm?re=1&ee=1&spv=0&st=0&srp=1&state=CA
- California Clean Energy Fund. About Us. Available online at: http://www.calcef.org/about.htm

Emission Reduction Ranges and Variables:
This is a Best Management Practice and therefore there is no quantifiable reduction at this time. Check with local agencies for guidance on any allowed reductions associated with implementation of best management practices.

Preferred Literature:
The City of Ann Arbor's Energy Fund provides a good example of a municipal general energy fund which provides grants for a wide variety of energy efficiency and renewable energy investments. The California Solar Initiative and the Energy Efficient Appliance Rebate Program (found on the DOE Database of State Initiatives for Renewables and Efficiency) are examples of California state energy funds which incentivize specific types of purchases. The DOE database provides a listing of many more California municipal and local programs.

Alternative Literature:

None

Other Literature Reviewed:

- The Energy Foundation. Programs: Power. Available online at: http://www.ef.org/programs.cfm

10.1.2 Establish a Local Farmer's Market

Range of Effectiveness: Varies depending on Project Applicant and strategies selected. Best Management Practice.

Measure Description:

Establishing a local farmer's market has the potential to reduce greenhouse gas emissions by providing project residents with a more local source of food, potentially resulting in a reduction in the number of trips and vehicle miles traveled by both the food and the consumers to grocery stores and supermarkets. If the food sold at the local farmer's market is produced organically, it can also contribute to greenhouse gas reductions by displacing carbon-intensive food production practices. As discussed in more detail below, these emissions reductions cannot be reasonably quantified at this time because they are based on several undefined parameters: the relative locations of the farmer's market, supermarket, and supermarket produce suppliers; the carbon intensity of food production practices; and the role of the farmer's market in a development, such as whether it supplements trips to the grocery store or completely displaces them.

Measure Applicability:

- Number of trips to supermarket and vehicle miles traveled
- Life cycle emissions of food production

Discussion:

Potential greenhouse gas emissions from establishing a local farmer's market can be divided into two types: emissions reductions from transportation and emissions reductions from food production practices. The transportation of food from a field to a store and the transportation of consumers from their homes to a store both contribute to greenhouse gas emissions. In many cases, especially in urban areas, a local farmer's market will reduce emissions associated with the distribution of food from the field to the consumer, since the farms represented at the local farmer's market are theoretically closer to the consumer than the farms which produce most of the food found at supermarkets and grocery stores. However, California has a large number of farms and orchards and in some cases the farms represented at a local farmer's market may not be different than those represented at the neighborhood grocery store. If a consumer obtains produce from a local farmer's market when they would otherwise drive a farther distance to purchase produce from a grocery store, the trip to the grocery stores is displaced, VMT is reduced, and GHG emissions reductions are achieved. However, if a consumer drives to the farmer's market and then to the grocery store (for example, to purchase food which the farmer's market cannot provide), the trip to the farmer's market is made in addition to the trip to the grocery store. Thus, an additional trip is made, VMT is added, and greenhouse gas emissions are actually increased. It is unclear how local farmer's markets affect the food purchasing behavior of consumers, and therefore the effect of a farmer's market on transportation greenhouse gas emissions is not quantifiable at this time. The carbon intensity of food production practices also contributes to greenhouse gas emissions; however, these emissions are accounted for in the life cycle analysis of the food and cannot be directly compared to a development's operational greenhouse gas emissions inventory (such as the transportation emissions detailed above). If food at a local farmer's market is produced organically, it is likely that less carbon-intensive practices were used than at the large-scale farms and orchards which produce most food found at grocery stores and supermarkets. Examples of carbon-intensive gardening practices include heated greenhouses and the heavy use of fertilizers and pesticides derived from fossil fuels. Local farms which do not practice organic or sustainable farming may employ these more carbon-intensive practices. Thus, the magnitude of the life-cycle greenhouse gas emissions is difficult to quantify and compare to operational inventories.

Preferred Literature:

None

10.1.3 Establish Community Gardens

Range of Effectiveness: Varies depending on Project Applicant and strategies selected. Best Management Practice.

Measure Description:

Establishing a community garden has the potential to reduce greenhouse gas emissions by providing project residents with a local source of food, potentially resulting in a reduction in the number of trips and vehicle miles traveled by both the food and the consumers to grocery stores and supermarkets. Community gardens can also contribute to greenhouse gas reductions by displacing carbon-intensive food production practices. As discussed in more detail below, these emissions reductions cannot be reasonably quantified at this time because they are based on several undefined parameters: the relative locations of the community garden, supermarket, and supermarket produce suppliers; the carbon intensity of gardening and farming practices; and the role of a community garden in a development, such as whether it supplements trips to the grocery store or completely displaces them.

Measure Applicability:

- Number of trips to supermarket and vehicle miles traveled
- Life cycle emissions of food production

Discussion:

Potential greenhouse gas emissions from establishing a community garden can be divided into two types: emissions reductions from transportation and emissions reductions from food production practices. The transportation of food from a field to a store and the transportation of consumers from their homes to a store both contribute to greenhouse gas emissions. In most cases a community garden will reduce emissions associated with the distribution of food from the field to the consumer, since with community gardens the food goes directly from the field to the consumer, while in grocery stores and supermarkets the path is more likely field to regional distribution center to store to consumer. If a consumer obtains produce from a community garden when they would otherwise drive a farther distance to purchase produce from a grocery store, the trip to the grocery stores is displaced, VMT is reduced, and GHG emissions reductions are achieved. However, if a consumer drives to the community garden and then to the grocery store (for example, to purchase food which the community garden cannot provide), the trip to the community garden is made in addition to the trip to the grocery store. Thus, an additional trip is made, VMT is added, and greenhouse gas emissions are actually increased. Furthermore, if community gardens displace backyard gardens, they increase transportation emissions. It is unclear how community gardens affect the food purchasing behavior of consumers, and therefore the effect of a community garden on transportation greenhouse gas emissions is not quantifiable at this time. The carbon intensity of food production practices also contributes to greenhouse gas emissions; however, these emissions are accounted for in the life cycle analysis of the food and cannot be directly compared to a development's operational greenhouse gas emissions inventory (such as the transportation emissions detailed above). Community gardens are likely to produce food using less carbon-intensive practices than the large-scale farms and orchards which produce most food found at grocery stores and supermarkets. Examples of carbon-intensive gardening practices include heated greenhouses and the heavy use of fertilizers and pesticides derived from fossil fuels; these practices are not likely to be used at community gardens. Although these qualitative conclusions can be drawn, the magnitude of the life-cycle greenhouse gas emissions is difficult to quantify and compare to operational inventories.

Preferred Literature:

None

10.1.4 Plant Urban Shade Trees

Range of Effectiveness: The reduction in GHG emissions is not quantifiable at this time, therefore this mitigation measure should be implemented as a Best Management Practice. If the study data were updated to account for Title 24 standards, the GHG emissions reductions could be quantified but would vary based on location, building type, and building size.

Measure Description:

Planting shade trees around buildings has been shown to effectively lower the electricity cooling demand of buildings by blocking incident sunlight and reducing heat gain through windows, walls, and roofs. Deciduous trees with large canopies are a desirable choice of shade tree because they provide shade in the warm months and shed their leaves in the winter months to allow sunlight to pass through and warm the building. By reducing cooling demand, shade trees help reduce electricity demand from the local utility and therefore reduce GHG emissions which would otherwise be emitted during the production of that electricity.

A study entitled "Calculating energy-saving potentials of heat-island reduction strategies" conducted by the Lawrence Berkeley National Laboratory (LBNL) Heat Island Group provides a method to quantify reductions in electricity use from planting shade trees around residences, offices, and retail stores. The electricity reductions are based on the LBNL model which assumes 4 shade trees are planted around residences, 8 trees are planted around offices, and 10 trees are planted around retail stores. The LBNL model is also based on electricity use data for two building stocks: Pre-1980 buildings (buildings constructed prior to 1980) and 1980+ buildings (buildings constructed on or after 1980). Other assumptions, including the geometry of the modeled trees and sunlight transmittance, are detailed in Section 2.5 of the study. This mitigation measure describes how to estimate greenhouse gas emissions reductions from planting shade trees based on the LBNL data. Since the model is based on electricity data for Pre-1980 and 1980+ buildings[110] it does not incorporate electricity use improvements due to the California 2001, 2005, or 2008 Title 24 measures. Given that buildings constructed in 2001 or later incorporate Title 24 electricity efficiency improvements, the electricity savings reported in the LBNL study are overestimates of the savings that would actually be achieved for these newer buildings.[111]

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[110] This data for these buildings is based on U.S. Department of Energy and California Energy Commission studies conducted in 1987 through 2001.

[111] The CEC 2003 Impact Analysis Report estimates a state-average 14.9%-26% savings in electricity use for cooling in residential buildings and 6.7% savings in electricity use for cooling in non-residential

While the electricity savings in the study overestimates savings for newer buildings, the data does show that electricity savings (and associated greenhouse gas emissions savings) from planting shade trees are real. A follow-up study which uses similar methodologies with models updated with the Title 24 standards would provide data which could be used to more accurately quantify electricity savings for new buildings.

Measure Applicability:

- Electricity use
- Limitation: It takes several years for trees to grow to the height necessary to provide shade to a building. Furthermore, without deed restrictions, the presence of shade trees around a building may not be permanent, as a new owner may decide to remove the trees or not replace them if they die.

Inputs:

The following information needs to be provided by the Project Applicant:

- Type of building (residential, office, or retail store)
- Square footage of roof
- Heating Degree Days (HDD) or Cooling Degree Days (CDD) of Project location

Baseline Method:

The CEC Residential Appliance Saturation Survey (RASS) and California Commercial Energy Use Survey (CEUS) datasets can be used to calculate the baseline electricity for building cooling. The data is available for different climate zones in California and electricity use from cooling alone can be extracted. The methodology for using RASS and CEUS to calculate $GHG_{baseline}$ is described in the baseline document.

Mitigation Method:

The electricity savings from reduced cooling demand are based on the location of the building. Table 4 of the LBNL study provides a list of cities and their HDD and CDD values. If a project's location is not listed, the Project Applicant should choose a representative city with climate similar to that of the project. Alternatively, the Project Applicant could determine the HDD and CDD of the project location from local meteorological data.

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buildings due to the 2005 update to the 2001 Title 24 standards. The CEC 2007 Impact Analysis Report estimates a state-average 19.7%-22.7% savings in overall electricity use for residential buildings and a 8.3% savings in electricity use for cooling in non-residential buildings due to the 2008 update to the 2005 Title 24 standards.

Tables 6 through 16 of the LBNL study show the expected electricity savings (in kWh per 1000 sqft of roof) based on the following parameters:

- Building type (residential, office, or retail store)
- Climate method (HDD or CDD – either can be used)
- Heating method (Gas heated-buildings or electric-heated buildings)

The Project Applicant should select data based on the appropriate parameters above. The entry corresponding to the "Shade tree savings" row and "1980+" column will provide the electricity savings in kWh per 1000 sqft of roof for the specified building type, climate method, and heating method. Note that value is an overestimate of savings for buildings which were manufactured under Title 24 standards.

Then the reduction in GHG emissions is calculated as follows:

$$GHG_{reduction} = SF \times ElecSavings \times Utility$$

Where

$GHG_{reduction}$ = Reduction in GHG emissions from planting shade trees (MT)

SF = Sqft of roof
Provided by Applicant

ElecSavings = Electricity savings (kWh / sqft roof)
From Tables 6 through 16 of LBNL study

Utility = Carbon intensity of local utility (MT CO_2e / kWh)
From Table below

Power Utility	Carbon-Intensity (lbs CO_2e/MWh)
LADW&P	1,238
PG&E	456
SCE	641
SDGE	781
SMUD	555

Therefore:

$$\text{Percent reduction in GHG emissions} = GHG_{reduction} / GHG_{baseline}$$

Since the Utility term is a factor of both $GHG_{reduction}$ and $GHG_{baseline}$, the percent reduction in GHG emissions does not depend on the value of Utility.

CEQA# MM T-14
MP# COS-3.2

GP-4

CEQA# MM T-14
MP# COS-3.2

GP-4

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	The following emissions reductions reflect the implementation of three heat island reduction strategies (installing reflective roofs, planting shade trees, and using high-albedo pavements) for the 1980+ stock buildings. The reduction from planting shade trees around new buildings is expected to be smaller than the estimate below. Additionally, savings are expected to be smaller for new buildings due to the Title 24 standards. • 20% for residential buildings • 5-12% for office buildings • 10-17% for retail buildings
All other pollutants	Same as above[112]

Assumptions:

Data based upon the following reference:

- H. Akbari, S. Konopacki. Lawrence Berkeley National Laboratory. 2005. Calculating Energy-Saving-Potentials of Heat-Island Reduction Strategies. Journal of Energy Policy. Volume 33, p. 721-756.

Preferred Literature:

The LBNL study conducted by Akbari and Konopacki of the Heat Island Group modeled energy savings from shade trees for residential, office, and retail building types. The model accounted for differences in climate by modeling in a range of heating-degree-days and cooling-degree days, and compared a basecase (building with no external shading) to a mitigated case (building with 4, 8, and 10 shade trees, depending on the building type). However, the study is based on pre-2001 data and does not account for updates to California's Title 24 standards. Furthermore, the model assumes a specific number of shade trees planted at specific orientations.

Alternative Literature:

- CCAR. 2010. Urban Forest Project Protocol Version 1.1. Available online at: http://www.climateactionreserve.org/how/protocols/adopted/urban-forest/current-urban-forest-project-protocol/

Section D.3 of the protocol describes a method to quantify the reductions in cooling and heating demand due to the planting of shade trees. Computer simulations incorporating

[112] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

building, climate, and shading effects were used to calculate the change in unit energy consumption (UEC) on a per tree basis. Total change in energy use is calculated by multiplying the change in UEC per try by the total number of trees. Buildings were modeled in three stocks with similar building characteristics: buildings constructed prior to 1950, buildings constructed between 1950 and 1980, and buildings constructed after 1980. As with the primary reference above, the data does not account for electricity efficiency improvements due to California's Title 24 standards.

Other Literature Reviewed:

- E. G. McPherson, J. R. Simpson. USDA Forest Service. 2003. Potential Energy Savings in Buildings by an Urban Tree Planting Programme in California. Journal of Urban Forestry & Urban Greening. Volume 2, p. 73-86.
- H. Akbari. Lawrence Berkeley National Laboratory. 2002. Shade Trees Reduce Building Energy Use and CO_2 Emissions from Power Plants. Journal of Environmental Pollution. Volume 116, p. 119-126.
- J. R. Simpson. Department of Environmental Horticulture at the University of California. 2002. Improved Estimates of Tree-Shade Effects on Residential Energy Use. Journal of Energy and Buildings. Volume 34, p. 1067-1076.

10.1.5 Implement Strategies to Reduce Urban Heat-Island Effect

Range of Effectiveness: The reduction in GHG emissions is not quantifiable at this time, therefore this mitigation measure should be implemented as a Best Management Practice. If the study data were updated to account for Title 24 standards, the GHG emissions reductions could be quantified but would vary based on location, building type, and building size.

Measure Description:

The urban heat island effect is the phenomenon in which a metropolitan area is warmer than its surrounding rural areas due to increased land surface which retains heat, such as concrete, asphalt, metal, and other materials found in buildings and pavements. This warming effect causes warmer locations, such as many cities in California, to require more energy for air conditioning and refrigeration than the surrounding rural areas. Higher energy requirements in turn result in higher CO_2 emissions from the generation of this energy.

Three strategies have been shown to have a positive impact on reducing localized temperatures and reducing the electricity demand for building cooling. These strategies are planting urban shade trees, installing reflective roofs, and using light-colored or high-albedo[113] pavements and surfaces. Planting shade trees around buildings and installing reflective roofs have both been found to result in direct electricity savings for buildings. The per building direct electricity savings from planting shade trees is discussed in a separate mitigation measure. Reflective roofs are covered under Title 24 Part 6 and the electricity savings is therefore incorporated in savings due to Title 24. The combination of the three strategies, however, has been shown to have a city-wide effect: a reduction in ambient air temperature. This reduction in air temperature results in buildings requiring less electricity for cooling, and is quantified as indirect savings in electricity use. The savings can be quantified on a per-building basis or on a city-wide basis.

A study entitled “Calculating energy-saving potentials of heat-island reduction strategies” conducted by the Lawrence Berkeley National Laboratory (LBNL) Heat Island Group provides a method to quantify per-building reductions in electricity use from implementing these three strategies on a city-wide scale. In addition, the study reports modeled city-wide electricity savings. The electricity reductions are based on a LBNL model with certain assumptions about the number and orientation of shade trees

[113] The albedo ratio of a surface represents how strongly the surface reflects sunlight. Pavements with higher albedo ratios reflect more sunlight and therefore retain less heat.

and the albedo values of roofs and pavements. Per-building electricity savings are also based on for two building stocks: Pre-1980 buildings (buildings constructed prior to 1980) and 1980+ buildings (buildings constructed on or after 1980).

This mitigation measure describes how to estimate greenhouse gas emissions reductions from implementing heat-island effect reduction strategies as reported in the LBNL study. Since the LBNL model is based on electricity data for Pre-1980 and 1980+ buildings[114] it does not incorporate electricity use improvements due to the California 2001, 2005, or 2008 Title 24 measures. Given that buildings constructed in 2001 or later incorporate Title 24 electricity efficiency improvements, the electricity savings reported in the LBNL study are overestimates of the savings that would actually be achieved for these newer buildings.[115]

While the electricity savings in the study overestimates savings for newer buildings, the data does show that electricity savings (and associated greenhouse gas emissions savings) from planting shade trees are real. A follow-up study which uses similar methodologies with models updated with the Title 24 standards would provide data which could be used to more accurately quantify electricity savings for new buildings.

Measure Applicability:

- Electricity use
- Limitation: It takes several years for trees to grow to the height necessary to provide shade to a building. Furthermore, without deed restrictions, the presence of shade trees around a building may not be permanent, as a new owner may decide to remove the trees or not replace them if they die.
- Limitation: it is assumed that the heat-island effect reduction strategies are implemented on a city-wide scale.

Inputs:

The following information needs to be provided by the Project Applicant:

- Type of building (residential, office, or retail store)
- Square footage of roof

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[114] This data for these buildings is based on U.S. Department of Energy and California Energy Commission studies conducted in 1987 through 2001.

[115] The CEC 2003 Impact Analysis Report estimates a state-average 14.9%-26% savings in electricity use for cooling in residential buildings and 6.7% savings in electricity use for cooling in non-residential buildings due to the 2005 update to the 2001 Title 24 standards. The CEC 2007 Impact Analysis Report estimates a state-average 19.7%-22.7% savings in overall electricity use for residential buildings and a 8.3% savings in electricity use for cooling in non-residential buildings due to the 2008 update to the 2005 Title 24 standards.

- Heating Degree Days (HDD) or Cooling Degree Days (CDD) of Project location

Baseline Method:

The CEC Residential Appliance Saturation Survey (RASS) and California Commercial Energy Use Survey (CEUS) datasets can be used to calculate the baseline electricity for building cooling. The data is available for different climate zones in California and electricity use from cooling alone can be extracted. The methodology for using RASS and CEUS to calculate $GHG_{baseline}$ is described in the baseline document.

Mitigation Method:

The electricity savings from reduced cooling demand are based on the location of the building. Table 4 of the LBNL study provides a list of cities and their HDD and CDD values. If a project's location is not listed, the Project Applicant should choose a representative city with climate similar to that of the project. Alternatively, the Project Applicant could determine the HDD and CDD of the project location from local meteorological data.

Tables 6 through 16 of the LBNL study show the expected electricity savings (in kWh per 1000 sqft of roof) based on the following parameters:

- Building type (residential, office, or retail store)
- Climate method (HDD or CDD – either can be used)
- Heating method (Gas heated-buildings or electric-heated buildings)

The Project Applicant should select data based on the appropriate parameters above. The entry corresponding to the "Indirect Savings" row and "1980+" column will provide the electricity savings in kWh per 1000 sqft of roof for the specified building type, climate method, and heating method. Note that value is an overestimate of savings for buildings which were manufactured under Title 24 standards.

Then the reduction in GHG emissions is calculated as follows:

$$GHG_{reduction} = SF \times ElecSavings \times Utility$$

Where

$GHG_{reduction}$	=	Reduction in GHG emissions from implementing heat island effect reduction strategies on a city-wide scale (MT)
SF	=	Sqft of roof Provided by Applicant
ElecSavings	=	Electricity savings (kWh / sqft roof) From Tables 6 through 16 of LBNL study
Utility	=	Carbon intensity of local utility (MT CO_2e / kWh)

CEQA# **MM E-8 & E-12**
MP# **LU-6.1**

GP-5

From Table below

Power Utility	Carbon-Intensity (lbs CO_2e/MWh)
LADW&P	1,238
PG&E	456
SCE	641
SDGE	781
SMUD	555

Therefore:

$$\text{Percent reduction in GHG emissions} = GHG_{reduction} / GHG_{baseline}$$

Since the Utility term is a factor of both $GHG_{reduction}$ and $GHG_{baseline}$, the percent reduction in GHG emissions does not depend on the value of Utility.

City-Wide GHG reductions

The LBNL study estimates that city-wide reductions in electricity use (and associated GHG emissions) range from about 10-20%. This range is based on the percent indirect savings modeled for five pilot cities: Houston, Baton Rouge, Chicago, Sacramento, and Salt Lake City, as reported in Figure 2 of the LBNL study.

Emission Reduction Ranges and Variables:

Pollutant	Category Emissions Reductions
CO_2e	The following per-building emissions reductions reflect the implementation of three heat island reduction strategies (installing reflective roofs, planting shade trees, and using high-albedo pavements) for the 1980+ stock buildings. Actual savings are expected to be lower for new buildings due to the Title 24 standards. • 20% for residential buildings • 5-12% for office buildings • 10-17% for retail buildings
All other pollutants	Same as above[116]

[116] Criteria air pollutant emissions may also be reduced due to the reduction in energy use; however, the reduction may not be in the same air basin as the project.

Assumptions:

Data based upon the following reference:

- H. Akbari, S. Konopacki. Lawrence Berkeley National Laboratory. 2005. Calculating Energy-Saving-Potentials of Heat-Island Reduction Strategies. Journal of Energy Policy. Volume 33, p. 721-756.
- S. Konopacki, H. Akbari. Lawrence Berkeley National Laboratory. 2000. Energy Savings Calculations for Heat Island Reduction Strategies in Baton Rouge, Sacramento, and Salt Lake City. LBNL 42890.

Preferred Literature:

The LBNL study conducted by Akbari and Konopacki of the Heat Island Group modeled energy savings from shade trees for residential, office, and retail building types. The model accounted for differences in climate by modeling in a range of heating-degree-days and cooling-degree days, and compared a basecase (building with no external shading) to a mitigated case (building with 4, 8, and 10 shade trees, depending on the building type). However, the study is based on pre-2001 data and does not account for updates to California's Title 24 standards. Furthermore, the model assumes a specific number of shade trees planted at specific orientations.

Alternative Literature:

None

Other Literature Reviewed:

Lawrence Berkeley National Laboratory. Heat Island Group: Benefits of Cooler Pavements. Available online at: http://eetd.lbl.gov/HeatIsland/Pavements/Overview/Pavements99-01.html. Accessed March 2010.

Lawrence Berkeley National Laboratory. Heat Island Group: The Cost of Hot Pavements. Available online at: http://heatisland.lbl.gov/Pavements/Cost.html. Accessed March 2010.

USEPA. Draft. Reducing Urban Heat Islands: Compendium of Strategies, Cool Pavements. Available online at: http://epa.gov/heatisland/resources/pdf/CoolPavesCompendium.pdf

Appendix A

List of Acronyms and Glossary of Terms

List of Acronyms

ACM	alternative calculation method
AF	acre feet
B20	biodiesel (20%)
BOD	biochemical oxygen demand
BMP	best management practice
C	carbon
CAFE	corporate average fuel economy
CAPCOA	California Air Pollution Control Officers Association
CAR	Climate Action Registry
CARB	California Air Resources Board
CCAR	California Climate Action Registry
CDWR	California Department of Water Resources
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CEUS	California Commercial End-Use Survey
CGBSC	California Green Building Standards Code
CH_4	methane
CHP	combined heat and power
CIWMB	California Integrated Waste Management Board
CNG	compressed natural gas
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
DE	destruction efficiency
DEIR	Draft Environmental Impact Report
DU	dwelling unit
EF	emission factor
EIA	United States Energy Information Administration
EIR	Environmental Impact Report
EMFAC	on-road vehicle emission factors model
ET_0	reference evapotranspiration
ETWU	estimated total water use
FCZ	forecasting climate zone
GHG	greenhouse gas
GP	General Plan
GRP	General Reporting Protocol
GWP	global warming potential
HA	hydrozone area
HHV	higher heating value
hp	horsepower
HVAC	heating, ventilating, and air conditioning
IE	irrigation efficiency
IPCC	Intergovernmental Panel on Climate Change
ITE	Institute of Transportation Engineers
ITS	intelligent transportation systems
kBTU	thousand British thermal units
kW	kilowatt
kWh	kilowatt-hour
kWh/yr	kilowatt-hours/year
lbs	pounds

LA	landscape area
LADWP	Los Angeles Department of Water and Power
LCA	life cycle assessment
LDA	light-duty auto
LDT	light-duty truck
LED	light-emitting diode
LFM	landfill methane
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MAWA	maximum applied water allowance
MMBTU	million British thermal units
MSW	mixed solid waste
MTCE	metric tonnes carbon equivalent
N_2O	nitrous oxide
NOx	nitrogen oxides
NRDC	Natural Resources Defense Council
NREL	National Renewable Energy Laboratory
OLED	organic light-emitting diode
OFFROAD	off-road vehicle emission factors model
PF	plant factor
PG&E	Pacific Gas and Electric
PM	particulate matter
PUP	Power/Utility Protocol
RASS	Residential Appliance Saturation Survey
SCAQMD	South Coast Air Quality Management District
SCE	Southern California Edison
SDGE	San Diego Gas and Electric
SLA	special landscape area
SMAQMD	Sacramento Metropolitan Air Quality Management District
SMUD	Sacramento Municipal Utility District
scf	standard cubic feet
SHP	separate heat and power
SO_2	sulfur dioxide
sqft	square feet
TDM	transportation demand management
TDV	time dependent valuation
TOD	transit-oriented development
tonnes	metric tonnes; 1,000 kilograms
TRU	truck refrigeration unit
URBEMIS	Urban Emissions Model
US	United States
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
VCAPCD	Ventura County Air Pollution Control District
VTPI	Victoria Transport Policy Institute
VMT	vehicle miles traveled
VTR	vehicle trip reduction
WARM	Waste Reduction Model
WMO	World Meteorological Organization
yr	year

Glossary of Terms

Alternative Calculation Method
Software used to demonstrate compliance with the California Building Energy Efficiency Standards (Title 24). The software must comply with the requirements listed in the Alternative Calculation Method Approval Manual.

Additionality[a]
The reduction in emissions by sources or enhancement of removals by sinks that is additional to any that would occur in the absence of the project. The project should not subsidize or take credit for emissions reductions which would have occurred regardless of the project.

Albedo[a]
The fraction of solar radiation reflected by a surface or object, often expressed as a ratio or fraction. Snow covered surfaces have a high albedo; the albedo of soils ranges from high to low; vegetation covered surfaces and oceans have a low albedo. The Earth"s albedo varies mainly through varying cloudiness, snow, ice, leaf area, and land cover changes. Paved surfaces with high albedos reflect solar radiation and can help reduce the urban heat island effect.

Below Market Rate Housing
Housing rented at rates lower than the market rate. Below market rate housing is designed to assist lower-income families. When below market rate housing is provided near job centers or transit, it provides lower income families with desirable job/housing match or greater opportunities for commuting to work through public transit.

Biochemical Oxygen Demand
Represents the amount of oxygen that would be required to completely consume the organic matter contained in wastewater through aerobic decomposition processes. Under the same conditions, wastewater with higher biochemical oxygen demand (BOD) concentrations will generally yield more methane than wastewater with lower BOD concentrations. BOD_5 is a measure of BOD after five days of decomposition.

Biogenic Emissions[b]
Carbon dioxide emissions produced from combusting a variety of biofuels, such as biodiesel, ethanol, wood, wood waste and landfill gas.

Carbon Dioxide Equivalent
A measure for comparing carbon dioxide with other greenhouse gases. Tonnes carbon dioxide equivalent is calculated by multiplying the tonnes of a greenhouse gas by its associated global warming potential.

California Environmental Quality Act
A statute passed in 1970 that requires state and local agencies to identify the significant environmental impacts of their actions and to avoid or mitigate those impacts, if feasible.

Carbon Neutral Power
A power generation system which has net zero carbon emissions. Examples of existing carbon neutral power systems are photovoltaics, wind turbines, and hydropower systems.

Carbon Sink
Any process or mechanism that removes carbon dioxide from the atmosphere. A forest is an example of a carbon sink, because it sequesters carbon dioxide from the atmosphere.

“Carrot”
The purpose of a carrot is to provide an incentive which encourages a particular action. Parking cash-out would be considered a “carrot” since the employee receives a monetary incentive for not driving to work, but is not punished for maintaining status quo.

Combined Heat and Power
Also known as cogeneration. Combined heat and power is the generation of both heat and electricity from the same process, such as combustion of fuel, with the purpose of utilizing or selling both simultaneously. In combined heat and power systems, the thermal energy byproducts of a process are captured and used, where they would be wasted in a separate heat and power system. Examples of combined heat and power systems include gas turbines, reciprocating engines, and fuel cells.

Compact Infill
A Project which is located within or contiguous with the central city. Examples may include redevelopment areas, abandoned sites, or underutilized older buildings/sites.

Climate Zone
Geographic area of similar climatic characteristics, including temperature, weather, and other factors which affect building energy use. The California Energy Commission identified 16 Forecasting Climate Zones (FCZs) for use in the CEUS and RASS analyses. The designation of these FCZs was based in part on the utility service area.

Cordon Pricing
Tolls charged for entering a particular area (a “cordon”), such as a downtown.

Density
The amount of persons, jobs, or dwellings per unit of land area. This is an important metric for determining traffic-related parameters.

Destination Accessibility
A measure of the number of jobs or other attractions reachable within a given travel time. Destination accessibility tends to be highest at central locations and lowest at peripheral ones.

Efficacy
The capacity to produce a desired effect.

ENERGY STAR
A joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy which sets national standards for energy efficient consumer products. ENERGY STAR certified products are guaranteed to meet the efficiency standards specified by the program.

Elasticity
The percentage change of one variable in response to a percentage change in another variable. Elasticity = percent change in variable A / percent change in variable B (where the

change in B leads to the change in A). For example, if the elasticity of VMT with respect to density is -0.12, this means a 100% increase in density leads to a 12% decrease in VMT.

Evapotranspiration[c]
The loss of water from the soil both by evaporation and by transpiration from the plants growing in the soil.

General Plan
A set of long-term goals and policies that guide local land use decisions. The 2003 *General Plan Guidelines* developed by the California Office of Planning and Research provides advice on how to write a general plan that expresses a community's long-term vision, fulfills statutory requirements, and contributes to creating a great community.

Global Warming Potential[b]
The ratio of radiative forcing that would result from the emission of one kilogram of a greenhouse gas to that from the emission of one kilogram of carbon dioxide over a fixed period of time.

Graywater
Non-drinkable water that can be collected and reused onsite for irrigation, flushing toilets, and other purposes. This water has not been processed through a waste water treatment plant.

Greenhouse Gas
For the purposes of this report, greenhouse gases are the six gases identified in the Kyoto Protocol: carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

Headway
The amount of time (in minutes) that elapses between two public transit vehicles servicing a given route and given line. Headways for buses and rail are generally shorter during peak periods and longer during off-peak periods. Headway is the inverse of frequency (headway = 1/frequency), where frequency is the number of arrivals over a given time period (i.e. buses per hour).

Intelligent Transportation System
A broad range of communications-based information and electronics technologies integrated into transportation system infrastructure and vehicles to relieve congestion and improve travel safety.

Job Center
An area with a high degree and density of employment.

Kilowatt Hour
A unit of energy. In the U.S., the kilowatt hour is the unit of measure used by utilities to bill consumers for energy use.

Land Use Index
Measures the degree of land use mix of a development. An index of 0 indicates a single land use while 1 indicates a full mix of uses.

Lumen
A unit of luminous flux. A measure of the brilliance of a source of visible light, or the power of light perceived by the human eye.

Master Planned Community
Large communities developed specifically incorporating housing, office parks, recreational area, and commercial centers within the community. Master planned communities tend to encompass a large land area with the intent of being self-sustaining. Many master planned communities may have lakes, golf courses, and large parks.

Mixed Use
A development that incorporates more than one type of land use. For example, a small mixed use development may have buildings with ground-floor retail and housing on the floors above. A larger mixed use development will locate a variety of land uses within a short proximity of each other. This may include integrating office space, shopping, parks, and schools with residential development. The mixed-use development should encourage walking and other non-auto modes of transport from residential to office/commercial/institutional locations (and vice versa).

Ordinance
A local law usually found in municipal code.

Parking Spillover
A term used to describe the effects of implementing a parking management strategy in a sub-area that has unintended consequences of impacting the surrounding areas. For example, assume parking meters are installed on all streets in a commercial/retail block with no other parking strategies implemented. Customers will no longer park in the metered spots and will instead "spillover" to the surrounding residential neighborhoods where parking is still unrestricted.

Photovoltaic[c]
A system that converts sunlight directly into electricity using cells made of silicon or other conductive materials (solar cells). When sunlight hits the cells, a chemical reaction occurs, resulting in the release of electricity.

Recycled Water
Non-drinkable water that can be reused for irrigation, flushing toilets, and other purposes. It has been processed through a wastewater treatment plant and often needs to be redistributed.

Ride Sharing
Any form of carpooling or vanpooling where additional passengers are carried on the trip. Ride-sharing can be casual and formed independently or be part of an employer program where assistance is provided to employees to match up commuters who live in close proximity of one another.

Renewable Energy[a]
Energy sources that are, within a short time frame relative to the Earth‟s natural cycles, sustainable, and include non-carbon technologies such as solar energy, hydropower, and wind, as well as carbon-neutral technologies such as biomass.

Self Selection
When an individual selects himself into a group.

Separate Heat and Power
The typical system for acquiring heat and power. Thermal energy and electricity are generated and used separately. For example, heat is generated from a boiler while electricity is acquired from the local utility. Separate heat and power systems are used as the baseline of comparison for combined heat and power systems.

Sequestration[a]
The process of increasing the carbon content of a carbon reservoir other than the atmosphere. Biological approaches to sequestration include direct removal of carbon dioxide from the atmosphere through afforestation, reforestation, and practices that enhance soil carbon in agriculture. Physical approaches include separation and disposal of carbon dioxide from flue gases or from processing fossil fuels to produce hydrogen- and carbon dioxide-rich fractions and longterm storage in underground in depleted oil and gas reservoirs, coal seams, and saline aquifers.

"Stick"
The purpose of a stick is to establish a penalty for a status quo action. Workplace parking pricing would be considered a "stick" since the employee is now monetarily penalized for driving to work.

Suburban
An area characterized by dispersed, low-density, single-use, automobile dependent land use patterns, usually outside of the central city (a suburb).

Suburban Center
The suburban center serves the population of the suburb with office, retail and housing which is denser than the surrounding suburb.

Title 24
Title 24 Part 6 is also known as the California Building Energy Efficiency Standard, which regulates building energy efficiency standards. Regulated energy uses include space heating and cooling, ventilation, domestic hot water heating, and some hard-wired lighting. Title 24 determines compliance by comparing the modeled energy use of a „proposed home‟ to that of a minimally Title 24 compliant „standard home‟ of equal dimensions. Title 24 focuses on building energy efficiency per square foot; it places no limits upon the size of the house or the actual energy used per dwelling unit. The current Title 24 standards were published in 2008.

Transit-Oriented Development
A development located near and specifically designed around a rail or bus station. Proximity alone does not characterize a development as transit-oriented. The development and surrounding neighborhood should be designed for walking and bicycling and parking management strategies should be implemented. The development should be located within a short walking distance to a high-quality, high frequency, and reliable bus or rail service.

Transportation Demand Management
Any transportation strategy which has an intent to increase the transportation system efficiency and reduce demand on the system by discouraging single-occupancy vehicle travel and encouraging more efficient travel patterns, alternative modes of transportation such as walking, bicycling, public transit, and ridesharing. TDM measures should also shift travel patterns from peak to off-peak hours and shift travel from further to closer destinations.

Transit Ridership
The number of passengers who ride in a public transportation system, such as buses and subways.

Tree and Grid Network
Describes the layout of streets within and surrounding a project. Streets that are characterized as a tree network actually look like a tree and its branches. Streets are not laid out in any uniform pattern, intersection density is low, and the streets are less connected. In a grid network, streets are laid out in a perpendicular and parallel grid pattern. Streets tend to intersect more frequently, intersection density is higher, and the streets are more connected.

Urban
An area which is located within the central city with higher density of land uses than you would find in the suburbs. It may be characterized by multi-family housing and located near office and retail.

Urban Heat Island Effect
The phenomenon in which a metropolitan area is warmer than its surrounding rural areas due to increased land surface which retains heat, such as concrete, asphalt, metal, and other materials found in buildings and pavements.

Vehicle Miles Traveled
The number of miles driven by vehicles. This is an important traffic parameter and the basis for most traffic-related greenhouse gas emissions calculations.

Vehicle Occupancy
The number of persons in a vehicle during a trip, including the driver and passengers.

Notes:

[a] Definition adapted from: IPCC. 2001. Third Assessment Report: Climate Change 2001 (TAR). Annex B: Glossary of Terms. Available online at: http://www.ipcc.ch/pdf/glossary/tar-ipcc-terms-en.pdf

[b] Definition adapted from: CCAR. 2009. General Reporting Protocol, Version 3.1. Available online at: http://www.climateregistry.org/resources/docs/protocols/grp/GRP_3.1_January2009.pdf

[c] Definition adapted from: USEPA. 2010. Greening EPA Glossary. Available online at: http://www.epa.gov/oaintrnt/glossary.htm

Appendix B

Greenhouse Gas Mitigation Measures Task 0:
Standard Approach to Calculate Unmitigated Emissions

Greenhouse Gas Mitigation Measures Task 0: Standard Approach to Calculate Unmitigated Emissions

Prepared for:
California Pollution Control Officers Association (CAPCOA)

Prepared by:
ENVIRON International Corporation
San Francisco, California

And

Fehr & Peers
San Francisco & Walnut Creek, California

Date:
August 2010

Contents

1 Introduction

ENVIRON International Corporation (ENVIRON) and Fehr & Peers worked with the California Air Pollution Control Officers Association (CAPCOA) to quantify reductions associated with greenhouse gas (GHG) mitigation measures that can be applied to California Environmental Quality Act (CEQA) Environmental Impact Report (EIR) analyses. The first part of this overall task defines a standard approach to calculate the baseline emissions before mitigation. This report contains the recommendations for methodologies and approaches to assess the baseline GHG emissions.

This report and its methodologies form the basis for the subsequent tasks associated with quantification of GHG mitigation measures. To the extent possible, default values are included with this report and in the mitigation measure Fact Sheets.

This report presents methods to be used to calculate short-term and one-time emissions sources as well as emissions that will occur annually after construction (operational emissions). The one-time emission sources include changes in carbon sequestration due to vegetation changes and emissions associated with construction. The annual operational emissions include the emissions associated with building energy use including natural gas and electricity, emissions associated with mobile sources, emissions associated with water use and wastewater treatment, emissions associated with area sources such as natural gas fired hearths , landscape maintenance equipment, swimming pools, and golf courses.

2 GHG Equivalent Emissions

The term "GHGs" includes gases that contribute to the greenhouse effect, such as carbon dioxide (CO_2,) methane (CH_4), and nitrous oxide (N_2O), as well as gases that are only man-made and that are emitted through the use of modern industrial products, such as hydrofluorocarbons (HFCs), chlorinated fluorocarbons (CFCs), and sulfurhexafluoride (SF_6). These last three families of gases, while not naturally present in the atmosphere, have properties that also cause them to trap infrared radiation when they are present in the atmosphere, thus making them GHGs. These six gases comprise the major GHGs that are recognized by the Kyoto Accords (water is not included).[1] There are other GHGs that are not recognized by the Kyoto Accords, due either to the smaller role that they play in climate change or the uncertainties surrounding their effects. Atmospheric water vapor is not recognized by the Kyoto Accords because there is not an obvious correlation between water concentrations and specific human activities. Water appears to act in a positive feedback manner; higher temperatures lead to higher water vapor concentrations in the atmosphere, which in turn can cause more global warming.[2] California has recently recognized nitrogen trifluoride as another regulated greenhouse gas.

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[1] This Kyoto Protocol sets legally binding targets and timetables for cutting the greenhouse gas emissions of industrialized countries. The US has not approved the Kyoto treaty.

[2] From the IPCC Third Assessment Report: http://www.grida.no/climate/ipcc_tar/wg1/143.htm and http://www.grida.no/climate/ipcc_tar/wg1/268.htm

Residents and the employees and patrons of commercial and municipal buildings and services use electricity, heating, water, and are transported by motor vehicles. These activities directly or indirectly emit GHGs. The most significant GHG emissions resulting from such residential and commercial developments are emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). GHG emissions are typically measured in terms of MT of CO_2 equivalents (CO_2e), calculated as the product of the mass emitted of a given GHG and its specific global warming potential (GWP).

The effect that each of these gases can have on global warming is a combination of the mass of their emissions and their global warming potential (GWP). GWP indicates, on a MT for MT basis, how much a gas is predicted to contribute to global warming relative to how much warming would be predicted to be caused by the same mass of CO_2. CH_4 and N_2O are substantially more potent GHGs than CO_2, with GWPs of 21 and 310, respectively according to the IPCC's Second Assessment Report (SAR).[3] In emissions inventories, GHG emissions are typically reported in terms of pounds (lbs) or MT[4] of CO_2 equivalents (CO_2e). CO_2e are calculated as the product of the mass emitted of a given GHG and its specific GWP. While CH_4 and N_2O have much higher GWPs than CO_2, CO_2 is emitted in such vastly higher quantities that it accounts for the majority of GHG emissions in CO_2e, both from developments and human activity in general. Since most regulatory agencies and protocols use the SAR GWP values as a basis, this assessment will also use SAR GWP values even though more recent values exist. However, SAR did not consider nitrogen trifluoride, however there are no sources of nitrogen trifluoride that would typically need to be quantified.

3 Units of measurement: MT of CO_2 and CO_2e

In many sections of this report, including the final summary sections, emissions are presented in units of CO_2e either because the GWPs of CH_4 and N_2O were accounted for explicitly, or the CH_4 and N_2O are assumed to contribute a negligible amount of GWP when compared to the CO_2 emissions from that particular emissions category.

Emissions and reductions are calculated in terms of metric tons. As such, "MT" will be used to refer to metric tons (1,000 kilograms). "Tons" will be used to refer to short tons (2,000 pounds [lbs]).

4 Indirect GHG Emissions from Electricity Use

As noted above, indirect GHG emissions are created as a result of electricity use. When electricity is used in a building, the electricity generation typically takes place offsite at the power plant; electricity use in a building generally causes emissions in an indirect manner. The project should use information specific for each local utility provider for different parts of

3 GWP values from IPCC's Second Assessment Report (SAR, 1996) are still used by international convention and are used in this protocol, even though more recent (and slightly different) GWP values were developed in the IPCC's Fourth Assessment Report (FAR, 2007)

4 In this report, "MT" will be used to refer to metric MT (1,000 kilograms). "Tons" will be used to refer to short tons (2,000 pounds).

California. Accordingly, indirect GHG emissions from electricity usage are calculated using the utility specific carbon-intensity factor based Power/Utility Protocol (PUP) report from California Climate Action Registry (CCAR)[5] for the 2006 baseline year. ENVIRON does not recommend using the 2004 PUP reports since this year was one of the first year's utilities reported emissions, as such, the data is likely less accurate than subsequent years since utilities had a chance to refine data collection methods for the later years. Furthermore, a large coal burning power plant in Mojave was going offline in 2005 which was factored into the Scoping Plan analysis. Therefore, ENVIRON suggests using the 2006 PUP reports since it likely represents a more accurate dataset year. This emission factor takes into account the baseline year's mix of energy sources used to generate electricity for a specific utility and the relative carbon intensities of these sources. The emission factor will be determined as a CO_2e incorporating the CO_2, CH_4, and N_2O emissions.

Power Utility	Carbon-Intensity (lbs CO_2e/MWh)
LADW&P	1,238
PG&E	456
SCE	641
SDGE	781
SMUD	555

5 Short-Term Emissions

Short-term or one-time emissions from the development of a Project are associated with vegetation removal and re-vegetation on the Project site and construction-related activities.

5.1 Construction Activities

Construction activities occur during the early stage of a project. Construction activities include any demolition, site grading, building construction, and paving. These construction activities have several main sources of GHG emissions. Off-road construction equipment such as dozers, pavers, and backhoes are used on-site during construction. These pieces of equipment typically are diesel fueled although other fuels are occasionally used. Besides the off-road construction, there are on-road vehicles. These vehicles are used for worker commuting, delivering of material to the site, and hauling material away from the site. The methodology to calculate these sources of emissions is described in the next sections.

5.1.1 Estimating GHG Emissions from Off-Road Construction Equipment

This section describes how emissions from off-road equipment used during demolition, site grading, building construction and paving are calculated. This section can be used for any fuel

[5] California Climate Action Registry (CCAR) Database. PUP Report.

burning equipment such as diesel, gasoline, or compressed natural gas (CNG). For electric equipment please see the method in the next section.

First, the number and type of equipment that will be used in the construction, as well as the duration of the entire construction project, is needed. Absent other data, ENVIRON recommends that each piece of equipment will operate for 8 hours a day, five days a week throughout the construction duration. An equipment hour is defined as one hour of a piece of equipment being used. Specifications for each type of construction equipment (horsepower, load factor, and GHG emission factor) are provided by OFFROAD2007[6]. CO_2 and CH_4 emissions for each type of construction equipment are calculated as follows:

$$\text{Equipment Emissions [grams]} = \text{Total equipment hours} \times \text{emission factor [grams per brake horsepower-hour]} \times \text{equipment horsepower} \times \text{load factor}^{7}$$

The grams of CO_2 and CH_4 are multiplied by their respective GWP and then the two emissions are summed to derive the final CO_2e emissions from the piece of off-road equipment. Since OFFROAD2007 does not provide an emission factor for N_2O which is a minor subset of nitrogen oxides (NO_x) emissions and the contribution to the overall GHG emissions is likely small, it is therefore not included in calculations that used OFFROAD2007. These were accounted for with alternative fuels since they have a larger proportion of N_2O and CH_4.

5.1.2 Estimating GHG emissions from Electric Off-Road Construction Equipment

In order to estimate the indirect GHG emissions associated with electricity consumption of electrical powered equipment, the following inputs are required. First, the total operating hours of the electrical piece of equipment is needed. Secondly, the amount of kilowatts the equipment uses per time is needed. These two pieces are used along with the carbon intensity factor for the local utility provider as follows:

$$\text{Equipment Emissions} = \text{Total equipment hours} \times \text{average power draw (kW/hr)} \times \text{Utility EF (g } CO_2e \text{ per kWhr)}$$

5.1.3 GHG Emissions from On-Road Vehicles Associated with Construction

Emissions from on-road vehicles associated with construction include workers commuting to the site, vendors delivering materials, and hauling away of materials. GHGs are emitted from these vehicles in two ways: running emissions, produced by driving the vehicle, and startup emissions, produced by turning the vehicle on. Idling emissions will not be considered since

[6] OFFROAD2007 is a model developed by the Air Resources Board which contains emission factors for off-road equipment. It is available at : http://www.arb.ca.gov/msei/offroad/offroad.htm

[7] Load factor is the percentage of the maximum horsepower rating at which the equipment normally operates.

regulations exist which limit idling[8] and they would represent a small contribution to the GHG emissions. The majority of these on-road vehicle emissions are running emissions.

Running emissions are calculated using the same method for all trip types. The total Vehicle Miles Traveled (VMT) for the trip type category is estimated, and then multiplied by the representative GHG emission factors for the vehicles expected to be driven. The total VMT for a given trip type is calculated as follows:

$$VMT \quad = \quad Number\ of\ round\ trips \quad x \quad average\ round\ trip\ length\ (miles)$$

The number of trips should be based on project specific information. Default values associated with each land use type can be obtained construction cost estimators or default values in emission estimator programs. Average round trip length should be based on project specific information or county specific default values. After total VMT is calculated, GHG emissions for on-road vehicles associated with construction can be calculated from the following equation:

$$CO_2\ emissions \quad = \quad VMT \quad x \quad EF_{running}$$

Where:

VMT = vehicle miles traveled
$EF_{running}$ = running emission factor for vehicle fleet for trip type

The CO_2 calculation involves the following assumptions:

a. Vehicle Fleet Defaults:

    a. Workers commute half with light duty trucks (LDTs) and half commute in light duty autos (LDAs). Half of the LDTs are type 1 and the other half type 2.

    b. Vendors are all heavy-heavy duty vehicles.

    c. Hauling is all heavy-heavy duty vehicles.

b. The emission factor depends upon the speed of the vehicle. A default value of 35 miles per hour will be used.

c. EMFAC emission factors from the construction year will be used for $EF_{running}$.

[8] The Air Resources Board adopted in 2004 and modified in 2005 an Air Toxic Control Measure that limits idling in diesel vehicles to 5-minutes. http://www.arb.ca.gov/msprog/truck-idling/truck-idling.htm

The emissions associated with CH_4 and N_2O are calculated in a similar manner or assumed to represent 5% of the total CO_2e emissions. They are then converted to CO_2e by multiplying by their respective global warming potential.

Startup emissions are CO_2 emitted from starting a vehicle. For the various trips during all phases, the startup emissions are calculated using the following assumptions:

a. The same vehicle fleet assumptions as used in running emissions.

b. Two engine startups per day with a 12 hour wait before each startup.[9]

The USEPA recommends assuming that CH_4, N_2O, and HFCs account for 5% of GHG emissions from on-road vehicles, taking into account their GWPs.[10] To incorporate these additional GHGs into the calculations, the total GHG footprint is calculated by dividing the CO_2 emissions by 0.95.

5.2 Vegetation Change

ENVIRON suggests following the IPCC protocol for vegetation since it has default values that work well with the information typically available for development projects. This method is similar to the CCAR Forest Protocol[11] and the Center for Urban Forest Research Tree Carbon Calculator[12], but it has more general default values available that will generally applicable to all areas of California without requiring detailed site-specific information[13].

5.2.1 Quantifying the One-Time Release by Changes in Carbon Sequestration Capacity

The one-time release of GHGs due to permanent changes in carbon sequestration capacity is calculated using the following four steps:[14]

1. *Identify and quantify the change in area of various land types due to the development (i.e. alluvial scrub, non-native grassland, agricultural, etc.).* These area changes include not only the area of land that will be converted to buildings, but also areas disrupted by the construction of utility corridors, water tank sites, and associated borrow and grading areas.

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[9] The emission factor grows with the length of time the engine is off before each ignition.

[10] USEPA. 2005. *Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle.* Office of Transportation and Air Quality. February.

[11] CCAR. 2007. Forest Sector Protocol Version 2.1. September. Available at: http://www.climateregistry.org/resources/docs/protocols/industry/forest/forest_sector_protocol_version_2.1_sept2007.pdf

[12] Available at: http://www.fs.fed.us/ccrc/topics/urban-forests/ctcc/

[13] The CCAR Forest Protocol and Urban Forest Research Tree Carbon Calculator are not used since their main focus is annual emissions for carbon offset considerations. As such they are designed to work with very specific details of the vegetation that is not available at a CEQA level of analysis.

[14] This section follows the IPCC guidelines, but has been adapted for ease of use for these types of Projects.

Areas temporarily disturbed that will eventually recover to become vegetated will not be counted as vegetation removed as there is no net change in vegetation or land use.[15]

2. *Estimate the biomass associated with each land type.* For the purposes of this report, ENVIRON suggests using the available general vegetation types found in the IPCC publication Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines).[16]

   California vegetation is heavily dominated by scrub and chaparral vegetation which may not be accurately characterized by default forest land properties. Consequently, ecological zones and biomass based subdivisions identified in the IPCC Guidelines were used to sub-categorize the vegetation as scrub dominated. These subcategories should be used to determine the CO_2 emissions resulting from land use impacts.

3. *Calculate CO_2 emissions from the net change of vegetation.* When vegetation is removed, it may undergo biodegradation,[17] or it may be combusted. Either pathway results in the carbon (C) present in the plants being combined with oxygen (O_2) to form CO_2. To estimate the mass of carbon present in the biomass, biomass weight is multiplied by the mass carbon fraction, 0.5. [18] The mass of carbon is multiplied by 3.67[19] to calculate the final mass of CO_2, assuming all of this carbon is converted into CO_2.

4. Calculate the overall change in sequestered CO_2. – For all types of land that change from one type of land to another,[20] initial and final values of sequestered CO_2 are calculated using the equation below.

   Overall Change in Sequestered CO_2 [MT CO_2]

$$= \sum_i (SeqCO_2)_i \times (area)_i - \sum_j (SeqCO_2)_j \times (area)_j$$

   Where:

$SeqCO_2$	=	mass of sequestered CO_2 per unit area [MT CO_2/acre]
area	=	area of land for specific land use type [acre]
i	=	index for final land use type
j	=	index for initial land use type

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[15] This assumption facilitates the calculation as a yearly growth rate and CO_2 removal rate does not have to be calculated. As long as the disturbed land will indeed return to its original state, this assumption is valid for time periods over 20 years.

[16] Available online at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.htm

[17] Cleared vegetation may also be deposited in a landfill or compost area, where some anaerobic degradation which will generate CH_4 may take place. However, for the purposes of this section, we are assuming that only aerobic biodegradation will take place which will result in CO_2 emissions only.

[18] The fraction of the biomass weight that is carbon. Here, a carbon fraction of 0.5 is used for all vegetation types from CCAR Forest Sector Protocol.

[19] The ratio of the molecular mass of CO_2 to the molecular mass of carbon is 44/12 or 3.67.

[20] For example from forestland to grassland, or from cropland to permanently developed.

5.2.2 Calculating CO_2 Sequestration by Trees

Planting individual trees will sequester CO_2. Changing vegetation as described above results in a one-time carbon-stock change. Planting trees is also considered to result in a one-time carbon-stock change. Default annual CO_2 sequestration rates on a per tree basis, based on values provided by the IPCC are used[21]. An average of 0.035 MT CO_2 per year per tree can be used for trees planted, if the tree type is not known.

Urban trees are only net carbon sinks when they are actively growing. The IPCC assumes an active growing period of 20 years. Thereafter, the accumulation of carbon in biomass slows with age, and will be completely offset by losses from clipping, pruning, and occasional death. Actual active growing periods are subject to, among other things, species, climate regime, and planting density. In this report, the IPCC default value of 20 years is recommended. For large tree sequestration projects, the Project may consider using the Forest or Urban tree planting protocols developed by Climate Action Registry (CAR). These protocols have slightly different assumptions regarding steady state, tree growth, and replacement of trees..

5.3 Built Environment

The amount of energy used, and the associated GHG emissions emitted per square foot of available space vary with the type of building. For example, food stores are far more energy intensive than warehouses, which have little climate-conditioned space. Therefore, this analysis is specific to the type of building.

GHGs are emitted as a result of activities in buildings for which electricity and natural gas are used as energy sources. Combustion of any type of fuel emits CO_2 and other GHGs directly into the atmosphere; when this occurs within a building (such as by natural gas consumption) this is a direct emission source[22] associated with that building. GHGs are also emitted during the generation of electricity from fossil fuels. When electricity is used in a building, the electricity generation typically takes place offsite at the power plant; electricity use in a building generally causes emissions in an indirect manner.

Energy use in buildings is divided into energy consumed by the built environment and energy consumed by uses that are independent of the construction of the building such as plug-in appliances. In California, Title 24 part 6 governs energy consumed by the built environment, mechanical systems, and some fixed lighting. This includes the space heating, space cooling, water heating, and ventilation systems. Non-building energy use, or “plug-in” energy use can be further subdivided by specific end-use (refrigeration, cooking, office equipment, etc.). The following two steps are performed to quantify the energy use due to buildings:

[21] The Center for Urban Forest Research Tree Carbon Calculator is not suggested since it requires knowledge on specific tree species to estimate carbon sequestered. This information is typically not available during the preparation of CEQA documents.

[22] California Climate Action Registry (CCAR) General Reporting Protocol (GRP), Version 3.1 (January). Available at: http://www.climateregistry.org/resources/docs/protocols/grp/GRP_3.1_January2009.pdf, Chapter 8

1. Calculate energy use from systems covered by Title 24[23] (HVAC system, water heating system, and the lighting system).
2. Calculate energy use from office equipment, plug-in lighting, and other sources not covered by Title 24.

The resulting energy use quantities are then converted to GHG emissions by multiplying by the appropriate emission factors obtained by incorporating information on local electricity providers for electricity, and by natural gas emission factors for natural gas combustion.

ENVIRON recommends using default values for Title 24 and non-Title 24 energy use for various building types. These will take into account the building size and climate zone. There are several sources of information that can be used to obtain building energy intensity. Each is described briefly below.

The *California Commercial Energy Use Survey* (CEUS) data is provided by the California Energy Commission (CEC). It is based on a survey conducted in 2002 for existing commercial buildings in various climate zones. Electricity and natural gas use per square foot for each end use in each building type and climate zone is extracted from the CEUS data. Since the data is provided by end use, it is straightforward to calculate the Title 24 and non-Title 24 regulated energy intensity for each building type.

Commercial Buildings Energy Consumption Survey (CBECS) is a survey of non-residential buildings that was conducted in 2003 by the Energy Information Administration (EIA). Electricity and natural gas use per square foot can be extracted from this data. The energy use estimates are assumed to represent 2001 Title 24 compliant buildings. Using CBECS, the percent of electricity and natural gas used for each end use can be calculated. It is then straightforward to calculate the Title 24 and non-Title 24 electricity and natural gas intensity for each building type. Similar surveys exist for manufacturing and residential energy use.

The *Residential Appliance Saturation Survey* (RASS) refers to the California Energy Commission Consultant Report entitled “California Statewide Residential Appliance Saturday Study”. Data from RASS is used to calculate the total electricity and natural gas use for residential buildings on a per dwelling unit. The RASS study estimates the unit energy consumption (UEC) values for individual households surveyed and also provides the saturation number for each type of end use. The saturation number indicates the proportion of households that have a demand for each type of end-use category. As the data is provided by end use, it is straightforward to calculate the Title 24 and non-Title 24 electricity and natural gas intensity for each building type.

Alternative Calculation Method (ACM) software is available that makes estimates of the energy consumption by a model Title 24 compliant building. These programs provide

[23] Title 24, Part 6, of the California Code of Regulations: California's Energy Efficiency Standards for Residential and Nonresidential Buildings. http://www.energy.ca.gov/title24/

annual energy use for the heating, ventilation, and air conditioning (HVAC) system in each building; therefore, estimates from ACM software represent Title 24-regulated energy use. These do not calculate the non-Title 24 energy use for the buildings.

The Department of Energy produced the *Building America Research Benchmark Definition* (BARBD) technical manual, which presents empirical equations for electricity and natural gas usage. As the data is provided by end use, it is straightforward to calculate the Title 24 and non-Title 24 electricity and natural gas intensity for each building type.

Literature surveys may also be used for building and land use types not well represented by the above sources.

ENVIRON suggests using the CEUS and RASS datasets for these calculations since the data is available for several land use categories in different climate zones in California.

The Title 24 standards have been updated twice (in 2005 and 2008) since some of these data were compiled. CEC has published reports estimating the percentage deductions in energy use resulting from these new standards. Based on CEC's discussion on average savings for Title 24 improvements, these CEC savings percentages by end use can be used to account for reductions in electricity use due to updates to Title 24. Since energy use for each different system type (ie, heating, cooling, water heating, and ventilation) as well as appliances is defined, this method will easily allow for application of mitigation measures aimed at reducing the energy use of these devices in a prescriptive manner.

Based on the electricity intensity, CO_2e intensity values (CO_2e emissions per square foot or dwelling unit, as applicable, per year) for each building type can be calculated. Electricity intensity data is multiplied by an electricity emission factor to generate CO_2e intensity values. The total CO_2e emissions from each building type are calculated by multiplying the CO_2e intensity values by the appropriate metric (building square footage for non-residential buildings or number of dwelling units for residential buildings). Summing the CO_2e emissions from all building types gives the total CO_2e emissions from electricity use in Title 24 and non-Title 24 sources in buildings.

Based on the natural gas intensity, CO_2e intensity values (CO_2e emissions per square foot or dwelling unit, as applicable, per year) for each building type can be calculated. Natural gas intensity data is multiplied by a natural gas emission factor to generate CO_2e intensity values. The total CO_2e emissions from each building type are calculated by multiplying the CO_2 intensity values by the appropriate metric (building square footage for non-residential buildings or number of dwelling units for residential buildings). Summing the CO_2e emissions from all building types gives the total CO_2e emissions from natural gas use in Title 24 and non-Title 24 sources in buildings.

5.3.1 Natural Gas Boilers

GHG emissions from the combustion of natural gas are calculated as the product of natural gas consumption, natural gas heat content, and carbon-intensity factor. The Project Applicant has to determine the natural gas consumption, while the heat content and carbon-intensity factor can obtained from the CCAR General Reporting Protocol.

5.4 Area Sources

Area sources are local combustion of fuel. The area sources covered in this section include natural gas fireplaces/stoves and landscape maintenance equipment. Natural gas usage from the primary building heating is not included in this category since it is already included with building energy use. Each of these area sources is discussed further.

5.4.1 Natural Gas Fireplaces/Stoves

GHG emissions associated with natural gas fired fireplaces are calculated using emission factors from CCAR. The average BTU per hour for fireplaces in homes needs to be specified. Default values for annual fireplace usage varies for each County. Natural gas is assumed to have 1,020 BTU per standard cubic foot[24].

5.4.2 Landscape Maintenance

Landscape maintenance includes fuel combustion emissions from equipment such as lawn mowers, roto tillers, shredders/grinders, blowers, trimmers, chain saws, and hedge trimmers, as well as air compressors, generators, and pumps.

Similar to construction off-road equipment, emission factors are based on the OFFROAD2007 model. These are combined with the hours of operation for each equipment piece as well as the horsepower and load factors. The GHG emissions will be calculated based on the emission factors for the equipment and fuel reported from OFFROAD2007 and the appropriate GWP. Default usages (hours of operation) should be determined for the landscape equipment based on the Project needs.

5.5 Water

Delivering and treating water for use at the project site requires energy. This embodied energy associated with the distribution of water to the end user is associated with the electricity to pump and treat the water. GHG emissions due to water use are related to the energy used to convey, treat and distribute water. Thus, these emissions are indirect emissions from the production of electricity to power these systems.

The amount of electricity required to treat and supply water depends on the volume of water involved. Three processes are necessary to supply water to users: (1) supply and conveyance of the water from the source; (2) treatment of the water to potable standards; and (3) distribution of the water to individual users.

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[24] USEPA. 1998. AP-42 Emission Factors. Chapter 1.4 Natural Gas Combustion.

Therefore, to quantify the GHG emissions associated with the distribution of water to an end user, the carbon intensity of electricity is used along with the amount of electricity used in pumping and treating the water. Since consumption of water varies greatly for each land use type, default values need to be determined with several listed in the mitigation measure fact sheets. Since buildings may have different percentages of water associated with indoor and outdoor water usage, the water usage is quantified separately. In addition since mitigation measures associated with water use may be directed separately toward indoor and outdoor water usage, this will be beneficial for this task.

5.5.1 Indoor

Indirect emissions resulting from electricity use are determined by multiplying electricity use by the CO_2e emission factor provided by the local electricity supplier. Energy use per unit of water for different aspects of water treatment (e.g. source water pumping and conveyance, water treatment, distribution to users) is determined using the stated volumes of water and energy intensities values (i.e., energy use per unit volume of water) provided by reports from the California Energy Commission (CEC) on energy use for California's water systems.[25] The CEC report estimates the electricity required to extract and convey one million gallons of water. Using this energy intensity factor, the expected indoor water demand, and the utility-specific carbon-intensity factor, GHG emissions from indoor water supply and conveyance may be calculated.

The amount of electricity required to treat and distribute one million gallon of potable water is estimated in the CEC report. Based on the estimated indoor water demand, these energy intensity factors, and the utility-specific carbon intensity factor, GHG emissions from indoor water treatment and distribution may be calculated.

The sum of emissions due to supplying, conveying, treating, and distributing indoor water gives the total emissions due to indoor water use.

5.5.2 Outdoor

Indirect emissions resulting from electricity use are determined by multiplying electricity use by the CO_2 emission factor provided by the local electricity supplier. Energy use per unit of water for different aspects of water treatment (e.g. source water pumping and conveyance, water treatment, distribution to users) is determined using the stated volumes of water and energy intensities values (i.e., energy use per unit volume of water) provided by reports from the California Energy Commission (CEC) on energy use for California's water systems.[26] The

[25] CEC 2005. California's Water-Energy Relationship. Final Staff Report. CEC-700-2005-011-SF,

CEC 2006. Refining Estimates of Water-Related Energy Use in California. PIER Final Project Report. Prepared by Navigant Consulting, Inc. CEC-500-2006-118. December.

[26] CEC 2005. California's Water-Energy Relationship. Final Staff Report. CEC-700-2005-011-SF,

CEC 2006. Refining Estimates of Water-Related Energy Use in California. PIER Final Project Report. Prepared by Navigant Consulting, Inc. CEC-500-2006-118. December.

energy needed to supply and convey the water will be used to pump this water from the sources and distribute it throughout the development. The CEC report estimates the electricity required to extract and convey one million gallons of water. Using this energy intensity factor, the expected outdoor water demand, and the utility-specific carbon-intensity factor, GHG emissions from outdoor water supply and conveyance may be calculated.

The amount of electricity required to treat and distribute one million gallon of potable water (see recycled water for non-potable water) is estimated in the CEC report. Based on the estimated outdoor water demand, these energy intensity factors, and the utility-specific carbon intensity factor, GHG emissions from outdoor water treatment and distribution may be calculated.

The sum of emissions due to supplying, conveying, treating, and distributing outdoor water gives the total emissions due to outdoor water use.

5.5.2.1 Landscape Watering – Turf Grass

The amount of outdoor water used in the landscape watering of turf grass is calculated based on the California Department of Water Resources (CDWR) 2009 Model Water Efficient Landscape Ordinance[27] and the CDWR 2000 report "A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California: The Landscape Coefficient Method and WUCOLS III."[28] Using this methodology, the amount of water required to support the baseline turf water demand ($Water_{baseline}$) is calculated as follows:

$$ETC = Kc \times ET_0$$

Where:

ETC	=	Crop Evapotranspiration, the total amount of water the baseline turf loses during a specific time period due to evapotranspiration[29] (inches water/day)
KC	=	Crop Coefficient, factor determined from field research, which compares the amount of water lost by the crop (e.g. turf) to the amount of water lost by a reference crop (unitless). Species-specific; provided in CDWR 2000
ET_0	=	Reference Evapotransporation, the amount of water lost by a reference crop (inches water/day) Region-specific; provided in Appendix A of CDWR 2009

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27 California Department of Water Resources. 2009. Model Water Efficient Landscape Ordinance. Available online at: http://www.water.ca.gov/wateruseefficiency/docs/MWELO09-10-09.pdf

28 California Department of Water Resources. 2000. A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California: The Landscape Coefficient Method and WUCOLS III. Available online at: http://www.water.ca.gov/pubs/conservation/a_guide_to_estimating_irrigation_water_needs_of_landscape_plantings_in_california__wucols/wucols00.pdf

29 Evapotranspiration is water lost to the atmosphere due to evaporation from soil and transpiration from plant leaves. For a more detailed definition, see this California Irrigation Management Information System (CIMIS) website: http://wwwcimis.water.ca.gov/cimis/infoEtoOverview.jsp;jsessionid=91682943559928B8A9A243D2A2665E19

Then:

$$Water_{baseline} = ETC \times Areabaseline \times 0.62 \times 365$$

Where:

$Water_{baseline}$	=	Volume of water required to support the baseline turf (gallons/year)
$Area_{baseline}$	=	Area of existing or standard turf (square feet)
0.62	=	conversion factor (gallons/squarefoot.inches water)
365	=	conversion factor (days/year)

Based on the estimated outdoor water demand for watering turf grass, the outdoor water energy intensity factors described above, and the utility-specific carbon intensity factor, GHG emissions from watering turf grass in lawns may be calculated.

5.5.2.2 Landscape Watering – General

The amount of outdoor water used in the landscape watering of landscapes and lawns is calculated based on the California Department of Water Resources (CDWR) 2009 Model Water Efficient Landscape Ordinance.[30] Using this methodology, the amount of water required to support the baseline lawn water demand ($Water_{baseline}$) is defined as the Maximum Applied Water Allowance (MAWA) and is calculated as follows:

$$Water_{baseline} = MAWA = ET_0 \times 0.62 \times [(0.7 \times LA) + (0.3 \times SLA)]$$

Where:

$Water_{baseline}$	=	Volume of water required to support the baseline lawn (gallons/year)
MAWA	=	Maximum Applied Water Allowance (gallons/year)
ET_0	=	Annual Reference Evapotranspiration[31] from Appendix A of CDWR 2009 (inches per year)
0.7	=	ET Adjustment Factor (ETAF)
LA	=	Landscape Area[32] includes Special Landscape Area[33] (square feet)

[30] California Department of Water Resources. 2009. Model Water Efficient Landscape Ordinance. Available online at: http://www.water.ca.gov/wateruseefficiency/docs/MWELO09-10-09.pdf

[31] Evapotranspiration is water lost to the atmosphere due to evaporation from soil and transpiration from plant leaves. For a more detailed definition, see this California Irrigation Management Information System (CIMIS) website: http://wwwcimis.water.ca.gov/cimis/infoEtoOverview.jsp;jsessionid=91682943559928B8A9A243D2A2665E19

[32] § 491 Definitions in CDWR 2009: "Landscape Area (LA) means all the planting areas, turf areas, and water features in a landscape design plan subject to the Maximum Applied Water Allowance calculation. The landscape area does not include footprints of buildings or structures, sidewalks, driveways, parking lots, decks, patios, gravel or stone walks, other pervious or non-pervious hardscapes, and other non-irrigated areas designed fro non-development (e.g., open spaces and existing native vegetation)."

[33] § 491 Definitions in CDWR 2009: "Special Landscape Area (SLA) means an area of the landscape dedicated

0.62	=	Conversion factor (to gallons per square foot)
SLA	=	Portion of the landscape area identified as Special Landscape Area (square feet)
0.3	=	the additional ETAF for Special Landscape Area

Based on the estimated outdoor water demand for watering lawns, the outdoor water energy intensity factors described above, and the utility-specific carbon intensity factor, GHG emissions from watering lawns may be calculated.

5.5.3 Recycled Water

After use, wastewater is treated and reused as reclaimed water. Any reclaimed water produced is generally redistributed to users via pumping. An estimate of the non-potable water demand to be met through the distribution of recycled water is needed. Estimates of the amount of energy needed to redistribute and, if necessary, treat reclaimed water is 400 kW-hr per acre foot.[34] Based on the estimated demand for reclaimed water, the estimated electricity demand and the utility-specific carbon-intensity factor, non-potable reclaimed water redistribution emissions are calculated.

5.5.4 Process

Industrial land uses can use a large amount of water for their processes. The water used for this will not be quantified since there is not sufficient water use data for this type of land use for the development of a default value. Water use is highly dependent on the specific industry..

5.6 Wastewater

Emissions associated with wastewater treatment include indirect emissions necessary to power the treatment process and direct emissions from degradation of organic material in the wastewater.

5.6.1 Direct Emissions

Direct emissions from wastewater treatment include emissions of CH_4 and biogenic CO_2. The method described by the Local Government Operations Protocol developed by the California Air Resources Board is suggested with default values assigned since detailed plant specific data will typically not be available.[35] The assumed daily 5-day carbonaceous biological oxygen

solely to edible plants, areas irrigated with recycled water, water features using recycled water and areas dedicated to active play such as parks, sports fields, golf courses, and where turf provides a playing surface.”

[34] CEC 2005. California’s Water-Energy Relationship. Final Staff Report. CEC-700-2005-011-SF.

[35] California Air Resources Board. 2008. *Local Government Operations Protocol - for the quantification and reporting of greenhouse gas emissions inventories*. Version 1.0. September 2008. Developed in partnership by California Air Resources Board, California Climate Action Registry, ICLEI - Local Governments for Sustainability, The Climate Registry

demand (BOD_5) of 200 mg/L-wastewater is multiplied by the protocol defaults for maximum CH_4-producing capacity (0.6 kg-CH_4/kg-BOD_5) and other default values to obtain the direct CH_4 emission. The amount of digester gas produced per volume of wastewater, and amount of N_2O per volume of wastewater needs to be determined. These values are then multiplied by the Global Warming Potential factor[36] of 21 for CH_4 or 310 for the GWP of N_2O that would be generated otherwise to obtain the annual CO_2 equivalent emissions.

5.6.2 Indirect Emissions

Indirect GHG emissions result from the electricity necessary to power the wastewater treatment process. The electricity required to operate a wastewater treatment plant is estimated to be 1,911 kW-hr per million gallons.[37] Based on the expected amount of wastewater requiring treatment, which will be assumed to be equal to the indoor potable water demand absent other data, the energy intensity factor and the utility-specific carbon-intensity factor, indirect emissions due to wastewater treatment are calculated.

5.7 Public Lighting

Lighting sources contribute to GHG emissions indirectly, via the production of the electricity that powers these lights. Lighting sources considered in this source category include streetlights, traffic lights, and parking lot lights. The annual electricity use may be estimated using the number of heads, the power requirements of each head, and the assumption that they operate for 12 hours a day on average for 365 days per year or 24 hours for traffic lights. The emission factor for public lighting is the utility-specific carbon-intensity factor. Multiplying the electricity usage by the emission factor gives an estimate of annual CO_2e emissions from public lighting.

5.8 Municipal Vehicles

GHG emissions from municipal vehicles are due to direct emissions from the burning of fossil fuels. Municipal vehicles considered in this source category include vehicles such as police cars, fire trucks, and garbage trucks. Data from reports by Medford, MA; Duluth, MN; Northampton, MA; and Santa Rosa, California[38] show that the CO_2 emissions from municipal

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[36] Intergovernmental Panel on Climate Change. IPCC Second Assessment - Climate Change 1995.

[37] CEC 2006. Refining Estimates of Water-Related Energy Use in California. PIER Final Project Report. Prepared by Navigant Consulting, Inc. CEC-500-2006-118. December.

[38] City of Medford. 2001. Climate Action Plan. October. http://www.massclimateaction.org/pdf/MedfordPlan2001.pdf

City of Northampton. 2006. Greenhouse Gas Emissions Inventory. Cities for Climate Protection Campaign. June. http://www.northamptonma.gov/uploads/listWidget/3208/NorthamptonInventoryClimateProtection.pdf

City of Santa Rosa. Cities for Climate Protection: Santa Rosa. http://ci.santa-rosa.ca.us/City_Hall/City_Manager/CCPFinalReport.pdf

Skoog., C. 2001. Greenhouse Gas Inventory and Forecast Report. City of Duluth Facilities Management and The International Council for Local Environmental Initiatives. October.http://www.ci.duluth.mn.us/city/information/ccp/GHGEmissions.pdf vehicles would be approximately[39] 0.05 MT per capita per year. Using these studies and the expected population, emissions from municipal vehicles may be calculated.

5.9 On-Road Mobile Sources

This section estimates GHG emissions from on-road mobile sources. The on-road mobile source emissions considered a project will be from the typical daily operation of motor vehicles by project residents and non-residents. The GHG emissions based upon all vehicle miles traveled associated with residential and non-residential trips regardless of internal or external destinations or purpose of trip are estimated. Traffic patterns, trip rates, and trip lengths are based upon the methods discussed below.

The CCAR GRP[40] recommends estimating GHG emissions from mobile sources at an individual vehicle level, assuming knowledge of the fuel consumption rate for each vehicle as well as the miles traveled per car. Since these parameters are not known for a future development, the CCAR guidance can not be used as recommended.

Estimating Trip Rates

The majority of transportation impact analysis conducted for CEQA documents in California apply trip generation rates provided by the Institute of Transportation Engineers (ITE) in their regularly updated report *Trip Generation*. The report is based on traffic counts data collected over four decades at built developments throughout the United States. This data is typically based on single-use developments, in suburban locations with ample free parking and with minimal transit service and demand management strategies in place. As a result, the ITE trip generation rates represent upper bound trip generation rates for an individual land use type. This represents a good basis against which to measure the trip-reducing effects of any one or more of the mitigation strategies that will be quantified in subsequent tasks. Therefore, we recommend ITE trip rates as the baseline condition against which the effectiveness of CAPCOA's mitigation measures is applied.

There are some CEQA traffic studies that use data other than ITE trip generation rates. Below we briefly discuss the possible use of these alternative datasets. These traffic studies typically use trip generation data from one of the following sources:

*SANDAG Traffic Generators***.** In the San Diego region, most studies use data from the SANDAG *Traffic Generators* report. This report is similar to the ITE *Trip Generation* in that it uses primarily suburban, single use developments, except that this dataset is based on traffic counts conducted in the San Diego region rather than throughout the United States. In studies where the SANDAG data is used, CAPCOA reviewers should apply the trip reduction estimates presented in subsequent tasks directly to the SANDAG trip generation rates.

[39] In an effort to be conservative, the largest per capita number from these four reports was used.

[40] California Climate Action Registry (CCAR). 2009. *General Reporting Protocol*. Version 3.1. January.

Travel Forecast Models. For some large development projects or general plans, the local or regional travel model is used to estimate the number of trips generated as well as trip lengths and vehicle speeds at which the individual trips occur. These models account for whether the trip segment occurs on a freeway or local streets as well as the degree of congestion. The values for trip generation rates and trip lengths using ITE and average trip lengths can be to assess the model estimates of vehicle trip generation and VMT. These comparisons should recognize that the travel models explicitly account for various factors that reduce trip-making and VMT, including the demographic characteristics of the site occupants, location and accessibility of the development site relative to other destinations in the region, the mix of land uses within the site and its surrounding area, and possibly the availability of effective transit service. When performing a comparison using the ITE trip rates and average trip lengths, the reviewer should take into consideration that these factors have already been accounted for in the modeling. Therefore, we recommend applying ITE trip rates and lengths along with the adjustments recommended elsewhere in this document (accounting for site location, design and demographics) as a means of reality-checking transportation model results.

Traffic counts at comparable developments. Some traffic assessments elect to conduct traffic counts at existing developments that are similar to the proposed development. When reviewing impact assessments produced using such information, the reviewer should take into account the extent to which the surveyed development(s) already contain trip generation and trip length reducing measures. Care needs to be used to avoid double-counting reductions.

Estimating VMT from Mobile Sources

Data on average trip lengths are used to translate trip generation rates into vehicle miles of travel (VMT). These trip lengths should be obtained from published sources of average trip lengths for different types of trip types (i.e., commute trips, shopping trips, and others) for each region within the state. Vehicle miles traveled (VMT) are calculated by multiplying ITE trip rates by the typical trip lengths.

Some mechanisms that reduce trip generation rates and trip lengths below these standard ITE-trip rates and current average trip lengths might be considered to be intrinsic parts of the development proposal rather than mitigation measures, such as project location (e.g., infill or transit oriented development [TOD]), density, mix of uses, and urban design. These are not considered part of the baseline condition, but are recognized and quantified as project design features (PDFs). This approach has the following advantages: 1) it creates a consistent basis of analysis for all development projects regardless of location and self-mitigating features already included in the project proposal, and 2) it highlights all elements of a project that reduce trip generation rates and vehicle miles traveled.

Other Factors Influencing Mobile Source GHG Emissions

Beyond trip generation, trip length and VMT, other factors that affect GHG emissions include traffic flow, vehicle fuel consumption rates, and fuel type.

Traffic speed and efficiency profiles are largely influenced by: a) the project location and degree of prevailing congestion in its vicinity, b) the degree to which the project implements traffic level-of-service mitigation measures often triggered by CEQA review, and c) actions taken by local, regional governments and Caltrans to reduce corridor or area-wide congestion.

The simplified mitigation assessment methods developed for this study use several categories of emissions factors per VMT that account for a) the generalized project location (core infill, inner ring suburbs, outer suburbs, rural), and b) and region-specific fleet and emissions rate if available.

While it is beyond the scope of this document to provide CAPCOA the ability to perform traffic speed and efficiency analysis, the study report advises CAPCOA on the type of analysis to expect to see in CEQA documents on development projects. CEQA impact and mitigation assessment methods should continue to perform air quality analysis using tools such as EMFAC that reference prevailing traffic speed profiles, especially for infill development and congested corridors, while applying appropriate credit for congestion reducing measures included in the project mitigation requirements, funded capital improvements plans, and fiscally constrained Regional Transportation Plans (RTPs.)

5.9.1 Estimating GHG Emissions from Mobile Sources

The CO_2 emissions from mobile sources were calculated with the trip rates, trip lengths and emission factors for running and starting emissions from EMFAC2007 as follows:

$$CO_2\ emissions = VMT \times EF_{running}$$

Where:

VMT = vehicle miles traveled
$EF_{running}$ = emission factor for running emissions

The CO_2e calculation involves the following assumptions:

- The emission factor depends upon the speed of the vehicle.
- EMFAC emission factors from the baseline year will be used for $EF_{running}$ based on County specific fleet mix for different trip types and adjusted to account for applicable regulations that are not currently incorporated yet into EMFAC.

Startup emissions are CO_2 emitted from starting a vehicle. Startup emissions are calculated using the following assumptions:

- The number of starts is equal to the number of trips made annually.
- The breakdown in vehicles is EMFAC fleet mix for County specific fleet mix.
- The emission factor for startup is calculated based on a weighted average of time between starts for each trip type (commute trips versus all other types).

Fleet distribution types will be based on EMFAC2007 or the most recent EMFAC version available. For mobile sources, the USEPA recommends assuming that CH_4, N_2O, and HFCs account for 5% of GHG emissions from on-road vehicles, taking into account their GWPs.[41] To incorporate these additional GHGs into the calculations, the total GHG footprint is calculated by dividing the CO_2 emissions by 0.95.

Emission factors for alternative fuel can be obtained from the CCAR General Reporting Protocol. For comparison with alternative fuel, N_2O and CH_4 emissions should be calculated separately as their emissions from alternative fuel are generally higher than from gasoline or diesel.

Low-emission-vehicle programs, such as neighborhood electric vehicles (NEV) or car sharing programs, will only be considered in accounting for GHG reductions if included in project-specific design or mitigation measures.

5.10 GHG Emissions from Specialized Land Uses

Below are methods to quantify GHG emissions from some additional land use categories that may be commonly found in development projects. These include golf courses and swimming pools. The methods proposed to determine GHG emissions associated with these sources is discussed in the following sections. The GHG emissions will typically fall into other categories such as landscape maintenance, water usage, and buildings, but since the data sources are different, they are explicitly described.

5.10.1 Golf Courses

Emission flux resulting from the construction of the golf course is not discussed, nor is the sequestration of CO_2 into the turf, trees, or lakes of the golf course. Operational CO_2 emissions were calculated for three areas: irrigation, maintenance (mowing), and on-site buildings' energy use. All three components are discussed in this section.

5.10.2 Calculating CO_2 Emissions from Irrigation of the Golf Course

The release of GHGs due to irrigation practices was calculated in two steps:

1. Identify the quantity of water needed.

2. Calculate the emissions associated with pumping the water.

1. *Identify the quantity of water needed.* Standard water use for an 18-hole golf course ranges from 250 to 450 acre-ft yearly. A survey of golf course superintendents conducted in the summer of 2003 by the Northern and Southern California Golf Associations revealed an annual average California usage of 345 acre-ft.[42] Numerous factors will affect the actual water usage

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[41] USEPA. 2005. *Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle.* Office of Transportation and Air Quality. February.

[42] Northern California Golf Association. Improving California Golf Course Water Efficiency, pg 14. http://www.owue.water.ca.gov/docs/2004Apps/2004-079.pdf

of a specific golf course, and it is likely to vary by year. ENVIRON recommends using the average usage of 345 acre-ft per year annually.

2. Calculate the associated emissions. Using the information identified above, ENVIRON calculates total emissions from irrigation of an 18-hole golf course as follows:

Estimate total dynamic head: This is the combination of lift (300 feet) and desired pressure. Standard athletic field sprinklers require a base pressure of approximately 65 psi.[43]

60 psi x 2.31 ft/psi [44]	=	*139 ft*
+ lift	=	*300 ft*
Total dynamic head	=	*439 ft*

Identify fuel unit and multiply by head: Possible pumping fuels include electricity, natural gas, diesel, and propane. In these calculations, ENVIRON assumes that all pumps will use electricity. Based on the literature, ENVIRON recommends using a pumping energy use of 1.551 kW-hr/acre-ft/ft.[45]

$$1.551 \text{ kW-hr/acre-ft/ft} \times 439 \text{ ft} = 681 \text{ kW-hr/acre-foot}$$

Multiply energy demand by emission factor and convert to MT: The energy demand per acre-ft calculated above is multiplied by the emission factor for the electricity generation source and converted to MT.

$$\frac{681 \text{kW-hr/acre-ft} \times 0.666 \text{ lbs } CO_2\text{/kW-hr}}{2204.62 \text{ lbs/ton}} = 0.21 \text{ MT } CO_2\text{/acre-ft}$$

The anticipated annual water demand will be multiplied by these values and then combined this with the calculated emission factor yields total annual emissions from irrigation of the golf course. Other outdoor land uses that require irrigation can follow a similar procedure.

5.10.3 Calculating CO_2 Emissions from Maintenance of the Golf Course

Maintenance emissions include the emissions resulting from the mowing of turf grass. The release of GHGs due to mowing was calculated in three steps:

1. Identify the area of turf and frequency of mowing.
2. Identify the efficiency of a typical mower.

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[43] Full Coverage Irrigation. Partial List of Customers Using FCI Nozzles. http://www.fcinozzles.com/clients.asp.

[44] Conversion factor: 1 psi = 2.31 feet of head. Kele & Associates Technical Reference: Liquid Level Measurement. http://www.kele.com/tech/monitor/Pressure/LiqLevMs.pdf

[45] Kansas State University Irrigation Management Series. Comparing Irrigation Energy Costs. Table 4. http://www.oznet.ksu.edu/library/ageng2/mf2360.pdf

3. Calculate the emissions associated with mowing.

1. *Identify the area of turf and frequency of mowing*: An Arizona State economic analysis of golf courses reports that on average 2/3 of the land within a golf course is maintained.[46] ENVIRON suggests assuming that the course will be mowed twice weekly, although high maintenance areas such as greens will be mowed more frequently.[47] ENVIRON recommends a growing season of 52 weeks/year.[48]

2. *Identify the efficiency of a typical mower*. Typical mower calculations are based on the specifications for a lightweight fairway mower (model 3235C) reported by John Deere's Golf & Turf division.[49] A typical mower will use one tank (18 gallons) of diesel per day (assumed to be 8 hours). Given the size specifications of the mower and assuming an average speed of 5.5 mph, such a mower can cover 44 acres on 18 gallons of diesel.

3. *Calculate the emissions associated with mowing*. Using the information collected above and a CO_2 emission factor for diesel combustion[50], ENVIRON calculates the emission factor for mowing the golf course:

$$\frac{2\ \text{mowings}/}{\text{week}} \times \frac{52\ \text{weeks}/}{\text{year}} \times \frac{18\ \text{gallons diesel}/}{44\ \text{acre-mowing}} \times \frac{22.4\ \text{lbs}\ CO_2/\ \text{gallon diesel}}{2204\ \text{lbs/ton}} = 0.43\ \text{MT}\ CO_2/\ \text{acre-year}$$

5.10.4 Calculating CO_2 Emissions from Building Energy Use at the Golf Course

Any of the non-residential building energy use data sources described in the Buildings section may be used to estimate energy intensity at the golf course.

5.11 Pools

Recreation centers may include various pools, spas, and restroom buildings; ENVIRON assumes that pools are the main consumers of energy in recreation centers. This section describes the methods used to estimate the GHGs associated with pools in recreation centers.

The energy used to heat and maintain a swimming pool depends on several factors, including (but not limited to): whether the pool is indoors or outdoors, size of the pool (surface area and depth), water temperature, and energy efficiency of pool pump and water heater, and whether

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[46] Total acreage divided by total acreage maintained. Arizona State University, Dr. Troy Schmitz. Economic Impacts and Environmental Aspects of the Arizona Golf Course Industry. http://agb.poly.asu.edu/workingpapers/0501.pdf.

[47] Based on Best Practices video. http://buckeyeturf.osu.edu/podcast/?p=51

[48] Based on 95% of Southern California Survey respondents report an irrigation season greater than 9-10 months. http://www.owue.water.ca.gov/docs/2004Apps/2004-079.pdf

[49] John Deere Product Specifications. 3235C Lightweight Fairway Mower. http://www.deere.com/en_US/ProductCatalog/GT/series/gt_lwfm_c_series.html

[50] EIA. Fuel and Energy Source Codes and Emission Coefficients. http://www.eia.doe.gov/oiaf/1605/factors.html

solar heating is used. By making assumptions for these parameters and using known or predicted values for energy use, ENVIRON estimates the electricity and natural gas use of an outdoor pool.

5.11.1 Recreation Center Characterization

In the calculations described below, ENVIRON assumes that the proposed pools will be outdoor pools with dimensions 50 meters by 22.9 meters (a typical, competition-size pool). ENVIRON bases electricity calculations on a pool that ran its standard water filter for 24 hours per day, 365 days per year. As there is little data publicly available on the energy use of commercial swimming pools, ENVIRON extrapolates energy consumption from information obtained from two sources: 1) Data on electricity used by pool pumps from Pacific Gas and Electric (PG&E),[51] and 2) Data on the annual cost to heat a commercial pool located in Carlsbad, CA.[52]

5.11.2 Electricity Use of Pools

A PG&E study on energy efficiency of a pool pump at the Lyons Pool in Oakland, CA, found an annual electricity use of 110,400 kilowatt hours per year (kWh per yr).[53] The study pool is smaller than the assumed size of the proposed pool (actual size of the Lyons Pool is 35 yards by 16 yards). Accordingly, ENVIRON scales the electricity use to reflect the larger size of the proposed pool.

5.11.3 Natural Gas Use of Pools

The estimated annual cost of heating a standard competition-size pool is $184,400 (or 72% of the total cost of pool operations).[54] ENVIRON used the average PG&E commercial rate for natural gas of $0.95 per therm to convert this cost into annual natural gas use (hundred cubic feet per year [ccf/year]).[55] The commercial rate averages the variable cost due to energy usage and time of year. This corresponds to approximately 184,400 ccf per year.[56]

This value is comparable to that obtained from the pool industry.[57] The estimated cost of heating a residential pool using a natural gas heater is about one dollar per square foot of water

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[51] PG&E. 2006. Energy Efficient Commercial Pool Program, Preliminary Facility Report. Lyons Pool, "City of Oakland/Oakland Unified School District." October.

[52] Mendioroz, R. 2006. Fueling Change: A Number of Design Schemes and Alternative-Energy Strategies Can Help Operators Beat the Price of Natural Gas. Athletic Business. March.

[53] PG&E. 2006. Energy Efficient Commercial Pool Program, Preliminary Facility Report. Lyons Pool, "City of Oakland/Oakland Unified School District." October.

[54] Mendioroz, R. 2006. Fueling Change: A Number of Design Schemes and Alternative-Energy Strategies Can Help Operators Beat the Price of Natural Gas. Athletic Business. March.

[55] Pacific Gas and Electric (PG&E). 2007. Gas Rate Finder. Vol 36-G, No. 9. September. http://www.pge.com/tariffs/GRF0907.pdf

[56] At the commercial rate given 1 ccf costs $1.

[57] SolarCraft Services Inc. 2007. Phone conversation with Chris Bumas on September 18, 2007. Novato, CA http://www.solarcraft.com/

surface area per month ($/sqft-month) in residential therms.[58] Applying this value to a competition-size pool yields an annual natural gas use of 147,600 ccf/year.

5.11.4 Conversion of Electricity and Natural Gas Use to Greenhouse Gas Emissions

ENVIRON used utility-specific electricity and natural gas emission factors to calculate the total CO_2 emissions for each pool. A summary of the calculations is shown below:

$$Emissions\ from\ Electricity\left(\frac{Tonnes\ CO_2/yr}{1{,}000\,sqft}\right) = \frac{Energy\ Use\ (ccf/yr) \times Emission\ Factor\ (lbs\ CO_2e/ccf) \times Conversion\ Factor\ (tonne/2205\,lbs)}{Surface\ Area\ of\ Pool\ (1{,}000\,sqft)}$$

$$Emissions\ from\ Natural\ Gas\left(\frac{Tonnes\ CO_2/yr}{1{,}000\,sqft}\right) = \frac{Energy\ Use\ (ccf/yr) \times Emission\ Factor\ (lbs\ CO_2e/ccf) \times Conversion\ Factor\ (tonne/2205\,lbs)}{Surface\ Area\ of\ Pool\ (1{,}000\,sqft)}$$

[58] The residential price for one therm of natural gas.

Appendix C

Transportation Appendices

Appendix C.1

Transportation Calculations

Appendix C.1 – Transportation Calculations

Table C-1 provides further detail into the calculations of percent reduction in vehicle miles traveled (VMT) for each of the fact sheets (that have references to the appendix). Many of the strategies in the table below do not provide the full equations for percent reduction in vehicle miles traveled. Only the equations or variables which require further detail are outlined here. The table also provides detail on any assumptions which are made to perform the calculations and the basis of such assumptions. An additional section below Table C-1 provides a detailed discussion of the calculations made for the transit accessibility strategy.

Table C-1
Transportation Calculations

Strategy	T#	Equation	Variable	Value	Source/Notes
Increase Density (Land Use/Location)	A2	A = Percentage increase in housing units per acre = (number of housing units per acre – number of housing units per acre for typical ITE development) / (number of housing units per acre for typical ITE development)	number of housing units per acre for typical ITE development	7.6 = blended average density of residential development in the US in 2003	A.C. Nelson. "Leadership in a New Era." *Journal of the American Planning Association,* Vol. 72, Issue 4, 2006, pp. 393-407 – as cited in *Growing Cooler*
		A = Percentage increase in jobs per job acre = (number of jobs per job acre – number of jobs per job acre for typical ITE development) / (number of jobs per job acre for typical ITE development)	number of jobs per job acre for typical ITE development	20 = average jobs per job acre	Year 2005 Land Use, Sacramento County Travel Demand Model, 2008
Improve Design of Development (Land Use/Location)	A3	A = Percentage increase in intersections versus a typical ITE suburban development = (intersections per square mile of project – intersections per square mile of typical ITE suburban development) / (intersections per square mile of typical ITE suburban development)	intersections per square mile of typical ITE suburban development	36 = ITE site average intersection density	Based on Fehr & Peers methodology for analysis in the report: *Proposed Trip Generation, Distribution, and Transit Mode Split Forecasts for the Bayview Waterfront Project Transportation Study*, Fehr & Peers, 2009

Table C-1 Transportation Calculations					
Strategy	**T#**	**Equation**	**Variable**	**Value**	**Source/Notes**
Increase Diversity (Mixed Use) (Land Use/Location)	A5	A = Percentage increase in land use index versus single use development = (project land use index – single land use index) / single land use index	single land use index	0.15 = - [1*(ln 1) + 0.01*(ln 0.01)+…+0.01*(ln 0.01)]/ ln(6)	--
Increase Destination Accessibility (Land Use/Location)	A6	A = Percentage decrease in distance to downtown or major job center = (distance to downtown/job center for typical ITE development – distance to downtown/job center for project) / (distance to downtown/job center for typical ITE development)	distance to downtown/job center for typical ITE development	12 miles (average work trip length from NHTS)	2000-2001 California Statewide Travel Survey, 2001 NHTS Summary of Travel Trends, p.15 (Table 5)
Increase Transit Accessibility (Land Use/Location)	A7	A = Increase in transit mode share = % transit mode share for project - % transit mode share for typical ITE development	% transit mode share for typical ITE development	1.3%	NHTS, 2001 http://www.dot.ca.gov/hq/tsip/tab/documents/travelsurveys/Final2001_StwTravelSurveyWkdayRpt.pdf, p.150 (Suburban – SCAG, SANDAG, Fresno County.)
		B = Adjustment from transit mode share to VMT = 1 / average vehicle occupancy * conversion from VT to VMT = 0.67	Divide by average vehicle occupancy to translate to VT	1 / average vehicle occupancy = 1 / 1.5 = 0.67	NHTS, http://www.dot.ca.gov/hq/tsip/tab/documents/travelsurveys/2000_Household_Survey.pdf, p.iii
			conversion from VT to VMT	1	Assume all trip lengths are equal (vehicle trips to VMT) [1]

[1] To convert to vehicle miles traveled, we assume that all vehicle trips will average out to typical trip length ("assume all trip lengths are equal"). Thus, we can assume that a percentage reduction in vehicle trips will equal the same percentage reduction in vehicle miles traveled.

Table C-1
Transportation Calculations

Strategy	T#	Equation	Variable	Value	Source/Notes
Unbundle Parking Cost from Property Cost (Parking Pricing/Policy)	C3	A = Adjustment from Vehicle Ownership to VMT = average trips per 2 vehicles * 1 vehicle per average trips =(9.8 trips/ 2 vehicles) * (1 vehicle / 5.7 trips) = 0.85	Average trips per X vehicles	Households with 2 vehicles take 9.8 trips while households with 1 vehicle take 5.7 trips per day	i.e. A reduction of 1 vehicle leads to an 0.85 reduction in vehicle trips http://www.dot.ca.gov/hq /tsip/tab/documents/travel surveys/2000_Household _Survey.pdf, table 8.7
Expand Transit Network (Transit System Improvements)	D2	D = Adjustment for Transit Ridership Increase to VMT	--	0.67	see Increase Transit Accessibility
Enhance Transit Service Frequency/Speed (Transit System Improvements)	D3	E = Adjustment for Transit Ridership Increase to VMT	--	0.67	see Increase Transit Accessibility
Implement Bus Rapid Transit (Transit System Improvements)	D4	D = Adjustment for Transit Ridership Increase to VMT	--	0.67	see Increase Transit Accessibility
Implement Required Trip Reduction Programs (Trip Reduction Programs)	E2	C = Adjustment from vehicle mode share to commute VMT	--	1	Assume all trip lengths are equal (vehicle mode share to vehicle trips to VMT) [i]
Provide a Transit Fare Subsidy (Trip Reduction Programs)	E3	C = Adjustment from commute VT to commute VMT	--	1	Assume all trip lengths are equal (vehicle trips to VMT) [i]
Implement Commute Trip Reduction Marketing (Trip Reduction Programs)	E7	C = Adjustment from commute VT to commute VMT	--	1	Assume all trip lengths are equal (vehicle trips to VMT) [i]

Table C-1 Transportation Calculations					
Strategy	**T#**	**Equation**	**Variable**	**Value**	**Source/Notes**
Provide Employer-Sponsored Vanpool/Shuttle (Trip Reduction Programs)	E8	C = Adjustment from vanpool mode share to commute VMT	--	0.67	see Increase Transit Accessibility
Implement Bike-Sharing Programs (Trip Reduction Programs)	E10	% VMT Reduction = A * B * C = 2% * 7% * 20% = 0.03%	--	--	--
		A = 2% = Net new bicycle mode share = (existing mode share * % increase in bicycle mode share) – existing mode share	Existing mode share	Estimate at 1%	Pucher et al., 2010
			% increase in bicycle mode share	135 – 300%	Pucher et al., 2010, Table 4 (see fact sheet for calculations)
		B = % of new bicycle trips shifting from vehicles (from literature)	--	6-7%	Pucher et al., 2010 and Bike-Share in NYC, 2009, Table 4, p.45
		C = adjustments to convert from vehicle mode share to VMT * adjustment for shorter than average trip lengths = 1*20%	adjustments to convert from vehicle mode share to VMT	1	Assume all trip lengths are equal (vehicle mode share to vehicle trips to VMT) [i]
			adjustment for shorter than average trip lengths	1.94/9.9 = 20%	Adjustment to reflect ratio of bike trip length to average trip length (this strategy will only replace the shorter vehicle trips that can be reasonably replaced by a bicycle). [1.94 miles (average bike trip length from Moving Cooler Appendices B-28 referencing NHTS) / 9.9 miles (average household trip length from NHTS Transferability, 2001 NHTS, http://nhts-gis.ornl.gov/transferability/Default.aspx)]

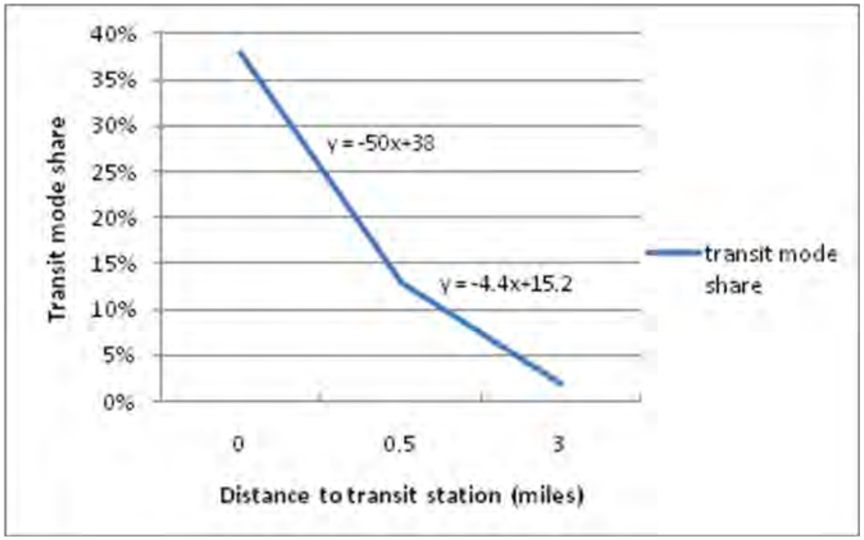
Table C-1 Transportation Calculations					
Strategy	**T#**	**Equation**	**Variable**	**Value**	**Source/Notes**
Provide End of Trip Facilities (Trip Reduction Programs)	E11	*utilizing the same equation in bike sharing program section, set A = 1.3% = (7.1% - 5.8%) % VMT Reduction = A * B * C = 1.3% * 7% * 20% = 0.02%	--	--	--
Establish Schoolpool (Trip Reduction Programs)	E13	B = Adjustments to convert from participation to daily VMT to annual school VMT = [(avg # of families per carpool - 1) / avg # of families per carpool] *% of school days	avg # of families per carpool	2.5	TDM Case Studies, DRCOG, p.13
			% of school days	75% = 39 school weeks/ 52 weeks	TDM Case Studies, DRCOG, p.13
Provide School Buses (Trip Reduction Programs)	E14	B = Adjustments to convert from participation to daily VMT to annual school VMT = % of school days	% of school days	75% = 39 school weeks/ 52 weeks	TDM Case Studies, DRCOG, p.13
Cordon Pricing (Road Pricing Management)	F2	A = % increase in pricing for passenger vehicles to cross cordon	--	100 – 500%	*Moving Cooler* uses peak hour price per mile instead of crossing price. The percentage change can still be calculated to provide a general estimate for a high range % change. Assuming a baseline of $0.10, calculated percentage increase to $0.49 - $0.65 (*Moving Cooler*) and adjusted with rounding
		C = % of VMT Impacted by Cordon Pricing and Mode Shift Adjustments = %VMT impacted by congestion pricing * Mode shift adjustment = 8.8% (peak period) and 21% (all day)	--	--	--

Table C-1 Transportation Calculations					
Strategy	**T#**	**Equation**	**Variable**	**Value**	**Source/Notes**
		Peak period = 25% * 35% = 8%	%VMT impacted by congestion pricing	25%	20% of trips are work trips (NHTS Transferability, 2001 NHTS, http://nhts-gis.ornl.gov/transferability/Default.aspx) and round up assuming other trips travel during peak periods
			Mode shift adjustment	35% = 20% + 30%/2	Of the estimated trips affected to the increase in price, assume 50% is either a time of day shift/route shift/no change, 30% convert to HOV trips (with average 2 ppl per HOV), and 20% are trip reductions/shift to transit, walk or bike
		Static all day price (London) = 60% * 35% = 21%	% VMT impacted by congestion pricing	60%	Conservatively assume 60% of trips fall in the peak periods and mid-day
			Mode shift adjustment	35%= 20% + 30%/2	Of the estimated reduced trips due to the increase in price, assume 50% is either a time of day shift/route shift/no change, 30% convert to HOV trips (with average 2 people per HOV), and 20% are trip reductions/shift to transit, walk or bike

Increase Transit Accessibility (Land Use/Location)

Distance to transit	Transit mode share calculation equation (where x = distance of project to transit)
0 – 0.5 miles	-50*x + 38

0.5 to 3 miles	-4.4*x + 15.2
> 3 miles	no impact
Source: Lund et al, 2004; Fehr & Peers 2010	



Data was taken from Table 5-25 of Lund et al, 2004. The table provided transit commute mode shares for those living with ½ mile of a rail station for 5 sites surveyed within California. Removing the extreme low and high percentages, this provided a range of transit commute mode share of 13% to 38%. A simple linear extrapolation was conducted to provide a relationship for distance to transit (between 0 and ½ mile) to transit mode share, via the equation: transit mode share = -50 * distance to transit + 38. The table also provided transit mode shares for those living from ½ to 3 miles from a station, a range from 2% to 13%. Using the same methodology, a relationship for distance to transit (between ½ mile and 3 miles) to transit mode share is provided via the equation: transit mode share = -4.4x + 15.2.

Appendix C.2

Trip Adjustment Factors

Appendix C.2 – Trip Adjustment Factors

The trip adjustment factors are not explicitly used for calculations of reduction in vehicle miles traveled (VMT) but serve as an added resource point for users of this document. For example, we report all commute trip reduction (CTR) program strategies as a percentage reduction in commute VMT. If the user would like to translate this to project level VMT (assuming the project is NOT an office park), and the user does not have statistics about the project area readily available, then the trip adjustment factors table can be utilized.

Example: Assume the user is providing a 15% reduction in commute VMT for a implementation of a ride share program. To calculate an estimated reduction in project level VMT, the user can multiple 15% by 20% (NHTS average % of work trips) and again multiply by 12.0 / 9.9 (average work trip length/average trip length) to adjust for both the portion of trips which are work related and that work trips tend to be longer than average trips.

TABLE C-2. TRIP ADJUSTMENT FACTORS

	NHTS[1]	Sacramento Region[2]	San Diego Region[3]	Rural (Kings County, CA)[4]
Average Work Trip Length (vehicle)	12.0	10.4	8.4	-
Average Trip Length (vehicle)	9.9	6.8	6.9	8.7
Average % of Work Trips	20%	20%	-	12%
Average % of School Trips	9.8%	-	-	-
Average Length of School Trips (Vehicle)	6.0	-	4.2	-
Average Vehicle Occupancy (All Trips)	1.5	1.4	1.5	-

Source:
1. 2000-2001 California Statewide Travel Survey, 2001 NHTS Summary of Travel Trends
2. SACMET model, Fehr & Peers, 2010.
3. SANDAG Brief Guide of Vehicular Traffic Generation Rates for the San Diego Region (April 2002)
4. NHTS Transferability, 2001 NHTS, http://nhts-gis.ornl.gov/transferability/Default.aspx

Appendix C.3

Induced Travel Memo

FEHR & PEERS
TRANSPORTATION CONSULTANTS

MEMORANDUM

Date: February 3, 2010

To: CAPCOA Team

From: Tien-Tien Chan, Jerry Walters, and Meghan Mitman

Subject: ***Induced Travel Material***

SF10-0475

Induced travel is a term used to describe how travel demand responds to roadway capacity expansion and roadway improvements. Consistent with the theory of supply and demand, the general topic of research concerning induced travel is that reducing the cost of travel (i.e., reduced travel time due to a new road improvement) will increase the amount of travel. In other words, road improvements alone can prompt traffic increases. To what degree and under what circumstances these increases occur is a matter of debate and the key subject of most induced travel research. We have attached the following documents which represent research on induced travel effects:

- *Comparative Evaluations on the Elasticity of Travel Demand* – study conducted for the Utah DOT which included national literature review of induced travel studies
- *Are Induced-Travel Studies Inducing Bad Investments?* – article by Cervero in Access Magazine: Transportation Research at the University of California
- *Road Expansion, Urban Growth, Growth, and Induced Travel: A Path Analysis* – APA Journal paper by Cervero, also discusses the impacts of induced growth and induced investments

The reader should be aware that conditions may vary considerably and the extent of induced travel depends on a variety of factors, including: the degree of prior congestion in the corridor, its duration over hours of the day, its extent over lane miles of the corridor, the degree to which un-served traffic diverts to local streets and the degree of congestion on those routes, the availability of alternate modes within the corridor, whether corridor is radial and oriented toward downtown with high parking cost and limited availability or circumferential, planned level of growth in the corridor, whether the corridor is interstate or interregional, whether it is a truck route, and other factors.

GHG reduction strategies such as transportation system management (e.g. signal coordination, adaptive signal control) may also have the potential for inducing travel. For such strategies, if the estimated improvement exceeds 10% benefit in travel time reduction, we recommend conducting project specific analysis on induced travel prior to establishing GHG reduction benefits.

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www.fehrandpeers.com

Appendix D

Building Mitigation Measure Quantification Methods

This Appendix summarizes the steps and assumptions used in two of the mitigation strategies – exceed Title 24 energy efficiency standards (BE-1) and installing energy efficient appliances (BE-4).

Background

GHGs are emitted as a result of activities in residential and commercial buildings when electricity and natural gas are used as energy sources. New California buildings must be designed to meet the building energy efficiency standards of Title 24, also known as the California Building Standards Code. Title 24 Part 6 regulates energy uses including space heating and cooling, hot water heating, ventilation, and hard-wired lighting. By committing to a percent improvement over Title 24, a development reduces its energy use and resulting GHG emissions.

The Title 24 standards have been updated twice (in 2005 and 2008)[1] since some of these data used to estimate energy use were compiled. California Energy Commission (CEC) has published reports estimating the percentage deductions in energy use resulting from these new standards. Based on CEC's discussion on average savings for Title 24 improvements, these CEC savings percentages by end use can be used to account for reductions in electricity and natural gas use due to the two most recent updates to Title 24. Since energy use for each different system type (ie, heating, cooling, water heating, and ventilation) as well as appliances is defined in this survey, the use of survey data with updates for Title 24 will easily allow for application of mitigation measures aimed at reducing the energy use of these devices in a prescriptive manner.

Another mitigation measure to reduce a building's energy consumption as well as the associated GHG emissions from natural gas combustion and electricity production is to use energy-efficient appliances. For residential dwellings, typical builder-supplied appliances include refrigerators and dishwashers. Clothes washers and ceiling fans would be applicable if the builder supplied them. For commercial land uses, only energy-efficient refrigerators have been evaluated for grocery stores.

1 California Energy Commission. 2003. Impact Analysis: 2005 Update to the California Energy Efficiency Standards for Residential and Nonresidential Buildings. Available at: http://www.energy.ca.gov/title24/2005standards/archive/rulemaking/documents/2003-07-11_400-03-014.PDF
California Energy Commission. 2006. California Commercial End-Use Survey. Prepared by Itron Inc. Available at: http://www.energy.ca.gov/ceus/

Methodology

Datasets

The Residential Appliance Saturation Survey (RASS)[2] and California Commercial Energy Use Survey (CEUS)[3] datasets were used to estimate the energy intensities of residential and non-residential buildings, respectively, since the data is available for several land use categories in different climate zones in California. The RASS dataset further differentiates the energy use intensities between single-family, multi-family and townhome residences.

The Energy Star and Other Climate Protection Partnerships 2008 Annual Report[4] and subsequent Annual Reports were reviewed for typical reductions for energy-efficient appliances. ENERGY STAR residential refrigerators, clothes washers, dishwashers, and ceiling fans use 15%, 25%, 40%, and 50% less electricity than standard appliances, respectively. ENERGY STAR commercial refrigerators use 35% less electricity than standard appliances.

Calculations

Exceeding Title 24 Energy Efficiency Standards (BE-1)

RASS and CEUS datasets were used to obtain the energy intensities of different end use categories for different building types in different climate zones. Energy intensities from CEUS are given per square foot per year and used as presented. RASS presents Unit Energy Consumption (UEC) per dwelling unit per year and saturation values; the energy intensities used in this analysis are products of the UEC and saturation values.

Data for some climate zones is not presented in the CEUS and RASS studies. However, data from adjacent climate zones is assumed to be representative and substituted as follows:

For non-residential building types:
Climate Zone 11 used Climate Zone 9 data.
Climate Zone 12 used Climate Zone 9 data.
Climate Zone 14 used Climate Zone 1 data.
Climate Zone 15 used Climate Zone 10 data.

For residential building types:
Climate Zone 6 used Climate Zone 2 data.
Climate Zone 14 used Climate Zone 1 data.
Climate Zone 15 used Climate Zone 10 data.

RASS and CEUS data are based on 2002 consumption data. Because older buildings tend to be less energy efficient, and the majority of the buildings in the survey were likely constructed

2 California Statewide Residential Appliance Saturation Study Reporting Center. Available at: http://websafe.kemainc.com/RASSWEB/DesktopDefault.aspx

3 California Energy Commission. 2006. California Commercial End-Use Survey. Prepared by Itron Inc. Available at: http://www.energy.ca.gov/ceus/

4 United States Environmental Protection Agency 2009. ENERGY STAR and Other Climate Protection Partnerships: 2008 Annual Report. Available at: http://www.epa.gov/cpd/pdf/2008AnnualReportFinal.pdf

before 2001, the RASS and CEUS data likely overestimate energy use for a 2001 Title 24-compliant building.

To account for updates since the 2001 Title 24 standards, percentage reductions for each end use category taken directly from the CEC's "Impact Analysis for 2005 Energy Efficiency Standards" and "Impact Analysis 2008 Update to the California Energy Efficiency Standards for Residential and Nonresidential Buildings" reports were applied to the CEUS and RASS datasets for improvements from 2001 to 2005, and 2005 to 2008, respectively (see Tables D-1 and D-2). For the CEUS data, exterior lighting was assumed to be covered by Title 24 lighting and therefore has the full percentage reductions taken. Interior lighting was assumed to be 50% Title 24 and 50% non-Title 24 uses. Therefore only half of the reduction for lighting was applied. The resulting 2008 numbers were then used as baseline energy intensities for this mitigation strategy. The total baseline energy intensities are calculated as follows:

$$\text{Baseline} = \sum\left[T24_{2001} \times \left(1 - R_{2001\text{-}2005}\right) \times \left(1 - R_{2005\text{-}2008}\right)\right] + \sum NT24$$

Where:

Baseline	=	Total baseline energy intensities of building category
$T24_{2001}$	=	Energy intensities of Title 24 regulated end use from RASS or CEUS
$R_{2001\text{-}2005}$	=	Reduction from 2001 to 2005
$R_{2005\text{-}2008}$	=	Reduction from 2005 to 2008
NT24	=	Non-Title 24 regulated end use energy intensities

Table D-1

Reduction in Title 24 Regulated End Use for Non-Residential Buildings

Energy Source	End Use	Reduction from 2001 to 2005	Reduction from 2005 to 2008
Electricity	Heating	4.9%	37.2%
	Ventilation	5.0%	1.5%
	Refrigeration	0.0%	0.0%
	Process	0.0%	0.0%
	Office Equipment	0.0%	0.0%
	Motors	0.0%	0.0%
	Miscellaneous	0.0%	0.0%
	Interior Lighting	4.9%	5.9%
	Water Heating	0.0%	0.0%
	Cooking	0.0%	0.0%
	Air Compressors	0.0%	0.0%
	Cooling	6.7%	8.3%
	Exterior Lighting	9.8%	11.7%
Natural Gas	Cooking	0.0%	0.0%
	Cooling	10.4%	9.3%
	Heating	3.1%	15.9%
	Water Heating	0.0%	0.0%
	Process	0.0%	0.0%
	Miscellaneous	0.0%	0.0%

Table D-2
Reduction in Title 24 Regulated End Use for Residential Buildings

Energy Source	End Use (As presented in RASS Dataset)	Reduction from 2001 to 2005			Reduction from 2005 to 2008		
		Multi-family	Single family	Town home	Multi-family	Single family	Town home
Electricity	Conv. Electric heat	24.3%	19.8%	24.3%	19.7%	22.7%	19.7%
	HP Eheat	24.3%	19.8%	24.3%	19.7%	22.7%	19.7%
	Aux Eheat	24.3%	19.8%	24.3%	19.7%	22.7%	19.7%
	Furnace Fan	24.3%	19.8%	24.3%	19.7%	22.7%	19.7%
	Central A/C	24.3%	19.8%	24.3%	19.7%	22.7%	19.7%
	Room A/C	24.3%	19.8%	24.3%	19.7%	22.7%	19.7%
	Evap Cooling	24.3%	19.8%	24.3%	19.7%	22.7%	19.7%
	Water Heat	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Solar Water Heater	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Dryer	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Clothes Washer	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Dish Washer	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	First Refrigerator	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Second Refrigerator	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Freezer	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pool Pump	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Spa	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Outdoor Lighting	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Range/Oven	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	TV	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Spa Electric Heat	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Microwave	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Home Office	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	PC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Water Bed	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Well Pump	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Miscellaneous	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Natural Gas	Primary Heat	15.7%	6.7%	15.7%	7.0%	10.0%	7.0%
	Auxiliary Heat	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Conv. Gas Water Heat	15.7%	6.7%	15.7%	7.0%	10.0%	7.0%
	Solar Water Heat w/Gas Backup	15.7%	6.7%	15.7%	7.0%	10.0%	7.0%
	Dryer	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Range/Oven	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pool Heat	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Spa Heat	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Miscellaneous	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

The same approach was used to quantify GHGs emission reduction from exceeding Title 24 energy efficiency standards by 1%. The 1% reduction was applied to only energy use intensities for Title 24 regulated end use categories. For the CEUS data, the reduction was not applied to any portion of interior lighting. The reduced energy use intensities were added to the unadjusted energy use intensities for non-Title 24 regulated end use categories to obtain the total energy use intensities for exceeding Title 24 energy efficiency standards by 1% for each building category. These were then compared to the baseline line energy intensities for the overall percentage reduction as follows:

$$\text{Percentage Reduction} = 1 - \frac{\sum\left[T24_{2001} \times \left(1 - R_{2001\text{-}2005}\right) \times \left(1 - R_{2005\text{-}2008}\right) \times 99\%\right] + \sum NT24}{\text{Baseline}}$$

Where:

Baseline	=	Total baseline energy intensities of building category
$T24_{2001}$	=	Energy intensities of Title 24 regulated end use from RASS or CEUS
$R_{2001\text{-}2005}$	=	Reduction from 2001 to 2005
$R_{2005\text{-}2008}$	=	Reduction from 2005 to 2008
NT24	=	Non-Title 24 regulated end use energy intensities

Installing Energy Efficient Appliances

The same baseline line energy use intensities from the Exceeding Title 24 Energy Efficiency Standards mitigation were used for this mitigation strategy. For all appliances except ceiling fan, the reductions as presented in the ENERGY STAR 2008 annual report were applied to the energy use intensities of the corresponding energy end use categories. All other end use categories were kept unadjusted. The percentage reductions were calculated as follows:

$$\text{Percentage Reduction} = 1 - \frac{\text{Appliance Intensity} \times \left(1 - \text{ESR}\right) + \sum \text{Other End Use}}{\text{Baseline}}$$

Where:

Baseline	=	Total baseline energy intensities of building category
Appliance Intensity	=	2008 baseline energy intensity of appliance in consideration
ESR	=	Reduction from ENERGY STAR appliance
Other End Use	=	2008 baseline energy intensity of all other end uses

RASS does not specify a ceiling fan end-use; rather, electricity use from ceiling fans is accounted for in the “Miscellaneous” category which includes interior lighting, attic fans, and other miscellaneous plug-in loads. Since the electricity usage of ceiling fans alone is not specified, a value from the National Renewable Energy Laboratory (NREL) Building American Research Benchmark Definition (BARBD)[5] was used. BARBD reported that the average energy use per ceiling fan is 84.1 kWh per year. In this mitigation measure, it was assumed that each multi-family, single-family, and townhome residence has one ceiling fan. Therefore, the 50% reduction from ENERGY STAR for ceiling fan was applied to 84.1 kWh of the electricity attributed to the Miscellaneous RASS category. In other words, 42.05 kWh was subtracted from the electricity end use intensities of the "Miscellaneous RASS" category in evaluating the GHGs emission reduction from installing energy efficient ceiling fans.

The total energy use intensities with reduction from each appliance in consideration were then compared to the baseline line energy intensities for the overall percentage reduction as follows:

$$\text{Percentage Reduction} = 1 - \frac{(\text{Misc} - 42.05) + \sum \text{Other End Use}}{\text{Baseline}}$$

Where:

Baseline = Total baseline energy intensities of building category
Misc = 2008 energy intensity in Miscellaneous category for electricity
Other End Use = 2008 baseline energy intensity of all other end uses

5 NREL. 2010. Building America Research Benchmark Definition. Available online at: http://www.nrel.gov/docs/fy10osti/47246.pdf

Appendix E

Carbon, Water and CO_2 Sequestration Intensity Factors

Table E-1: Carbon Intensity

Utility	CO_2 intensity (lb/MWh)[1]								
	2000	2001	2002	2003	2004	2005	2006	2007	Suggested Value[2]
Anaheim Public Utilities						1,399.80	1,416.74	1,543.28	1,416.74
Austin Energy						1,127.37	1,077.97	1,117.37	1,077.97
City and County of San Francisco						76.28			76.28
City of Palo Alto Public Utilities						320.94	39.02	426.82	39.02
Glendale Water & Power						1,065.00			1,065.00
Los Angeles Department of Water & Power	1,407.44	1,403.39	1,348.48	1,360.07	1,360.60	1,303.58	1,238.52	1,227.89	1,238.52
Pacific Gas & Electric Company					566.2	489.16	455.81	635.67	455.81
PacifiCorp					1,811.00	1,812.22	1,747.30	1,775.28	1,747.30
Pasadena Water & Power						1,409.65	1664.14		1,664.14
Platte River Power Authority						1,970.93	1,955.66	1,847.88	1,955.66
Riverside Public Utilities						1,333.45	1,346.15	1,325.65	1,346.15
Roseville Electric							565.52	793.8	565.52
Sacramento Municipal Utility District					769	616.07	555.26	714.31	555.26
Salt River Project							1,546.28	1,469.90	1,546.28
San Diego Gas & Electric					613.75	546.46	780.79	806.27	780.79
Seattle City Light								17.77	17.77
Sierra Pacific Resources								1,442.78	1,442.78
Southern California Edison					678.88	665.72	641.26	630.89	641.26
Turlock Irrigation District							682.48	807	682.48

Notes:
1. Based on Table G6 of Local Government Operation Protocol version 1.1
2. The suggested values are based on 2006. If no 2006 value was available, 2005 was used followed by 2007.

Table E-2: Water Intensity

	Indoor Water Uses		Outdoor Water Uses	
	Northern California	Southern California	Northern California	Southern California
	kWh/MG			
Water Supply and Conveyance	2,117	9,727	2,117	9,727
Water Treatment	111	111	111	111
Water Distribution	1,272	1,272	1,272	1,272
Wastewater Treatment	1,911	1,911	0	0
Regional Total	5,411	13,022	3,500	11,111

Note: Based on Table ES-1 from CEC. 2006. Refining Estimates of Water-Related Energy Use in California, CEC-500-2006-118.

Table E-3: Default CO_2 Sequestration Accumulation

Land Use	Sub-Category	Default annual CO_2 accumulation per acre[1] (tonnes CO_2/year)
Forest Land	Scrub	14.3
	Trees	
Cropland		111
Grassland	--	6.2
Wetlands	--	4.31

Note: Based on Tables 4.3, 4.7 and 6.4 from IPCC. 2006. Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines). Available online at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.htm

EXHIBIT

5

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Travel and the Built Environment

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Travel and the Built Environment

A Meta-Analysis

Reid Ewing and Robert Cervero

Problem: Localities and states are turning to land planning and urban design for help in reducing automobile use and related social and environmental costs. The effects of such strategies on travel demand have not been generalized in recent years from the multitude of available studies.

Purpose: We conducted a meta-analysis of the built environment-travel literature existing at the end of 2009 in order to draw generalizable conclusions for practice. We aimed to quantify effect sizes, update earlier work, include additional outcome measures, and address the methodological issue of self-selection.

Methods: We computed elasticities for individual studies and pooled them to produce weighted averages.

Results and conclusions: Travel variables are generally inelastic with respect to change in measures of the built environment. Of the environmental variables considered here, none has a weighted average travel elasticity of absolute magnitude greater than 0.39, and most are much less. Still, the combined effect of several such variables on travel could be quite large. Consistent with prior work, we find that vehicle miles traveled (VMT) is most strongly related to measures of accessibility to destinations and secondarily to street network design variables. Walking is most strongly related to measures of land use diversity, intersection density, and the number of destinations within walking distance. Bus and train use are equally related to proximity to transit and street network design variables, with land use diversity a secondary factor. Surprisingly, we find population and job densities to be only weakly associated with travel behavior once these other variables are controlled.

Takeaway for practice: The elasticities we derived in this meta-analysis may be used to adjust outputs of travel or activity models that are otherwise insensitive to variation in the built environment, or be used in sketch planning applications ranging from climate action plans to health impact assessments. However, because sample sizes are small, and very few studies control for residential preferences and attitudes, we cannot say that planners should generalize broadly from our results. While these elasticities are as accurate as currently possible, they should be understood to contain unknown error and have unknown confidence intervals. They provide a base, and as more built-environment/travel studies appear in the planning literature, these elasticities should be updated and refined.

Keywords: vehicle miles traveled (VMT), walking, transit, built environment, effect sizes

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Some of today's most vexing problems, including sprawl, congestion, oil dependence, and climate change, are prompting states and localities to turn to land planning and urban design to rein in automobile use. Many have concluded that roads cannot be built fast enough to keep up with rising travel demand induced by the road building itself and the sprawl it spawns.

The purpose of this meta-analysis is to summarize empirical results on associations between the built environment and travel, especially nonwork travel. A number of studies, including Boarnet and Crane (2001), Cao, Mokhtarian, and Handy (2009b), Cervero (2002a), Cervero and Kockelman (1997), Crane (1996), Kockelman (1997), and Zhang (2004), provide economic and behavioral explanations of why built environments might be expected to influence travel choices. We do not repeat them here, focusing instead on measuring the magnitude of such relationships. We aim to quantify effect sizes while also updating earlier work, including walking and transit use as outcome measures, and addressing the methodological issue of self-selection.

Little work on this topic to date has generalized across studies or helped make sense of differing results. Without this, readers have glimpses of many trees rather than a panoramic view of this complex and rich forest of research. We authored one previous attempt, a literature review (Ewing & Cervero, 2001), in which we derived composite elasticities by informal inspection, an inherently imprecise process. The current meta-analysis, by contrast, is a more systematic way to combine information from many studies, arriving at weighted averages as bottom lines.

There are now more than 200 built-environment/travel studies, of which most were completed since our 2001 review.[1] Compared to earlier studies, the newer ones have estimated effects of more environmental variables simultaneously (expanding beyond density, diversity, design, and destinations, to include distance to transit), controlled for more confounding influences (including traveler attitudes and residential self-selection), and used more sophisticated statistical methods. In response to the U.S. obesity epidemic, the public health literature has begun to link walking to dimensions of the built environment. The first international studies have appeared using research designs similar to those of U.S. studies. This collective and enlarged body of research provides a substantial database for a meta-analysis.

The transportation outcomes we studied in 2001, vehicle miles traveled (VMT) and vehicle trips (VT), are critically linked to traffic safety, air quality, energy consumption, climate change, and other social costs of automobile use. However, they are not the only outcomes of interest. Walking and transit use have implications for mobility, livability, social justice, and public health. The health benefits of walking, in particular, are widely recognized (Badland & Schofield, 2005; Cunningham & Michael, 2004; Frank, 2000; Frank & Engelke, 2001; Humpel, Owen, & Leslie, 2002; Kahn, Ramsey, Brownson, Heath, & Howze, 2002; Krahnstoever-Davison & Lawson, 2006; Lee & Moudon, 2004; McCormack, Giles-Corti, Lange, Smith, Martin, & Pikora, 2004; Owen, Humpel, Leslie, Bauman, & Sallis, 2004; Saelens & Handy, 2008; Transportation Research Board & Institute of Medicine Committee on Physical Activity, Health, Transportation, and Land Use, 2005; Trost, Owen, Bauman, Sallis, & Brown, 2002). Transit use is less obviously related to public health, but is still classified as active travel since it almost always requires a walk at one or both ends of the trip (Besser & Dannenberg, 2005; Edwards, 2008; Zheng, 2008). So, to VMT we add walking and transit use as outcomes of interest.[2]

More than anything else, the possibility of self-selection bias has engendered doubt about the magnitude of travel benefits associated with compact urban development patterns. According to a National Research Council report (Transportation Research Board & Institute of Medicine Committee on Physical Activity, Health, Transportation, and Land Use, 2005), "If researchers do not properly account for the choice of neighborhood, their empirical results will be biased in the sense that features of the built environment may appear to influence activity more than they in fact do. (Indeed, this single potential source of statistical bias casts doubt on the majority of studies on the topic to date…)" (pp. 134–135).

At least 38 studies using nine different research approaches have attempted to control for residential self-selection (Cao, Mokhtarian, & Handy, 2009a; Mokhtarian & Cao, 2008). Nearly all of them found "resounding" evidence of statistically significant associations between the built environment and travel behavior, independent of self-selection influences (Cao, Mokhtarian, et al. 2009a, p. 389). However, nearly all of them also found that residential self-selection attenuates the effects of the built environment on travel.

Using travel diary data from the New York/New Jersey/Connecticut regional travel survey, Salon (2006) concluded that the built environment accounted for one half to two thirds of the difference in walking levels associated with changes in population density in most areas of New York City. Using travel diary data from the Austin travel survey, Zhou and Kockelman (2008) found that the built environment accounted for 58% to 90% of the total influence of residential location on VMT, depending on model specifications. Using travel diary data from northern California, Cao (2010) reported that, on average, neighborhood type accounted for 61% of the observed effect of the built environment on utilitarian walking frequency and 86% of the total effect on recreational walking frequency. Using data from a regional travel diary survey in Raleigh, NC, Cao, Xu, and Fan (2009) estimated that anywhere from 48% to 98%[3] of the difference in vehicle miles driven was due to direct environmental influences, the balance being due to self-selection. Using data from the 2000 San

Francisco Bay Area travel survey, Bhat and Eluru (2009) found that 87% of the VMT difference between households residing in conventional suburban and traditional urban neighborhoods is due to "true" built environment effects, while the remainder is due to residential self-selection. So, while the environment seems to play a more important role in travel behavior than do attitudes and residential preferences, both effects are present.

The D Variables as Measures of the Built Environment

The potential to moderate travel demand by changing the built environment is the most heavily researched subject in urban planning. In travel research, such influences have often been named with words beginning with D. The original "three Ds," coined by Cervero and Kockelman (1997), are density, diversity, and design, followed later by destination accessibility and distance to transit (Ewing & Cervero, 2001; Ewing et al., 2009). Demand management, including parking supply and cost, is a sixth D, included in a few studies. While not part of the environment, demographics are the seventh D, controlled as confounding influences in travel studies.

Density is always measured as the variable of interest per unit of area. The area can be gross or net, and the variable of interest can be population, dwelling units, employment, building floor area, or something else. Population and employment are sometimes summed to compute an overall *activity density* per areal unit.

Diversity measures pertain to the number of different land uses in a given area and the degree to which they are represented in land area, floor area, or employment. Entropy measures of diversity, wherein low values indicate single-use environments and higher values more varied land uses, are widely used in travel studies. Jobs-to-housing or jobs-to-population ratios are less frequently used.

Design includes street network characteristics within an area. Street networks vary from dense urban grids of highly interconnected, straight streets to sparse suburban networks of curving streets forming loops and lollipops. Measures include average block size, proportion of four-way intersections, and number of intersections per square mile. Design is also occasionally measured as sidewalk coverage (share of block faces with sidewalks); average building setbacks; average street widths; or numbers of pedestrian crossings, street trees, or other physical variables that differentiate pedestrian-oriented environments from auto-oriented ones.

Destination accessibility measures ease of access to trip attractions. It may be regional or local (Handy, 1993). In some studies, regional accessibility is simply distance to the central business district. In others, it is the number of jobs or other attractions reachable within a given travel time, which tends to be highest at central locations and lowest at peripheral ones. The gravity model of trip attraction measures destination accessibility. Local accessibility is different, defined by Handy (1993) as distance from home to the closest store.

Distance to transit is usually measured as an average of the shortest street routes from the residences or workplaces in an area to the nearest rail station or bus stop. Alternatively, it may be measured as transit route density,[4] distance between transit stops, or the number of stations per unit area.

Note that these are rough categories, divided by ambiguous and unsettled boundaries that may change in the future. Some dimensions overlap (e.g., diversity and destination accessibility). We still find it useful to use the D variables to organize the empirical literature and provide order-of-magnitude insights.

Literature

Qualitative Reviews

There are at least 12 surveys of the literature on the built environment and travel (Badoe & Miller, 2000; Cao, Mokhtarian, et al., 2009a; Cervero, 2003; Crane, 2000; Ewing & Cervero, 2001; Handy, 2004; Heath, Brownson, Kruger, Miles, Powell, Ramsey, & the Task Force on Community Preventive Services, 2006; McMillan, 2005, 2007; Pont, Ziviani, Wadley, Bennet, & Bennet, 2009; Saelens, Sallis, & Frank, 2003; Stead & Marshall, 2001). There are 13 other surveys of the literature on the built environment and physical activity, including walking and bicycling (Badland & Schofield, 2005; Cunningham & Michael, 2004; Frank, 2000; Frank & Engelke, 2001; Humpel et al., 2002; Kahn et al., 2002; Krahnstoever-Davison & Lawson, 2006; Lee & Moudon, 2004; McCormack et al., 2004; Owen et al., 2004; Saelens & Handy, 2008; Transportation Research Board & Institute of Medicine Committee on Physical Activity, Health, Transportation, and Land Use, 2005; Trost et al., 2002). There is considerable overlap among these reviews, particularly where they share authorship. The literature is now so vast it has produced two reviews of the many reviews (Bauman & Bull, 2007; Gebel, Bauman, & Petticrew, 2007).

From our earlier review (Ewing & Cervero, 2001), the most common travel outcomes modeled are trip frequency, trip length, mode choice, and VMT (as a composite measure of travel demand). Hence, we can describe measured associations between D variables and these outcomes with more confidence than we could for outcomes studied less often, like trip chaining in multipurpose tours or internal capture of trips within mixed use developments.

Our earlier review (Ewing & Cervero, 2001) held that trip frequency is primarily a function of socioeconomic characteristics of travelers and secondarily a function of the built environment; trip length is primarily a function of the built environment and secondarily of socioeconomic characteristics; and mode choice depends on both, although probably more on socioeconomics. VMT and vehicle hours of travel (VHT) also depend on both. Trip lengths are generally shorter at locations that are more accessible, have higher densities, or feature mixed uses. This holds true both when comparing home-based trips from different residential neighborhoods and trips to non-home destinations in different activity centers. Destination accessibility is the dominant environmental influence on trip length. Transit use varies primarily with local densities and secondarily with the degree of land use mixing. Some of the density effect is, no doubt, due to better walking conditions, shorter distances to transit service, and less free parking. Walking varies as much with the degree of land use mixing as with local densities.

The third D, design, has a more ambiguous relationship to travel behavior than the first two. Any effect is likely to be a collective one involving multiple design features. It also may be an interactive effect with other D variables. This is the idea behind composite measures such as Portland, Oregon's urban design factor, which is a function of intersection density, residential density, and employment density.

Our Earlier Quantitative Synthesis

Using 14 travel studies that included sociodemographic controls, we previously synthesized the literature on the elasticities of VMT and VT with respect to density, diversity, design, and destination accessibility (Ewing & Cervero, 2001). The U.S. Environmental Protection Agency (EPA) incorporated these summary measures into its Smart Growth Index (SGI) model, a widely used sketch-planning tool for travel and air quality analysis. The SGI model measures density as residents plus jobs per square mile; diversity as the ratio of jobs to residents divided by the regional average of that ratio; and design as street network density, sidewalk coverage, and route directness (road distance divided by direct distance). Two of these three measures relate to street network design.

Our 2001 study (Ewing & Cervero, 2001) suggested, for example, that a doubling of neighborhood density would reduce both per capita VT and VMT by approximately 5%, all else being equal. We also concluded that VMT was more elastic with respect to destination accessibility than the other three built environmental measures, meaning that highly accessible areas such as center cities produce substantially lower VMT than dense mixed-use developments in the exurbs. However, as noted earlier, our 2001 study relied on only 14 studies, and the elasticities were imprecise, some obtained by aggregating results for dissimilar environmental variables (e.g., local diversity measured as both entropy and jobs-housing balance). In this update, we compute weighted averages of results from a larger number of studies, and use more uniformly defined built-environmental variables.

Meta-Analyses in Planning

Unlike traditional research methods, meta-analysis uses summary statistics from individual primary studies as the data points in a new analysis. This approach has both advantages and disadvantages for validity and reliability, as every standard textbook on meta-analysis explains (Borenstein, Hedges, Higgins, & Rothstein, 2009; Hunter & Schmidt, 2004; Lipsey & Wilson, 2001; Littell, Corcoran, & Pillai, 2008; Lyons, 2003 Schulze, 2004).

The main advantage of meta-analysis is that it aggregates all available research on a topic, allowing common threads to emerge. The pooling of samples in a carefully constructed meta-analysis also makes its results more generalizable than those of the smaller primary studies on which it is based. But meta-analysis has drawbacks too. Combining stronger studies with weaker ones may contaminate the results of the former. Further, meta-analysis inevitably mixes apples and oranges due to the variation among studies in modeling techniques, independent and dependent variables, and sampling units. If we compare only very similar studies, sample sizes can become small, threatening statistical reliability, a problem that we admit characterizes some of the subcategories for which we present results in this article. Last, the studies for a meta-analysis are usually chosen from the published literature. This can result in *publication bias*, since studies that show statistical significance are more likely to be published (Rothstein, Sutton, & Borenstein, 2005). Publication bias may inflate the absolute size of the effects estimated with a meta-analysis.

Addressing these potential weaknesses involves tradeoffs. We sought to minimize publication bias in this meta-analysis by searching for unpublished reports, preprints, and white papers, as well as published articles. Online searches using Google Scholar and the Transportation

Research Information Service (TRIS) were particularly helpful in this regard. We sought to minimize the apples-and-oranges problem by focusing on a subset of studies that employed disaggregate data and comparably defined variables. Yet, our efforts to avoid publication bias may have exacerbated the strong-weak study problem, and our efforts to achieve greater construct validity by segmenting the analysis into subgroups sharing comparably defined dependent and independent variables produced small sample sizes.

More than a dozen studies have applied meta-analytical methods to the urban planning field (Babisch, 2008; Bartholomew & Ewing, 2008; Bunn, Collier, Frost, Ker, Roberts, & Wentz, 2003; Button & Kerr, 1996; Button & Nijkamp, 1997; Cervero, 2002b; Debrezion, Pels, & Rietveld, 2003; Duncan, Spence, & Mummery, 2005; Graham & Glaister, 2002; Hamer & Chida, 2008; Lauria & Wagner, 2006; Leck, 2006; Nijkamp & Pepping, 1998; Smith & Huang, 1995; Stamps, 1990, 1999; Zhang, 2009). Bartholomew and Ewing (2008) combined results from 23 recent scenario planning studies to calculate the impacts of land-use changes on transportation greenhouse gas emissions. Button and Kerr (1996) explored the implications of urban traffic restraint schemes on congestion levels. Cervero (2002b) synthesized the results of induced travel demand studies. Debrezion et al. (2003) measured the impact of railway stations on residential and commercial property values. Nijkamp and Pepping (1998) analyzed factors critical to the success of sustainable city initiatives. Smith and Huang (1995) calculated the public's willingness to pay for cleaner air. Stamps (1990, 1999) applied meta-analysis to the visual preference literature.

Most relevant to the present study, Leck (2006) identified 40 published studies of the built environment and travel, and selected 17 that met minimum methodological and statistical criteria. While Leck's meta-analysis stopped short of estimating average effect sizes, it did evaluate the statistical significance of relationships between the built environment and travel, finding residential density, employment density, and land use mix to be inversely related to VMT at the $p < .001$ significance level.

Approach

Sample of Studies

We identified studies linking the built environment to travel using the Academic Search Premier, Google, Google Scholar, MEDLINE, PAIS International, PUBMED, Scopus, TRIS Online, TRANweb, Web of Science, and ISI Web of Knowledge databases using the keywords "built environment," "urban form," and "development," coupled with keywords "travel," "transit," and "walking." We also reviewed the compact discs of the Transportation Research Board's annual programs for relevant papers, contacted all leading researchers in this subject area for copies of their latest research, and put out a call for built-environment/travel studies on the academic planners' listserv, PLANET. Finally, we examined the bibliographies of the previous literature reviews in this topic area to identify other pertinent studies.

We inspected more than 200 studies that relate, quantitatively, characteristics of the built environment to measures of travel. From the universe of built-environment/travel studies, we computed effect sizes for the more than 50 studies shown in Table 1. These studies have several things in common. As they analyze effects of the built environment on travel choices, all these studies control statistically for confounding influences on travel behavior, sociodemographic influences in particular. They use different statistical methods because the outcome variables differ from study to study.[5] All apply statistical tests to determine the significance of the various effects. Almost all are based on sizeable samples, as shown in the appendix tables. Most capture the effects of more than one D variable simultaneously. Most importantly, we selected only studies for which data were available for computing effect sizes.

We left out many quantitative studies for various reasons. Many studies did not publish average values of dependent and independent variables from which point elasticities could be calculated. Although we followed up with authors to try to obtain these descriptive statistics, in many cases the research was several years old and the authors had moved on to other subjects. In a few cases, we could not track the authors down or get them to respond to repeated data requests.

Many studies used highly aggregated city, county, or metropolitan level data (e.g., Newman & Kenworthy, 2006; van de Coevering & Schwanen, 2006). Such studies have limited variance in both dependent and independent variables with which to explain relationships. More importantly, it is inappropriate to make causal and associative inferences about individuals based on results obtained from aggregate data, an error called the *ecological fallacy*. As we would like our elasticities to be suitable for use in models predicting individual behavior, we did not use studies relying on aggregate data.

Several studies used statistical methods from which simple summary effect size measures could not be calculated, including some using structural equation models (SEM) to capture complex interactions among built environment and travel variables (e.g., Bagley & Mokhtarian,

Table 1. Studies included in the sample.

	Study sites	Data	Methods	Controls	Self-selection controlled for[a]
Bento et al., 2003	Nationwide Personal Transportation Survey (114 metropolitan statistical areas)	D	LNR/LGR	SE/LS/OT	no
Bhat & Eluru, 2009	San Francisco Bay Area, CA	D	COP	SE/OT	yes
Bhat, Sen, et al., 2009	San Francisco Bay Area, CA	D	MDC/LGR	SE/OT	no
Bhatia, 2004	20 communities in Washington, DC	A	LNR	SE	no
Boarnet et al., 2004	Portland, OR	D	LNR/PRR	SE/OT	no
Boarnet et al., 2008	Portland, OR	D	TOR	SE	yes
Boarnet et al., in press	8 neighborhoods in southern CA	D	NBR	SE	no
Boer et al., 2007	10 U.S. metropolitan areas	D	PSM	SE/WE	no
Cao et al., 2006	6 neighborhoods in Austin, TX	D	NBR	SE/AT	yes
Cao, Mokhtarian, et al., 2009b	8 neighborhoods in northern CA	D	SUR	SE/AT	yes
Cao, Xu, et al., 2009	Raleigh, NC	D	PSM	SE/AT	yes
Cervero, 2002a	Montgomery County, MD	D	LGR	SE/LS	no
Cervero, 2006	225 light rail transit stations in 11 metropolitan areas	A	LNR	ST/LS	no
Cervero, 2007	26 TODs in five CA regions	D	LGR	SE/ LS/WP/AT	yes
Cervero & Duncan, 2003	San Francisco Bay Area, CA	D	LGR	SE/OT	no
Cervero & Duncan, 2006	San Francisco Bay Area, CA	D	LNR	SE/WP	no
Cervero & Kockelman, 1997	50 neighborhoods in the San Francisco Bay Area, CA	D	LNR/LGR	SE/LS	no
Chapman & Frank, 2004	Atlanta, GA	D	LNR	SE	no
Chatman, 2003	Nationwide Personal Transportation Survey	D	TOR	SE/WP	no
Chatman, 2008	San Francisco, CA/San Diego, CA	D	LNR/NBR	SE/LS/OT	no
Chatman, 2009	San Francisco, CA/San Diego, CA	D	NBR	SE/LS/OT/AT	yes
Ewing et al., 1996	Palm Beach County/Dade County, FL	D	LNR	SE	no
Ewing et al., 2009	52 mixed use developments in Portland	D	HLM	SE	no
Fan, 2007	Raleigh-Durham, NC	D	LNR	SE/LS/OT/AT	yes
Frank & Engelke, 2005	Seattle, WA	D	LNR	SE/LS	no
Frank et al., 2008	Seattle, WA	D	LGR	SE/LS	no
Frank et al., 2009	Seattle, WA	D	LNR	SE	no
Greenwald, 2009	Sacramento, CA	D	LNR/TOR/ NBR	SE	no
Greenwald & Boarnet, 2001	Portland, OR	D	OPR	SE/LS	no
Handy & Clifton, 2001	6 neighborhoods in Austin, TX	D	LNR	SE	no
Handy et al., 2006	8 neighborhoods in northern CA	D	NBR	SE/AT	yes
Hedel & Vance, 2007	German Mobility Panel Survey	D	LNR/PRR	SE/OT	no
Hess et al., 1999	12 neighborhood commercial centers in Seattle, WA	A	LNR	SE	no
Holtzclaw et al., 2002	Chicago, IL/Los Angeles, CA/San Francisco, CA	A	NLR	SE	no
Joh et al., 2009	8 neighborhoods in southern CA	D	LNR	SE/CR/AT	yes
Khattak & Rodriguez, 2005	2 neighborhoods in Chapel Hill, NC	D	NBR	SE/AT	yes
Kitamura et al., 1997	5 communities in San Francisco, CA region	D	LNR	SE/AT	yes
Kockelman, 1997	San Francisco Bay Area, CA	D	LNR/LGR	SE	no
Kuby et al., 2004	268 light rail transit stations in nine metropolitan areas	A	LNR	ST/OT	no
Kuzmyak et al., 2006	Baltimore, MD	D	LNR	SE	no
Kuzmyak, 2009a	Los Angeles, CA	D	LNR	SE	no
Kuzmyak, 2009b	Phoenix, AZ	D	LNR	SE	no
Lee & Moudon, 2006a	Seattle, WA	D	LGR	SE/LS	yes
Lund, 2003	8 neighborhoods in Portland, OR	D	LNR	SE/AT	yes
Lund et al., 2004	40 TODs in four CA regions	D	LGR	SE/LS/WP/AT	yes
Naess, 2005	29 neighborhoods in Copenhagen, Denmark	D	LNR	SE/WP/AT	yes

Table 1. (continued).

	Study sites	Data	Methods	Controls	Self-selection controlled for[a]
Pickrell & Schimek, 1999	Nationwide Personal Transportation Survey	D	LNR	SE	no
Plaut, 2005	American Housing Survey	D	LGR	SE/OT	no
Pushkar et al., 2000	795 zones in Toronto, Ontario, Canada	A	SLE	SE/LS	no
Rajamani et al., 2003	Portland, OR	D	LGR	SE/LS	no
Reilly, 2002	San Francisco, CA	D	LGR	SE/OT	no
Rodriguez & Joo, 2004	Chapel Hill, NC	D	LGR	SE/LS/OT	no
Rose, 2004	3 neighborhoods in Portland	D	LNR/POR	SE	no
Schimek, 1996	Nationwide Personal Transportation Survey	D	SLE	SE	no
Shay et al., 2006	1 neighborhood in Chapel Hill, NC	D	NBR	SE/AT	yes
Shay & Khattak, 2005	2 neighborhoods in Chapel Hill, NC	D	LNR/NBR	SE	no
Shen, 2000	Boston, MA	A	LNR	SE	no
Sun et al., 1998	Portland, OR	D	LNR	SE	no
Targa & Clifton, 2005	Baltimore, MD	D	POR	SE/AT	yes
Zegras, 2007	Santiago, Chile	D	LNR/LGR	SE	no
Zhang, 2004	Boston, MA/Hong Kong	D	LGR	SE/LS/OT	no
Zhou & Kockelman, 2008	Austin, TX	D	LNR/PRR	SE	yes

Notes:
We use the following abbreviations:

Data: A = aggregate
D = disaggregate

Methods: COP = Copula-based switching model
GEE = generalized estimating equations
HLM = hierarchical linear modeling
LGR = logistic regression
LNR = linear regression
MDC = multiple discrete continuous extreme value model
NBR = negative binomial regression
NLR = nonlinear regression
OPR = ordered probit regression
POR = Poisson regression
PRR = probit regression
PSM = propensity score matching
PSS = propensity score stratification
SLR = simultaneous linear equations
SUR = seemingly unrelated regression
TOR = Tobit regression

Controls: AT = attitudinal variables
CR = crime variables
LS = level of service variables
OT = other variables
SE = socioeconomic variables
ST = station variables
WE = weather variables
WP = workplace variables

a. Cao, Mokhtarian, et al. (2009a) notes nine different approaches used to control for residential self-selection. The least rigorous incorporates attitudinal measures in multivariate regression models, while the most rigorous jointly estimates models of residential choice and travel behavior, treating residential choice as an endogenous variable.

2002; Cao, Mokhtarian, & Handy, 2007; Cervero & Murakami, 2010). In SEM, different equations represent different effects of variables on one another, both direct and indirect through intermediate variables. These cannot be aggregated into a single elasticity.[6]

We excluded many studies because they dealt with limited populations or trip purposes (e.g., Chen & McKnight, 2007; Li, Fisher, Brownson, & Bosworth, 2005; Waygood, Sun, Kitamura, 2009). Notably, several recent studies of student travel to school cannot be generalized to other populations and trip purposes. The literature suggests that the choice of mode for the journey to school is based on very different considerations than those for other trip making (Ewing, Schroeer, & Greene, 2004; Yarlagadda & Srinivasan, 2008).

We excluded some studies because they characterized the built environment subjectively rather than objectively, that is, in terms of qualities perceived and reported by travelers rather than variables measured in a standardized way by researchers (e.g., Craig, Brownson, Cragg, & Dunn, 2002; Handy, Cao, & Mokhtarian, 2005). Subjective measures are common in public health studies. While perceptions are important, they differ from objective measures of the built environment and are arguably more difficult for planners and public policymakers to influence (e.g., Livi-Smith, 2009; McCormack et al., 2004; McGinn, Evenson, Herring, Huston, & Rodriguez, 2007). For studies that include both types of measures, we analyzed relationships only for the objective measures.

Finally, we excluded several studies because they created and then applied built environmental indices without true zero values (e.g., indices derived through factor analysis). There is no defensible way to compute elasticities, the common currency of this article, for such studies (e.g., Estupinan & Rodriguez, 2008; Frank, Saelens, Powell, & Chapman, 2007; Livi-Smith, 2009). For the same reason, we excluded several excellent studies whose independent variables, although initially continuous, had been converted to categorical variables to simplify the interpretation of results (e.g., Lee & Moudon, 2006b; McGinn et al., 2007; Oakes, Forsyth, & Schmitz, 2007).

We analyzed studies using nominal variables to characterize the built environment separately from those using continuous variables. Examples of the former include studies distinguishing between traditional urban and conventional suburban development or between transit-oriented and auto-oriented development. We only included such studies if they analyzed disaggregate data and controlled for individual socioeconomic differences across their samples, thereby capturing the marginal effects of neighborhood type.[7]

Common Metrics

To combine results from different studies, a meta-analysis requires a common measure of effect size. Our common metric is the elasticity of some travel outcome with respect to one of the D variables. An *elasticity* is the ratio of the percentage change in one variable associated with the percentage change in another variable (a *point elasticity* is the ratio when these changes are infinitely small). Elasticities are dimensionless (unit-free) measures of the associations between pairs of variables and are the most widely used measures of effect size in economic and planning research.

For outcomes measured as continuous variables, such as numbers of walk trips, an elasticity can be interpreted as the percent change in the outcome variable when a specified independent variable increases by 1%. For outcomes measured as categorical variables, such as the choice of walking over other modes, an elasticity can be interpreted as the percent change in the probability of choosing that alternative (or the percent change in that alternative's market share) when the specified independent variable increases by 1%.

Elasticities in Individual Studies in the Sample

We obtained elasticities from the individual studies in our sample in one of four ways, just as in Ewing and Cervero (2001). We either: (1) copied them from published studies where they were reported explicitly; (2) calculated them ourselves from regression coefficients and the mean values of dependent and independent variables; (3) derived them from data sets already available to us or made available by other researchers; or (4) obtained them directly from the original researchers. Most commonly, we used one of the formulas shown in Table 2 to compute elasticities, depending on which statistical method was used to estimate coefficient values.

When regression coefficients were not significant, we could have chosen to drop the observations or substitute zero values for the elasticities, since the coefficients were not statistically different from zero, but we chose instead to use the reported coefficients to compute elasticities, again using the formulas in Table 2. Dropping the observations would have biased the average elasticities away from the null hypothesis of zero elasticity, and thus we rejected this option. Substituting zero values for computed elasticities would have had the opposite effect, biasing average values toward the null hypothesis, thus we rejected it as well. Instead, we used the best available estimates of central tendency in all cases, the regression coefficients themselves, to compute elasticities. This is the standard approach in meta-analysis (see, e.g., Melo, Graham, & Noland, 2009).

Table 2. Elasticity estimation formulas.

Regression specification	Elasticity
Linear	$\beta * \frac{\bar{x}}{\bar{y}}$
Log-log	β
Log-linear	$\beta * \bar{x}$
Linear-log	$\frac{\beta}{\bar{y}}$
Logistic[a]	$\beta * \bar{x}\left(1-\left(\frac{\bar{y}}{n}\right)\right)$
Poisson	$\beta * \bar{x}$
Negative binomial	$\beta * \bar{x}$
Tobit[b]	$\beta * \left(\frac{\bar{x}}{\bar{y}}\right)$

Notes:

β is the regression coefficient on the built-environment variable of interest, $\bar{y}$ the mean value of the travel variable of interest, and $\bar{x}$ the mean value of the built-environment variable of interest.

a. $\left(\frac{\bar{y}}{n}\right)$ is the mean estimated probability of occurrence.

b. Applied only to positive values of the Tobit distribution (i.e., where $y > 0$).

Borenstein et al. (2009) argue against another possibility, using significance levels as proxies for effect size, since they depend not only on effect size but also on sample size: "Because we work with the effect sizes directly we avoid the problem of interpreting nonsignificant *p*-values to indicate the absence of an effect (or of interpreting significant *p*-values to indicate a large effect)" (p. 300).

Ideally, the original studies would have computed elasticities for each observation (trip, traveler, or household) and then averaged them over the sample. Indeed, a few of the researchers who reported elasticities did exactly that (e.g., Bento, Cropper, Mobarak, & Vinha, 2003; Bhat, Sen, & Eluru, 2009; Rodriguez & Joo, 2004). However, since we could not ask all these busy people to go back and compute elasticities, we have instead estimated elasticities at the overall sample means of the dependent and/or independent variables, as indicated in Table 3.

While commonplace, this procedure could introduce a fair amount of error in the elasticity estimates. Elasticities calculated at mean values of dependent and independent variables may differ significantly from the average values of individual elasticities due to the nonlinear nature of many of the functions involved (e.g., logistic functions). "In general, the probability evaluated at the average utility underestimates the average probability when the individuals' choice probabilities are low and overestimates when they are high" (Train, 1986, p. 42). Train (1986) cites work by Talvitie (1976), who found in a mode choice analysis that elasticities at the average representative utility can be as much as two to three times greater or less than the average of individual elasticities. This is a greater concern with discrete choice models than with the linear regression models that Table 1 shows are most commonly used to study the built environment and travel.

Due to the large number studies we summarize here, we show the effect sizes for individual studies in appendix tables for each travel outcome of interest (VMT, walking, and transit use) with respect to each built environment variable of interest (density, diversity, design, destination accessibility, distance to transit, and neighborhood type). All effect sizes are measured as elasticities, except those for neighborhood type, which is a categorical variable. The effect size for neighborhood type is the proportional difference in a travel outcome between conventional suburban neighborhoods and more compact, walkable neighborhoods.

Table 3. Weighted average elasticities of VMT with respect to built-environment variables.

		Total number of studies	Number of studies with controls for self-selection	Weighted average elasticity of VMT(*e*)
Density	Household/population density	9	1	−0.04
	Job density	6	1	0.00
Diversity	Land use mix (entropy index)	10	0	−0.09
	Jobs-housing balance	4	0	−0.02
Design	Intersection/street density	6	0	−0.12
	% 4-way intersections	3	1	−0.12
Destination accessibility	Job accessibility by auto	5	0	−0.20
	Job accessibility by transit	3	0	−0.05
	Distance to downtown	3	1	−0.22
Distance to transit	Distance to nearest transit stop	6	1	−0.05

We consistently report the elasticity values with a positive sign indicating the effects of greater accessibility, which required reversing signs in many cases, as noted in the tables. Thus, for example, a negative elasticity of VMT with respect to measures of destination accessibility in our appendix tables always indicates that VMT drops as destination accessibility improves. Where destination accessibility was measured originally in terms of jobs reachable within a given travel time, our sign is the same as that obtained by the original study. However, where destination accessibility was measured in terms of distance to downtown, for example, we reversed the sign of the elasticity in the original source so that higher values of the independent variable correspond to better, not worse, accessibility.

Where studies reported results for general travel and, in addition, for different trip purposes or different types of travelers, we report effect sizes only for the most general class of travel. Thus, for example, if a study estimated VMT models for all trips and for work trips alone, we present only the former. A few studies analyzed only subcategories of travel, and in these cases, we sometimes present more than one set of results for a given study.

Weighted Average Elasticities

We used individual elasticities from primary studies to compute weighted average elasticities for many dependent/independent variable pairs representing travel outcomes and attributes of the built environment. We show the resulting weighted average elasticities in Tables 3, 4, and 5. We calculated averages where three conditions were met: (1) a sample of at least three studies was available; (2) for these particular studies, dependent and independent variables were comparably defined; and (3) for these particular studies, disaggregate travel data were used to estimate models. The numbers of studies in each sample are as indicated in Tables 3, 4, and 5.

These results should be used only as ballpark estimates, both because of the minimum sample size we chose and because of how we computed weighted average elasticities. We settled on a minimum sample size of three studies[8] due to data limitations (as in Tompa, de Oliveira, Dolinschi, & Irvin, 2008). While the relationship between the built environment and travel is the most heavily researched subject in urban planning, when studies are segmented by variable type, samples never reach what some would consider a reasonable minimum sample size (Lau, Ioannidis, Terrin, Schmid, & Olkin, 2006). Also, to maximize our

Table 4. Weighted average elasticities of walking with respect to built environment variables.

		Total number of studies	Number of studies with controls for self-selection	Weighted average elasticity of walking (*e*)
Density	Household/population density	10	0	0.07
	Job density	6	0	0.04
	Commercial floor area ratio	3	0	0.07
Diversity	Land use mix (entropy index)	8	1	0.15
	Jobs-housing balance	4	0	0.19
	Distance to a store	5	3	0.25
Design	Intersection/street density	7	2	0.39
	% 4-way intersections	5	1	–0.06
Destination accessibility	Job within one mile	3	0	0.15
Distance to transit	Distance to nearest transit stop	3	2	0.15

Table 5. Weighted average elasticities of transit use with respect to built environment variables.

		Total number of studies	Number of studies with controls for self-selection	Weighted average elasticity of transit use
Density	Household/population density	10	0	0.07
	Job density	6	0	0.01
Diversity	Land use mix (entropy index)	6	0	0.12
Design	Intersection/street density	4	0	0.23
	% 4-way intersections	5	2	0.29
Distance to transit	Distance to nearest transit stop	3	1	0.29

sample sizes, we mixed the relatively few studies that control for self-selection with the many that do not. We advise readers to exercise caution when using the elasticities based on small samples of primary studies (see Tables 3, 4, and 5), but rather than omit the categories for which only small samples were available, we aimed in this analysis to seed the meta-study of built environments and travel, expecting that others would augment and expand our database over time.

We computed weighted average elasticities using sample size as a weighting factor because we lacked consistent standard error estimates from individual studies. Weighting by sample size is by far the most common approach in meta-analyses, since sample sizes are nearly always known (Shadish & Haddock, 1994, p. 264). However, it is not the optimal weighting scheme. Hedges and Olkin (1985) demonstrated that optimal weights are related to the standard errors of the effect size estimates, and this has become the gold standard in meta-analysis. Specifically, because larger standard errors correspond to less precise estimates of effect sizes, the preferred method is to calculate a meta-analysis weight as an *inverse variance weight,* or the inverse of the squared standard error (Borenstein et al., 2009; Hunter & Schmidt, 2004; Lipsey & Wilson, 2001; Littell et al., 2008; Schulze, 2004). From a statistical standpoint, such weights are optimal since they minimize the variance of the average effect size estimates. They also make intuitive sense, as they give the greatest weight to the most precise estimates from individual studies.

No weighting factor except standard error allows judging whether the resulting weighted averages are statistically different from zero. Since we combine significant and insignificant individual effect sizes, and do not have the data necessary to test for significance, we do not report statistical confidence for any of the results. It is thus possible that any given meta-elasticity is not significantly different from zero. We particularly advise readers to exercise caution in using weighted average elasticities when the elasticities on which they are based are statistically insignificant, as shown in the appendix tables.

Discussion

For all of the variable pairs we discuss here, the relationships between travel variables and built environmental variables are inelastic. The weighted average elasticity with the greatest absolute magnitude is 0.39, and most elasticities are much smaller. Still, the combined effect of several built environmental variables on travel could be quite large.

As in our 2001 meta-study (Ewing & Cervero, 2001), the D variable most strongly associated with VMT is destination accessibility. Our elasticity of VMT with respect to "job accessibility by auto" in this meta-analysis, –0.20, is identical to the elasticity in the earlier study. In fact, the –0.20 VMT elasticity is nearly as large as the elasticities of the first three D variables (density, diversity, and design) combined; this too is consistent with our earlier meta-study.

Equally strongly related to VMT is the inverse of the distance to downtown. This variable is a proxy for many Ds, as living in the city core typically means higher densities in mixed-use settings with good regional accessibility. Next most strongly associated with VMT are the design metrics intersection density and street connectivity. This is surprising, given the emphasis in the qualitative literature on density and diversity, and the relatively limited attention paid to design. The weighted average elasticities of these two street network variables are identical. Both short blocks and many interconnections apparently shorten travel distances to about the same extent.

Also surprising are the small elasticities of VMT with respect to population and job densities. Conventional wisdom holds that population density is a primary determinant of vehicular travel, and that density at the work end of trips is as important as density at the home end in moderating VMT. This does not appear to be the case once other variables are controlled.

Our previous study (Ewing & Cervero, 2001) did not address walking and transit use, thus we have no benchmarks against which to compare the results in Tables 4 and 5. The meta-analysis shows that mode share and likelihood of walk trips are most strongly associated with the design and diversity dimensions of built environments. Intersection density, jobs-housing balance, and distance to stores have the greatest elasticities. Interestingly, intersection density is a more significant variable than street connectivity. Intuitively this seems right, as walkability may be limited even if connectivity is excellent when blocks are long. Also of interest is the fact that jobs-housing balance has a stronger relationship to walking than the more commonly used land use mix (entropy) variable. Several variables that often go hand-in-hand with population density have elasticities that are well above that of population density. Also, as with VMT, job density is less strongly related to walking than is population density. Finally, Table 5 suggests that having transit stops nearby may stimulate walking (Cervero, 2001; Ryan & Frank, 2009).

The mode share and likelihood of transit trips are strongly associated with transit access. Living near a bus stop appears to be an inducement to ride transit, supporting the transit industry's standard of running buses within a quarter mile of most residents. Next in importance are road network variables and, then, measures of land use mix. High intersection density and great street connectivity shorten access distances and provide more routing options for transit users and transit service providers. Land use mix makes it possible to efficiently link transit trips with errands on the way to and from transit stops. It is sometimes said that "mass transit needs 'mass'"; however, this is not supported by the low elasticities of transit use with respect to population and job densities in Table 5.

No clear pattern emerges from scanning across the Tables 3, 4, and 5. Perhaps what can be said with the highest degree of confidence is that destination accessibility is most strongly related to both motorized (i.e., VMT) and nonmotorized (i.e., walking) travel and that among the remaining Ds, density has the weakest association with travel choices. The primacy of destination accessibility may be due to lower levels of auto ownership and auto dependence at central locations. Almost any development in a central location is likely to generate less automobile travel than the best-designed, compact, mixed-use development in a remote location.

The relatively weak relationships between density and travel likely indicate that density is an intermediate variable that is often expressed by the other Ds (i.e., dense settings commonly have mixed uses, short blocks, and central locations, all of which shorten trips and encourage walking). Among design variables, intersection density more strongly sways the decision to walk than does street connectivity. And, among diversity variables, jobs-housing balance is a stronger predictor of walk mode choice than land use mix measures. Linking where people live and work allows more to commute by foot, and this appears to shape mode choice more than sprinkling multiple land uses around a neighborhood.

Controls for residential self-selection appear to increase the absolute magnitude of elasticities if they have any effect at all. This conclusion follows from a simple review of elasticities in the appendix. There may be good explanations for this unexpected result. In a region with few pedestrian- and transit-friendly neighborhoods, residential self-selection likely matches individual preferences with place characteristics, increasing the effect of the D variables, a possibility posited by Lund, Willson, and Cervero (2006).

> …if people are simply moving from one transit-accessible location to another (and they use transit regularly at both locations), then there is theoretically no overall increase in ridership levels. If, however, the resident was unable to take advantage of transit service at their prior residence, then moves to a TOD (transit-oriented development) and begins to use the transit service, the TOD is fulfilling a latent demand for transit accessibility and the net effect on ridership is positive. (p. 256)

Similarly, Chatman (2009) hypothesizes that "[r]esidential self-selection may actually cause underestimates of built environment influences, because households prioritizing travel access—particularly, transit accessibility—may be more set in their ways, and because households may not find accessible neighborhoods even if they prioritize accessibility" (p. 1087). He carries out regressions that explicitly test for this, and finds that self-selection is more likely to enhance than diminish built environmental influences.

Still, we are left with a question. Most of the literature reviewed by Cao, Mokhtarian, et al. (2009a) shows that the effect of the built environment on travel is attenuated by controlling for self-selection, whereas we find no effect (or enhanced effects) after controlling for self-selection. The difference may lie in the different samples included in our study and that of Cao, Mokhtarian, et al. (2009a), or in the crude way we operationalized self-selection, lumping all studies that control for self-selection together regardless of methodology.

Applications

This article provides elasticities in two forms that may be useful to planners: elasticity estimates from primary studies (in the appendix tables) and average elasticities from our pooled samples (in Tables 3, 4, and 5). If a planner happens to have an application in a location near one of those listed in the appendix tables, if not too many years have intervened since that study was completed, and if the study included the right D variables, he or she can simply borrow an elasticity estimate from the appendix, provided that the appendix table indicates it meets conventional statistical significance criteria. Thus, for applications in Boston in the near future, Zhang's (2004) estimate of the elasticity of walk/bike mode choice with respect to population density (0.11) may be used without modification.

More commonly, geographic and functional gaps in the literature may make the elasticities in Tables 3, 4, and 5 useful to planners. These elasticities may be applied in sketch planning to compute estimates of VMT, walking, and transit use relative to a base case, or in post-processing travel and activity forecasts from four-step travel demand models to reflect the influence of the five Ds.

The literature covers post-processing applications well (Cervero, 2006; DKS Associates, 2007; Johnston, 2004; Walters, Ewing, & Allen, 2000). These new elasticity values can be used in exactly the same way as earlier elasticity estimates.

Sketch planning applications are limited only by the creativity of planning analysts. To illustrate, climate action planning of the type currently underway in California and 18 other states will require VMT estimates in order to extrapolate current trends and project an alternative lower-carbon future. These states have set greenhouse gas emission reduction targets and, with their metropolitan planning organizations, will need to pull together verifiable plans that include smart growth elements. If planners are willing to make assumptions about the increases in density and other D variables that can be achieved with policy changes, they can use elasticity values from this article to estimate VMT reductions in urbanized areas and to translate these in turn into effects on CO_2.

Another potential sketch planning application could be to assess health impacts. Rates of physical activity, including walking, are inputs to health assessment models. Again, once planners make assumptions about changes in the D variables under future scenarios, increases in walking can easily be computed using elasticities. Until now there has been no empirically grounded methodology for making such projections.

Elasticities could also be applied to traffic impact analysis. There has been no way to adjust the Institute of Transportation Engineers' (ITE) trip generation rates for walking and transit use, which has left developers of dense developments at urban sites paying impact fees and other exactions at the same rate as their suburban counterparts. The only adjustment previously allowed was for internal capture of trips within mixed-use developments, which did nothing for the typical infill project. Elasticity values can be used to adjust ITE trip rates for suburban developments to reflect how greater densities and other environmental attributes would affect trip making.

The elasticities in this meta-analysis are based on the most complete data available as of late 2009. However, as we acknowledge, sample sizes are small and the number of studies controlling for residential preferences and attitudes is still miniscule. We also do not know the confidence intervals around our meta-analysis results. Users should weigh these shortcomings when applying results to any particular context or local setting. However, they provide a base on which to build. As more built environment-travel studies appear in the planning literature, it will be important to update and refine our results.

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Notes

1. A full list of studies is available from the corresponding author.
2. Vehicle trips (VT) is not studied as widely as these other outcome measures and is not related to as many important outcomes. However, it is a critical determinant of regulated vehicle emissions, which was the focus of our 2001 literature review.
3. The percentage varied depending on which locations were paired and compared, whether urban and suburban locations, urban and exurban, etc.
4. Transit route density is measured by miles of transit routes per square mile of land area.
5. Linear regression is used where the travel variable in continuous, Poisson regression where the travel variable is a count, logistic regression where the dependent variable is a probability, and so forth.
6. Several studies applied ordered probit regression to data on counts of walk and transit trips. We excluded all but one of these studies from the meta-analysis because the breakpoint parameters (μ) for the ordered categories were unavailable, which meant we could not calculate marginal effects. These parameters were available for one ordered probit study (Greenwald & Boarnet, 2001), and Jason Cao computed elasticities for us. We used elasticities for the median ordered category.
7. Due to a dearth of solid research, we could not study certain important travel outcomes with meta-analysis. Most notably, this article is silent regarding the effects of the built environment on trip chaining in multipurpose tours, internal capture of trips within mixed-use developments, and the choice of bicycling as a travel mode.
8. The following quotation from Rodenburg, Benjamin, de Roos, Meijer, and Stams (2009) explains that a meta-analysis in another field settled on seven studies as a minimum sample size:

> Some limitations of this meta-analytic study should be mentioned. Although the minimum number of studies to permit a meta-analysis is only three studies (Treadwell, Tregear, Reston, & Turkelson, 2006) and many published meta-analyses contain nine or fewer studies (Lau, Ioannidis, Terrin, Schmid, & Olkin, 2006), the small number of seven studies included in this meta-analytic review limits the generalizability of our findings and the possibilities of examining and adjusting for publication bias by means of more complex analytic methods (Macaskill, Walter, & Irwig, 2001). (p. 605)

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Appendix: Individual Study Results

Table A-1. Elasticity of VMT with respect to density.

Study	*N*	*y*	*x*	*e*	In meta-analysis?
Bhatia, 2004	20	VMT per household	Household	−0.34 *	
Boarnet et al., 2004	6,153	Nonwork VMT per person	Population	−0.04	
Boarnet et al., 2004	6,153	Nonwork VMT per person	Job	0.03	
Boarnet et al., 2004	6,153	Nonwork VMT per person	Retail job	−0.02	
Chatman, 2003	14,478	VMT for commercial trips per person	Household	−0.58	
Chatman, 2003	14,478	VMT for commercial trips per person	Job	−0.34 ψ	
Chatman, 2008	527	Nonwork VMT per person	Population per road mile	−1.05 ψ	
Chatman, 2008	527	Nonwork VMT per person	Retail job	−0.19 **	
Ewing et al., 1996 (Dade County)	1,311	VHT per household	Population and employment	−0.05	
Ewing et al., 1996 (Palm Beach County)	764	VHT per household	Population and employment	0.00	
Ewing et al., 2009	1,466	VMT per household	Population	0.00	y
Ewing et al., 2009	1,466	VMT per household	Job	−0.06	y
Fan, 2007	7,422	Miles traveled per person	Parcel	−0.07 **	
Frank & Engelke, 2005	4,552	VMT per household	Net residential	0.00	y
Greenwald, 2009	3,938	VMT per household	Net residential	−0.07	y
Greenwald, 2009	3,938	VMT per household	Net job	0.01	y
Hedel & Vance, 2007	28,901	VKT per person	Commercial	−0.01	
Holtzclaw et al., 2002 (Chicago)	314	VMT per household	Household	−0.14	
Holtzclaw et al., 2002 (Los Angeles)	1,459	VMT per household	Household	−0.11	
Holtzclaw et al., 2002 (San Francisco)	1,047	VMT per household	Household	−0.14	
Kockelman, 1997	8,050	VMT per household	Population	0.00	y
Kockelman, 1997	8,050	VMT per household	Job	0.00	y
Kuzmyak, 2009a	5,926	VMT per household	Household	−0.04 **	y
Kuzmyak, 2009b	3,615	VMT per household	Household	0.00	y
Naess, 2005	1,414	Weekday travel distance by car per person	Population and employment	0.00	
Pickrell & Schimek, 1999	40,000	Miles driven per vehicle	Population	−0.06 **	
Schimek, 1996	15,916	VMT per household	Population	−0.07	y
Sun et al., 1998	4,000	VMT per household	Job	0.00	y
Zegras, 2007	4,279	Daily automobile use per household	Dwelling unit	−0.04 **	y
Zhou & Kockelman, 2008	1,903	VMT per household	Population	−0.12 **	y
Zhou & Kockelman, 2008	1,903	VMT per household	Job	0.02 ψ	y

ψ$p < .10$ *$p < .05$ **$p < .01$

Table A-2. Elasticity of VMT with respect to diversity.

Study	*N*	*y*	*x*	*e*	In meta-analysis?
Bento et al., 2003	6,808	VMT per household	Job-housing imbalance	−0.06 ψa	y
Cervero & Kockelman, 1997	896	VMT per household	Land use dissimilarity	0.00	
Cervero & Kockelman, 1997	896	VMT per household	Proportion vertical mix	0.00	
Cervero & Kockelman, 1997	896	VMT per household	Proportion of population within 1/4 mile of store	0.00	
Chapman & Frank, 2004	8,592	VMT per person	Land use mix (entropy index)	−0.04 **	y
Ewing et al., 1996 (Palm Beach County)	764	VHT per household	Job-population balance	−0.09	
Ewing et al., 2009	1,466	VMT per household	Job-population balance	0.00	y
Fan, 2007	7,422	Miles traveled per person	Retail store count	0.00	
Frank & Engelke, 2005	4,552	VMT per household	Land use mix (entropy index)	−0.02 **	y
Frank et al., 2009	2,697	VMT per household	Land use mix (entropy index)	−0.04	y
Greenwald, 2009	3,938	VMT per household	Non-retail job-housing balance	0.03	y
Greenwald, 2009	3,938	VMT per household	Retail job-housing balance	−0.01	y
Greenwald, 2009	3,938	VMT per household	Job mix (entropy index)	0.01	
Hedel & Vance, 2007	28,901	VKT per person	Land use mix (entropy index)	−0.06	y
Kockelman, 1997	8,050	VKT per household	Land use dissimilarity	−0.10 **	
Kockelman, 1997	8,050	VKT per household	Land use mix (entropy index)	−0.10 *	y
Kuzmyak et al., 2006	2,707	VMT per household	Land use mix (entropy index)	−0.09	y
Kuzmyak et al., 2006	2,707	VMT per household	Walk opportunities within 1/2 mile of home	−0.10 *	y
Kuzmyak, 2009a	5,926	VMT per household	Land use mix (entropy index)	−0.27 **	y
Kuzmyak, 2009b	3,615	VMT per household	Land use mix (entropy index)	−0.09 **	y
Pushkar et al., 2000	795	VKT per household	Land use mix (entropy index)	−0.11 **	
Sun et al., 1998	4,000	VMT per household	Land use mix (entropy index)	−0.10	y
Zegras, 2007	4,279	Automobile use per household	Land use diversity	−0.01 **	y

ψ$p < .10$ * $p < .05$ ** $p < .01$

Note:

VKT is vehicle kilometers of travel.

a. Sign reversed.

Table A-3. Elasticity of VMT with respect to design.

Study	***N***	***y***	***x***	***e***	**In meta-analysis?**
Bhat & Eluru, 2009	3,696	VMT per household	Bicycle lane density	−0.08 **	
Bhat, Sen, et al., 2009	8,107	VMT per household	Bicycle lane density	−0.05 *	
Bhat, Sen, et al., 2009	8,107	VMT per household	Street block density	0.01 *	
Boarnet et al., 2004	6,153	Nonwork VMT per person	Intersection density	−0.19 **	
Boarnet et al., 2004	6,153	Nonwork VMT per person	Proportion 4-way intersections	−0.06 *	
Boarnet et al., 2004	6,153	Nonwork VMT per person	Pedestrian environment factor	0.05	
Cervero & Kockelman, 1997	896	VMT per household	Proportion 4-way intersections	0.00	y
Cervero & Kockelman, 1997	896	VMT per household	Proportion quadrilateral blocks	0.19 **	
Cervero & Kockelman, 1997	896	VMT per household	Sidewalk width	0.00	
Cervero & Kockelman, 1997	896	VMT per household	Proportion front and side parking	0.00	
Chapman & Frank, 2004	8,592	VMT per person	Intersection density	−0.08 **	y
Chatman, 2008	527	Nonwork VMT per person	4-way intersection density	−0.06	
Ewing et al., 2009	1,466	VMT per household	Intersection density	−0.31 *	y
Fan, 2007	7,422	Miles traveled per person	Proportion connected intersections	−0.11	y
Fan, 2007	7,422	Miles traveled per person	Sidewalk length	−0.02 ψ	
Frank & Engelke, 2005	4,552	VMT per household	Intersection density	−0.10 **	y
Frank et al., 2009	2,697	VMT per household	Intersection density	−0.11 **	y
Greenwald, 2009	3,938	VMT per household	Intersection density	−0.29 **	y
Hedel & Vance, 2007	28,901	VKT per person	Street density	−0.04 *	y
Pushkar et al., 2000	795	VKT per household	Intersections per road km	−0.04 *	
Zegras, 2007	4,279	Automobile use per household	Proportion 3-way intersections	−0.15 *[a]	y
Zegras, 2007	4,279	Daily automobile use per household	Plaza density	−0.03 *	

ψ $p < .10$ * $p < .05$ ** $p < .01$

Note:

a. Sign reversed.

Table A-4. Elasticity of VMT with respect to destination accessibility.

Study	*N*	*y*	*x*	*e*	**In meta-analysis?**
Bento et al., 2003	6,808	VMT per household	Population centrality	−0.15 **	
Bhat & Eluru, 2009	3,696	VMT per household	Accessibility to shopping	−0.01 **	
Bhatia, 2004	20	VMT per household	Job/household accessibility by transit	−0.19 *	
Boarnet et al., 2004	6,153	Nonwork VMT per person	Distance to CBD	−0.18 **	
Cervero & Duncan, 2006	16,503	Work VMT per person	Job accessibility by auto	−0.31 **	
Cervero & Duncan, 2006	16,503	Shopping VMT per person	Retail job accessibility by auto	−0.17 **	
Cervero & Kockelman, 1997	896	VMT per household	Job accessibility by auto	−0.27 **	y
Ewing et al., 1996 (Palm Beach County)	764	VHT per household	Job accessibility by auto	−0.04 **	
Ewing et al., 1996 (Dade County)	1,311	VHT per household	Job accessibility by auto	−0.15 **	
Ewing et al., 2009	1,466	VMT per household	Job accessibility by auto	−0.03	y
Frank et al., 2009	2,697	VMT per household	Job accessibility by transit	−0.10 **	y
Greenwald, 2009	3,938	VMT per household	Job accessibility by auto	−0.06 **	y
Kockelman, 1997	8,050	VMT per household	Job accessibility by auto	−0.31 **	y
Kuzmyak et al., 2006	2,707	VMT per household	Job accessibility by auto and transit	−0.13 *	
Kuzmyak, 2009a	5,926	VMT per household	Job accessibility by transit	−0.04 **	y
Kuzmyak, 2009b	3,615	VMT per household	Job accessibility by transit	−0.03 **	y
Naess, 2005	1,414	Weekday travel distance by car per person	Distance to downtown	−0.27 **[a]	y
Pushkar et al., 2000	795	VKT per household	Distance to CBD	−0.20 **[a]	
Shen, 2000	3,565	Average commute time	Job accessibility by auto and transit	−0.18	
Sun et al., 1998	4,000	VMT per household	Job accessibility by auto	−0.17 **	y
Sun et al., 1998	4,000	VMT per household	Household accessibility by auto	−0.34 **	
Zegras, 2007	4,279	Daily automobile use per household	Distance to CBD	−0.20 **[a]	y

$^{\psi}p < .10$ $^{*}p < .05$ $^{**}p < .01$
Note:
a. Sign reversed.

Table A-5. Elasticity of VMT with respect to transit access.

Study	N	y	x	e	In meta-analysis?
Bento et al., 2003	6,808	VMT per household	Distance to transit stop	−0.08 **[a]	
Frank & Engelke, 2005	4,546	VMT per household	Distance to bus stop	−0.01 [a]	y
Frank et al., 2009	2,697	VMT per household	Distance to bus stop squared	−0.04 **[a,b]	y
Hedel & Vance, 2007	28,901	VKT per individual	Walk minutes to transit	−0.02 ψ[a]	y
Naess, 2005	1,414	Weekday travel distance by car per person	Distance to rail station	−0.14 *[a]	y
Pushkar et al., 2000	795	VKT per household	Distance to transit station	−0.03 **[a]	
Zegras, 2007	4,279	Daily automobile use per Household	Distance to Metro	−0.19 **[a]	y

ψ$p < .10$ *$p < .05$ **$p < .01$.
Notes:
a. Sign reversed.
b. Sign reversed and multiplied by 2 to make *x* variable equivalent to others.

Table A-6. Effect on VMT[a] of neighborhood type.

Study	N	y	x	e	In meta-analysis?
Bhat & Eluru, 2009	3,696	VMT per household	Urban neighborhood	−0.34 **	
Cao, Xu, et al., 2009	3,376	Vehicle miles driven per person	Urban neighborhood	−0.28 **	
Cervero, 2007	226	Commute VMT per person	Transit-oriented development	−0.29 **	
Khattak & Rodriguez, 2005	302	Daily miles traveled per household	New urbanist neighborhood	−0.20 ψ	
Shay & Khattak, 2005	399	Auto VMT per household	New urbanist neighborhood	−0.22 *	

ψ$p < .10$ *$p < .05$ **$p < .01$
Note:
a. Proportional reduction relative to conventional suburban neighborhood.

Table A-7. Elasticity of walk trips with respect to density.

Study	***N***	***y***	***x***	***e***	**In meta-analysis?**
Bhatia, 2004	20	Walk trips per household	Household density	0.83 **	
Boarnet et al., 2008	6,362	Miles walked per person	Population density	0.13 *	
Boarnet et al., 2008	6,362	Miles walked per person	Retail job density	0.07 **	
Boarnet et al., 2008	6,362	Miles walked per person	Job density	0.00	
Boarnet et al., 2009	1,370	Walk trips per person	Residential density	−0.50	y
Boarnet et al., 2009	1,370	Walk trips per person	Business density	0.14 *	y
Boer et al., 2007	29,724	Miles walked per person	Housing density	0.21 [b]	
Chatman, 2009	999	Walk/bike trips per person	Population per road mile	0.16	
Chatman, 2009	999	Walk/bike trips per person	Retail job density	0.00	
Ewing et al., 2009	3,823	Walk mode choice	Population density	0.01	y
Ewing et al., 2009	3,823	Walk mode choice	Job density	0.10	y
Fan, 2007	988	Daily walking time per person	Parcel density	0.08 ψ	
Frank et al., 2008	8,707	Walk mode choice for work trips	Retail floor area ratio	0.07 *	
Frank et al., 2008	10,475	Walk mode choice for other trips	Retail floor area ratio	0.04 *	
Frank et al., 2009	2,697	Walk trips per household	Retail floor area ratio	0.20 **	
Frank et al., 2009	2,697	Walk trips per household	Number of retail parcels	0.08 **	
Greenwald & Boarnet, 2001	1,084	Walk trips per person for nonwork purposes	Population density	0.34 **[a]	y
Greenwald & Boarnet, 2001	1,084	Walk trips per person for nonwork purposes	Retail job density	0.11 *[a]	
Greenwald, 2009	3,938	Walk/bike trips per household	Residential density	0.28 **	y
Greenwald, 2009	3,938	Walk/bike trips per household	Job density	0.03	y
Hess et al., 1999	12	Pedestrians per hour	Population density	1.39	
Joh et al., 2009	2,125	Walk trips per person	Neighborhood business density	0.19 **	
Kockelman, 1997	8,050	Walk/bike mode choice	Population density	0.00	y
Kockelman, 1997	8,050	Walk/bike mode choice	Job density	0.00	y
Naess, 2005	1,406	Weekday travel distance by walk/bike per person	Population + employment density	0.00	
Rajamani et al., 2003	2,500	Walk mode choice for nonwork trips	Population density	0.01	y
Reilly, 2002	7,604	Walk mode choice for nonwork trips	Population density	0.16 **	y
Targa & Clifton, 2005	2,934	Walk trips per person	Household density	0.03	y
Zhang, 2004 (Boston)	1,619	Walk/bike mode choice for work trips	Population density	0.11 *	y
Zhang, 2004 (Boston)	1,619	Walk/bike mode choice for work trips	Job density	0.03 *	y
Zhang, 2004 (Boston)	1,036	Walk/bike mode choice for nonwork trips	Population density	0.06 *	y
Zhang, 2004 (Boston)	1,036	Walk/bike mode choice for nonwork trips	Job density	0.00	y

ψ$p < .10$ *$p < .05$ **$p < .01$

Notes:

a. Computed at median cutpoint by Jason Cao.

b. Significance level indeterminate.

Table A-8. Elasticity of walk trips with respect to diversity.

Study	*N*	*y*	*x*	*e*	In meta-analysis?
Bento et al., 2003	4,456	Walk/bike mode choice	Job-housing imbalance	0.30 *a	y
Boer et al., 2007	29,724	Miles walked per person	Business types in neighborhood	0.20 b	
Cao, Mokhtarian, et al., 2009b	1,277	Nonwork walk trips per person	Business types within 400 meters	0.07 **	
Cao et al., 2006	837	Walk trips to store per person	Distance to store	0.56 **a	y
Cervero & Kockelman, 1997	2,850	Non-person vehicle choice for nonwork trips	Land use dissimilarity	0.00	
Cervero & Kockelman, 1997	2,850	Non-person vehicle choice for nonwork trips	Proportion vertical mix	0.00	
Cervero & Kockelman, 1997	2,850	Non-person vehicle choice for nonwork trips	Proportion of population within 1/4 mile of store	0.00	
Ewing et al., 2009 (Portland)	3,823	Walk mode choice	Job-population balance	0.18	y
Frank et al., 2008	8,707	Walk mode choice for work trips	Land use mix (entropy index)	0.22 **	y
Frank et al., 2008	10,475	Walk mode choice for other trips	Land use mix (entropy index)	0.03 *	y
Frank et al., 2009	2,697	Walk trips per household	Land use mix (entropy index)	0.08 y	
Greenwald, 2009	3,938	Walk/bike trips per household	Non-retail job-housing balance	0.25 ψ	y
Greenwald, 2009	3,938	Walk/bike trips per household	Retail job-housing balance	0.02	y
Greenwald, 2009	3,938	Walk/bike trips per household	Job mix (entropy index)	0.09	
Handy & Clifton, 2001	1,368	Walk trips to store per person	Distance to nearest store	0.48 **a	y
Handy et al., 2006	1,480	Walk trips to store per person	# Business types within 800m	0.29 **	
Handy et al., 2006	1,480	Walk trips to store per person	Distance to nearest grocery	0.17 **a	y
Kitamura et al., 1997	14,639	Fraction walk/bike trips	Distance to nearest park	0.11 *a	
Kockelman, 1997	8,050	Walk/bike mode choice	Land use mix (entropy index)	0.23 *	y
Rajamani et al., 2003	2,500	Walk mode choice for nonwork trips	Land use mix (diversity index)	0.36 *	y
Reilly, 2002	7,604	Walk mode choice for nonwork trips	Distance to closest commercial use	0.16 **a	y
Shay et al., 2006	348	Walk trips per household	Distance to commercial center	0.98 **a	y
Targa & Clifton, 2005	2,934	Walk trips per person	Land use mix (entropy index)	0.08 **	y
Zhang, 2004 (Boston)	1,619	Walk/bike mode choice for work trips	Land use mix (entropy index)	0.00	y
Zhang, 2004 (Boston)	1,036	Walk/bike mode choice for nonwork trips	Land use mix (entropy index)	0.12	y

$^{\psi}p < .10$ $^{*}p < .05$ $^{**}p < .01$

Notes:

a. Sign reversed.

b. Significance level indeterminate.

Table A-9. Elasticity of walk trips with respect to design.

Study	***N***	***y***	***x***	***e***	**In meta-analysis?**
Boarnet et al., 2008	6,362	Miles walked per person	Intersection density	0.45 **	
Boarnet et al., 2008	6,362	Miles walked per person	Pedestrian environment factor	0.04	
Boarnet et al., 2009	1,370	Walk trips per person	Block size	0.35 [a]	y
Boarnet et al., 2009	1,370	Walk trips per person	% 4-way intersections	−0.09	y
Boer et al., 2007	29,724	Miles walked per person	Proportion 4-way intersections	0.39 [d]	
Boer et al., 2007	29,724	Miles walked per person	Block length (long side)	−0.31 [a,d]	
Cervero & Kockelman, 1997	2,850	Non-private vehicle choice for nonwork trips	Proportion 4-way intersections	0.00	
Cervero & Kockelman, 1997	2,850	Non-private vehicle choice for nonwork trips	Proportion quadrilateral blocks	0.00	
Cervero & Kockelman, 1997	2,850	Non-private vehicle choice for nonwork trips	Sidewalk width	0.09 *	
Cervero & Kockelman, 1997	2,850	Non-private vehicle choice for nonwork trips	Proportion front and side parking	0.12 **[a]	
Chatman, 2009	999	Walk/bike trips per person	4-way intersection density	0.30 *	
Ewing et al., 2009	3,823	Walk mode choice	Intersection density	0.43 **	y
Ewing et al., 2009	3,823	Walk mode choice	Sidewalk coverage	0.27 **	y
Fan, 2007	988	Daily walking time per person	% connected intersections	0.40 **	
Fan, 2007	988	Daily walking time per person	Sidewalk length	0.12 **	
Frank et al., 2008	8,707	Walk mode choice for work trips	Intersection density	0.21 **	y
Frank et al., 2008	10,475	Walk mode choice for other trips	Intersection density	0.28 **	y
Frank et al., 2009	2,697	Walk trips per household	Intersection density	0.55 **	y
Greenwald, 2009	3,938	Walk/bike trips per household	Intersection density	1.11 **	y
Greenwald & Boarnet, 2001	1,084	Walk trips per person for nonwork purposes	Pedestrian environment factor	0.25 [b]	
Hess et al., 1999	12	Pedestrians per hour	Block size	0.35 **[a]	
Joh et al., 2009	2,125	Walk trips per person	Block size	0.01 [a]	y
Joh et al., 2009	2,125	Walk trips per person	% 4-way intersections	−0.27	y
Rajamani et al., 2003	2,500	Walk mode choice for nonwork trips	% Culs-de-sac	0.00 **[c]	y
Rodriguez & Joo, 2004	448	Walk mode choice for commute trips	Sidewalk coverage	1.23 **	
Rodriguez & Joo, 2004	448	Walk mode choice for commute trips	Path directness	0.03 $^{\psi}$	
Soltani & Allan, 2006	1,842	Walk/bike mode choice	Path directness	0.11	
Targa & Clifton, 2005	2,934	Walk trips per person	Block size	0.32 **[a]	y
Zhang, 2004 (Boston)	1,619	Walk/bike mode choice for work trips	Street connectivity	0.07 $^{\psi}$	y
Zhang, 2004 (Boston)	1,036	Walk/bike mode choice for nonwork trips	Street connectivity	0.05	

$^{\psi}p < 0.10$ $^{*}p < 0.05$ $^{**}p < 0.01$

Notes:

a. Sign reversed.

b. Computed at the median cutpoint by Jason Cao.

c. Because either the elasticity or significance level must be misreported in the published article we dropped this observation from the meta-analysis.

d. Significance level indeterminate.

Table A-10. Elasticity of walk trips with respect to destination accessibility.

Study	*N*	*y*	*x*	*e*	In meta-analysis?
Bento et al., 2003	4,456	Walk/bike mode choice	Population centrality	1.00 ψ	
Boarnet et al., 2008	6,362	Miles walked per person	Distance to cbd	0.49 **a	
Cervero & Duncan, 2003	7,836	Walk mode choice	Jobs within one mile	0.04	y
Cervero & Kockelman, 1997	2,850	Non-person vehicle choice for nonwork trips	Job accessibility by auto	0.00	
Chatman, 2009	999	Walk/bike trips per person	Distance to downtown	0.29 ψa	
Ewing et al., 2009	3,823	Walk mode choice	Jobs within one mile	0.23 *	y
Greenwald, 2009	3,938	Walk/bike trips per household	Job accessibility by auto	−0.32 **	
Kockelman, 1997	8,050	Walk/bike mode choice	Job accessibility by walking	0.22 **	y
Naess, 2005	1,406	Weekday travel distance by walk/bike per person	Distance to downtown	0.29 **a	

ψ$p < .10$ *$p < .05$ **$p < .01$
Note:
a. Sign reversed.

Table A-11. Elasticity of walk trips with respect to transit access.

Study	*N*	*y*	*x*	*e*	In meta-analysis?
Bento et al., 2003	4,456	Walk/bike mode choice	Distance to nearest transit stop	0.30 a	y
Boarnet et al., 2008	6,362	Miles walked per person	Distance to light rail	−0.17 *a	
Kitamura et al., 1997	14,639	Fraction walk/bike trips	Distance to nearest bus stop	0.10 *a	y
Naess, 2005	1,406	Weekday travel distance by walk/bike per person	Distance to closest rail station	0.00 a	
Rajamani et al., 2003	2,500	Walk mode choice for nonwork trips	% within walking distance of bus	0.02 a	
Targa & Clifton, 2005	2,934	Walk trips per person	Distance to nearest bus stop	0.08 **a	y

ψ$p < .10$ *$p < .05$ **$p < .01$
Note:
a. Sign reversed.

Table A-12. Effect on walk trips[a] of neighborhood type.

Study	*N*	*y*	*x*	*e*	In meta-analysis?
Cao, Mokhtarian, et al., 2009b	1,277	Nonwork walk trips per person	Traditional neighborhood	0.44 **	
Handy & Clifton, 2001	1,368	Walk trips to store per person	Traditional neighborhood	1.20 **	
Khattak & Rodriguez, 2005	302	Walk trips per household	New urbanist neighborhood	3.06 **	
Lund, 2003	427	Destination walk trips per person	Neighborhood with retail	0.38 **	
Lund, 2003	427	Destination walk trips per person	Neighborhood with retail and park	0.85 **	
Plaut, 2005	26,950	Walk mode choice for commute trips	Neighborhood with retail	0.79 **	
Rose, 2004	244	Walk trips per person	New urbanist neighborhood	0.35 *	

ψ$p < .10$ *$p < .05$ **$p < .01$
Note:
a. Proportional increase relative to conventional neighborhood.

Table A-13. Elasticity of transit trips with respect to density.

Study	***N***	***y***	***x***	***e***	**In meta-analysis?**
Bhatia, 2004	20	Transit trips per household	Household density	0.37 *	
Cervero, 2002a	427	Transit mode choice	Gross population density	0.39 *	y
Cervero, 2006	225	Weekday boardings per station	Population density	0.19 **	
Ewing et al., 2009	3,823	Transit mode choice	Population density	−0.01	y
Ewing et al., 2009	3,823	Transit mode choice	Job density	0.08	y
Fan, 2007	154	Daily transit travel time per person	Parcel density	0.00	
Frank et al., 2008	8,707	Transit mode choice for work trips	Retail floor area ratio	0.21 **	y
Frank et al., 2008	10,475	Transit mode choice for nonwork trips	Retail floor area ratio	0.17 **	y
Greenwald, 2009	3,938	Transit trips per household	Net residential density	0.41 **	y
Greenwald, 2009	3,938	Transit trips per household	Net job density	−0.05 *	y
Kuby et al., 2004	268	Weekday boardings per station	Population within walking distance	0.11 *	
Kuby et al., 2004	268	Weekday boardings per station	Employment within walking distance	0.07 *	
Rajamani et al., 2003	2,500	Transit mode choice for nonwork trips	Population density	0.08	y
Reilly, 2002	7,604	Transit mode choice for nonwork trips	Population density	0.20 *	y
Rodriguez & Joo, 2004	454	Transit mode choice for commute trips	Population density	−0.20	y
Zhang, 2004 (Boston)	1,619	Transit mode choice for work trips	Population density	0.12 *	y
Zhang, 2004 (Boston)	1,036	Transit mode choice for nonwork trips	Population density	0.13 *	y
Zhang, 2004 (Boston)	1,619	Transit mode choice for work trips	Job density	0.09 *	y
Zhang, 2004 (Boston)	1,036	Transit mode choice for nonwork trips	Job density	0.00	y
Zhang, 2004 (Hong Kong)	20,246	Transit mode choice for work trips	Population density	0.01	y
Zhang, 2004 (Hong Kong)	15,281	Transit mode choice for nonwork trips	Population density	0.01 *	y
Zhang, 2004 (Hong Kong)	20,246	Transit mode choice for work trips	Job density	0.01 **	y
Zhang, 2004 (Hong Kong)	15,281	Transit mode choice for nonwork trips	Job density	0.01	y

$^{\psi}p < .10$ $^{*}p < .05$ $^{**}p < .01$

Table A-14. Elasticity of transit trips with respect to diversity.

Study	***N***	***y***	***x***	***e***	**In meta-analysis?**
Bento et al., 2003	4,456	Transit mode choice	Job-housing imbalance	0.60 [a]	y
Cervero, 2002a	427	Transit mode choice	Land use mix (entropy index)	0.53 *	y
Cervero & Kockelman, 1997	1,544	Non-personal vehicle choice for work trips	Land use dissimilarity	0.00	
Cervero & Kockelman, 1997	1,544	Non-personal vehicle choice for work trips	Proportion vertical mix	0.00	
Cervero & Kockelman, 1997	1,544	Non-personal vehicle choice for work trips	Proportion of population within 1/4 of store	0.00	
Fan, 2007	154	Daily transit travel time per person	Retail store count	−0.04 ψ	
Frank et al., 2008	8,707	Transit mode choice for work trips	Land use mix (entropy index)	0.09 *	y
Frank et al., 2008	10,475	Transit mode choice for nonwork trips	Land use mix (entropy index)	0.19	y
Greenwald, 2009	3,938	Transit trips per household	Job-housing balance	0.23 *	y
Greenwald, 2009	3,938	Transit trips per household	Job mix (entropy index)	0.04	
Kitamura et al., 1997	14,639	Fraction transit trips	Distance to nearest park	0.11 *	
Rajamani et al., 2003	2,500	Transit mode choice for nonwork trips	Land use mix (diversity index)	−0.04	y
Reilly, 2002	7,604	Transit mode choice for nonwork trips	Distance to closest commercial use	−0.19 **	
Zhang, 2004 (Boston)	1,619	Transit mode choice for work trips	Land use mix (entropy index)	0.00	y
Zhang, 2004 (Boston)	1,036	Transit mode choice for nonwork trips	Land use mix (entropy index)	0.12	y

$^{\psi}p < .10$ $^{*}p < .05$ $^{**}p < .01$

Note:

a. Sign reversed.

Table A-15. Elasticity of transit trips with respect to design.

Study	*N*	*y*	*x*	*e*	In meta-analysis?
Cervero, 2002a	427	Transit mode choice	Sidewalk ratio	0.16	
Cervero, 2007	726	Transit mode choice for work trips	% 4-way intersections	1.08	y
Cervero & Kockelman, 1997	1,544	Non-personal vehicle choice for work trips	Proportion front and side parking	0.00	
Cervero & Kockelman, 1997	1,544	Non-personal vehicle choice for work trips	Proportion 4-way intersections	0.00	
Cervero & Kockelman, 1997	1,544	Non-personal vehicle choice for work trips	Sidewalk width	0.00	
Cervero & Kockelman, 1997	1,544	Non-personal vehicle choice for work trips	Proportion quadrilateral blocks	0.19	
Fan, 2007	154	Daily transit travel time per person	% connected intersections	0.27	
Fan, 2007	154	Daily transit travel time per person	Sidewalk length	0.00	
Frank et al., 2008	8,707	Transit mode choice for work trips	Intersection density	0.20 *	y
Frank et al., 2008	10,475	Transit mode choice for nonwork trips	Intersection density	0.24 ψ	y
Frank et al., 2009	2,697	Transit trips per household	Intersection density	0.12	y
Greenwald, 2009	3,938	Transit trips per household	Intersection density	0.37 *	y
Lund et al., 2004	967	Transit mode choice	% 4-way intersections at destination	1.08 **	y
Rajamani et al., 2003	2,500	Transit mode choice for nonwork trips	% Culs-de-sac	0.00 [a]	y
Rodriguez & Joo, 2004	454	Transit mode choice for commute trips	Sidewalk coverage	0.28 *	
Rodriguez & Joo, 2004	454	Transit mode choice for commute trips	Path directness	0.01 ψ	
Zhang, 2004 (Boston)	1,619	Transit mode choice for work trips	Street connectivity	0.08 ψ	y
Zhang, 2004 (Boston)	1,036	Transit mode choice for nonwork trips	Street connectivity	0.04	y

ψ$p < .10$ *$p < .05$ **$p < .01$
Note:
a. Sign reversed.

Table A-16. Elasticity of transit trips with respect to destination accessibility.

Study	*N*	*y*	*x*	*e*	In meta-analysis?
Bento et al., 2003	4,456	Transit mode choice	Population centrality	0.00	
Cervero, 2006	225	Weekday boardings per station	Distance to CBD	0.21 **[a]	
Ewing et al., 2009	3,823	Transit mode choice	Job accessibility by transit	0.29 **	
Frank et al., 2009	2,697	Transit trips per household	Job accessibility by transit	0.16 *	
Greenwald, 2009	3,938	Transit trips per household	Job accessibility by auto	0.05	
Kuby et al., 2004	268	Weekday boardings per station	Average time to other stations	0.95 **[a]	
Lund et al., 2004	967	Transit mode choice	Job accessibility by auto	−0.70 **	

ψ$p < .10$ *$p < .05$ **$p < .01$
Note:
a. Sign reversed.

Table A-17. Elasticity of transit trips with respect to transit access.

Study	*N*	*y*	*x*	*e*	In meta-analysis?
Bento et al., 2003	4,456	Transit mode choice	Distance to transit stop	1.00 [a]	y
Ewing et al., 2009	3,823	Transit mode choice	Bus stop density	0.08	
Frank et al., 2009	2,697	Walk trips per household	Distance to bus stop squared	0.02 [b]	y
Kitamura et al., 1997	14,639	Fraction transit trips	Distance to rail station	0.13 **[a]	y
Rajamani et al., 2003	2,500	Transit mode choice for nonwork trips	% within walking distance of bus	0.42 *	

$^{\psi}p < .10$ *$p < .05$ **$p < .01$

Notes:

a. Sign reversed.

b. Sign reversed and multiplied by 2 to make x variable equivalent to others.

Table A-18. Effect on transit trips[a] of neighborhood type.

Study	*N*	*y*	*x*	*e*	In meta-analysis?
Rose, 2004	244	Transit trips per person	New urbanist neighborhood	0.66	

Note:

a. Proportional increase relative to conventional neighborhood.

EXHIBIT
6

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Environmental Noise Pollution: Has Public Health Become too Utilitarian?

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Abstract

Environmental noise pollution is an ever-increasing problem. The various sources: Aircraft, Road Traffic and Wind Farms are reviewed, but the latter source, because of the intrusive, impulsive and incessant nature of the sound emitted, is the major focus of this review. Wind turbines produce a range of sound but it is the Infrasound and low frequency noise which deserves special attention. Infrasound is considered to be below the range of human hearing so it is not measured in routine noise assessments in the wind farm planning process. There is, however, evidence that many can register it and a sizeable minority is sensitive, or becomes sensitised to it. The actual route of transmission still requires elucidation. The net effect of the entire range of noise produced is interference with sleep and sleep deprivation. Sleep, far from being a luxury is vitally important to health and insufficient sleep, in the long term, is associated with a spectrum of diseases, particularly Cardiovascular. The physiological benefits of sleep are reviewed, as is the range of diseases which the sleep-deprived are predisposed to. Governments, anxious to meet Green targets and often receiving most of their advice on health matters from the wind industry, must commission independent studies so that the Health and Human Rights of their rural citizens is not infringed. Public Health, in particular, must remember its roots in Utilitarianism which condoned the acceptance of some *Collateral Damage* provided that the greatest happiness of the greatest number was ensured. The degree of *Collateral Damage* caused by wind farms should be totally unacceptable to Public Health which must, like good government, fully exercise the *Precautionary Principle.* The types of study which should be considered are discussed. Indeed, the father of Utilitarian Philosophy, Jeremy Bentham, urged that government policy should be fully evaluated.

Keywords

Environmental Noise Pollution, Wind Farms, Infrasound, Health Impacts, Public Health, Utilitarianism, Collateral Damage, Precautionary Principle

1. Introduction

There are a number of emerging threats to Public Health, and some of these can be directly ascribed to human activity, chief among which are Global Warming, air pollution and environmental noise pollution. This paper will concentrate on the issue of environmental noise pollution and examine how modern Public Health has lived up to its responsibilities in controlling it. Over a century ago, the Nobel Prize-winning microbiologist, Robert Koch, predicted [1] "One day man will have to fight noise as fiercely as cholera and pest (plague)." The accuracy of this prediction is attested to by the statement [2] from the United States Environmental Protection Agency that, "The over-all loudness of environmental noise has been doubling every ten years in pace with social and industrial growth, and, if allowed to continue unchecked, the cost of alleviating it in the future may be insurmountable." Perhaps surprisingly, this statement is more than 40 years old, yet the problem has been growing, unchecked, ever since.

From an evolutionary perspective, an awareness of sound is essential to alert us of incipient danger, but our aural acuity may have left us vulnerable to when it is present in excess. The earliest problems arose with the introduction of noisy industrial processes a couple of centuries ago, which induced deafness [3]. We are now being bombarded with noise pollution from diverse sources, which predisposes us to a range of diseases. Light radiation ranges from Ultraviolet to Infrared, and apart from its intensity, its wavelength will determine its effect on the receiver: typically different wavelengths in the Ultraviolet range have different effects on our skin [4]. Similarly, it is not just the amplitude of noise which brings health consequences, but also, its "frequency content" (considering the sound as a stimulus rather than how frequency in the audible range is perceived as pitch).

Sound is caused by a series of pressure pulsations, or more broadly, by changes in air pressure. The spectrum of sound [4] frequency ranges from >1 to more than 20,000 cycles per second or Hz, with the range up to 20 Hz classified [5] as Infrasound, >20 - 200 Hz as low frequency sound (the lowest note on a piano has a frequency of 33 Hz and Middle C, 262 Hz [6]), >200 - 20,000 Hz as the human auditory range, and >20,000 Hz as Ultrasound. Strictly, pressure pulsations outside our auditory range cannot be described as sound but they are still able to exert an effect on us [5].

As with light, sound's effects on human health are not only determined by its intensity, or amplitude, but also by its frequency and the rate of change in amplitude. The term Infrasound is confusing, because how could sound which we are unable to hear have an effect on us? Perhaps a better way to look at it would be in terms of pressure pulsations. There is increasing evidence that Infrasound is perceived by the brain [7], and possibly by other sensory systems' vibratory receptors [8]: in the vestibular organ of balance, skin and joints, rather than by those transmitting auditory sensation [7]. Another problem with noise in the lower registers is that it persists longer, travels further and, thanks to diffraction, can turn corners [6].

This, from another evolutionary perspective, is no surprise. Many of our fellow mammals use Infrasound extensively for communication: e.g., giraffes, rhinoceroses, whales and elephants—the latter are capable of sensing distant thunderstorms, because of the Infrasound the storms emit, from over a hundred kilometres away [9], and set off in that direction in the knowledge that they will find water and green vegetation to consume. Humans carry a large range of genes which were acquired in our evolutionary past, but which are now redundant. Sometimes however, these are expressed, for example when, occasionally, someone grows a tail [10]. Olfactory receptor (OR) genes provide a good example of genes which humans possess but do not express. Mammals have over 1000 OR genes and these constitute the largest mammalian gene superfamily. In humans about 60% of these are pseudogenes and have been annulled through mutation [11]. In other primates, the pseudogene rate is about half of this. It is postulated that reduced chemosensory dependence in man drives this OR gene disruption. Individual differences in gene-expression might also explain why a small, but significant, proportion of the population may be more sensitive to the effects of Infrasound than others, and to noise in general [7]. An alternative hypothesis is that sufferers have been "sensitized" through past exposure [5], although both factors could contribute.

This review will concentrate on the adverse health effects associated with environmental noise, particularly those due to the Infrasound and low frequency noise emitted by industrial wind turbines. Some of the adverse health effects are due to sleep deprivation, and the evidence linking it to several diseases, particularly cardiovascular, will be discussed. The control of wind farm noise emissions, and its effectiveness, will be reviewed along with the appropriateness of the Guidelines governing noise limits, and where wind farms are sited. The studies which need to be mounted will then be described. The history of Public Health will be discussed, including the seminal role that Utilitarian Philosophy (the greatest happiness of the greatest number) played in its inception. The response of Public Health to new health threats will be evaluated in the light of the concepts of *Collateral Damage* and the *Precautionary Principle*. The overall aim is to evaluate the adverse health effects of industrial wind turbines and the adequacy of the Public Health response to the problems arising. In particular, the adequacy of the protection of the Health and Human Rights of rural citizens whose health is compromised by wind turbines will be scrutinized.

2. Literature Review

2.1. Extent of the Problem

The problem of noise pollution has been justly highlighted in two recent World Health Organisation reports. The first of these, entitled 'Night Noise Guidelines for Europe', stated [12] that "… environmental noise is emerging as one of the major Public Health concerns of the twenty-first century." It observed that, "Many people have to adapt their lives to cope with the noise at night," and that the young and the old are particularly vulnerable. This is because hearing in young people is more acute and, in older people, a loss of hearing of higher sound frequencies renders them more susceptible to the effects of low frequency noise [13]. A more recent World Health Organisation report calculated [14] that more than a million healthy life years (Disability Adjusted Life Years) are lost due to environmental noise annually in western EU member states. The vast bulk of these are lost because of noise-induced sleep disturbance, followed by 'Annoyance.' This is a construct assembled from subjects' responses to a questionnaire, where subjects are asked to indicate their 'Level of Annoyance' on a scale [15]. Annoyance is a common finding reported in a population exposed to environmental noise. It is difficult to define accurately, but one authority maintains that it can result from noise interfering with daily activities, feelings, thoughts, sleep or rest, and might be accompanied by negative responses, such as anger, displeasure, exhaustion and stress-related symptoms [16]. It clearly is not a trivial state.

Sleep disturbance is serious if it leads to sleep deprivation [17], which is associated with a gamut of Cardiovascular Diseases (CVD), obesity, diabetes, and poor memory consolidation [1]. In an up-to-date meta-analysis of 160,867 subjects, in whom 11,702 cases occurred, insomnia symptoms were shown to be significantly associated with the risk of cardio-cerebral vascular events [18]; and even some cancers [19]. On top of this, inadequate sleep in children is associated with impaired memory and learning, poor cognitive function, mental health disorders, and obesity [20]. The mechanism for this is not well understood but it may be connected to higher levels of a cannabis-like chemical found in individuals who are deprived of sleep [21]. The latter is of concern because it tends to sow the seeds for diabetes and CVD in later life.

2.2. Importance of Sleep

There is an ever-mounting volume of research to show that sleep is essential for the brain and the physiological well-being of the entire body. Sleep deprivation interferes with learning, causing memory impairment because memory is laid down and reinforced during both the Slow Wave and Rapid Eye Movement phases of sleep. In mice, it has been shown that sleep plays a key role in promoting learning-dependent synapse formation and maintenance on selected dendritic branches, which contribute to memory storage [22]. There are a number of other adverse effects associated with sleep deprivation. Tired individuals are more likely to have road traffic accidents and injure themselves while operating machinery. During sleep, neurotoxins are removed from the brain [23]. Lately, an association between sleep deprivation and loss of brain volume has been demonstrated [24]. This study was based on serial MRI scans carried out in 147 community-dwelling adults. In addition, it has been demonstrated [25] that various inflammatory biomarkers are affected by sleep deprivation.

Sleep deprivation produced experimentally also very rapidly alters the expression in a wide range of genes, involving several body systems [26] [27]. This could explain the links between sleep deprivation and CVD where the putative intermediate risk factors include blood pressure, clotting factors, blood viscosity, and blood lipids and glucose [1]. The cardiovascular effects of environmental noise exposure have been reviewed recently in studies carried out in 11 countries. These compared aircraft, road and railway sources of noise: aircraft noise was identified as the most highly annoying, and railways the least [1]. It is unclear as to which frequencies are contributing most because very often the full acoustic spectrum is not assessed. Jet aircraft, in particular, produce Infrasound and low frequency noise in abundance, so people dwelling near airports suffer adverse health effects [28] [29].

Why has environmental noise pollution become such a problem? Air and road traffic have increased and industrial installations have tended to get bigger. There are noise limits set, but they may not always be enforced. The other aspect, which should be of great concern to Public Health, is that the cut-points established as safe for any factor whose risk is continuously distributed, are nearly always set too high—e.g., blood pressure and LDL cholesterol—and subsequently have to be revised downwards. Asbestos is a prime example, with the permitted level of asbestos being successively reduced over many years [30] until its use was banned in most developed countries. Airports invariably have night time restrictions on flying and road traffic noise tends to be less at night. Wind farms emit noise, sometimes for days on end, and this is a problem because they are being constructed in rural areas where background noise is low. It is a particular problem at night, because Infrasound persists long after the higher frequencies have been dissipated [6]. This paper will concentrate on the health effects of wind turbine noise, which has been shown [31] to be particularly troublesome because of its impulsive, intrusive and incessant nature.

2.3. Health Effects of Wind Turbine Noise

The major adverse health effects caused by wind turbines seem to be due to sleep disturbance and deprivation, with the main culprits identified as loud noise in the auditory range and low frequency noise, particularly Infrasound. This is inaudible in the conventional sense, and is propagated over large distances and penetrates the fabric of dwellings, where it may become amplified by resonance. A report [32] commissioned by the Scottish Government, which is investing in wind energy to a heroic degree, grudgingly accepts that wind turbine noise interferes with sleep. A recent Swedish study, conducted [33] on healthy volunteers in a sleep laboratory, has shown that the noise produced by wind turbines, particularly low frequency band amplitude modulation, is disruptive to sleep. This was indicated by an increase in electro-physiological awakenings, lighter sleep with more wakefulness, and reduced deep sleep and Rapid Eye Movement sleep.

A recent review identified [34] 146 potential papers assessing the effects of wind turbine noise, and after applying stringent criteria, came up with a shortlist of 18, of which eight were included in a meta-analysis. All studies were cross-sectional and a meta-analysis of six of these (n = 2364) revealed that the odds of being annoyed are significantly increased by wind turbine noise (OR: 4.08; 95% CI: 2.37 to 7.04; $p < 0.00001$). The odds of sleep disturbance were also significantly increased with greater exposure to wind turbine noise (OR: 2.94; 95% CI: 1.98 to 4.37; $p < 0.00001$). Four studies reported that wind turbine noise significantly interfered with Quality of Life. Furthermore, the visual perception of wind turbine generators was associated with a greater frequency of reported negative health effects. Visual perception and sound emissions (effects of emissions after propagation on the environment) are directly related to distance so studies need to carefully differentiate the two sources of annoyance to ensure that each is properly assessed.

Sleep deprivation has also been shown [35] to be associated with heart failure in the HUNT Study. The data are quite robust as they are based on 54,279 Norwegians free of disease at baseline (men and women aged 20 - 89 years). A total of 1,412 cases of heart failure developed over a mean follow-up of 11.3 years. A dose-dependent relationship was observed between the risk of disease and the number of reported insomnia symptoms: i) difficulty in initiating sleep; ii) difficulty in maintaining sleep; and iii) lack of restorative sleep. The Hazard Ratios were "0" for none of these; "0.96" for one; "1.35" for two; and, "4.53" for three; this achieved significance at the 2% level. This means that such a result could occur once by chance if the study were to be repeated 50 times. Significance is conventionally accepted at the 5% level.

Another important, recent study is MORGEN, which followed [36] nearly 18,000 Dutch men and women, free of CVD at baseline, over 10 - 14 years. In this period there were 607 events: fatal CVD, non-fatal Myocardial Infarction and Stroke. Adequate sleep, defined as at least seven hours a night, was a protective factor which augmented the benefits conferred by the absence of four traditional cardiovascular risk factors. For example, the benefit of adequate sleep equalled the protective contribution of not smoking cigarettes. Given that cigarette smoking is such a potent risk factor for CVD, this result is striking. The findings built on earlier ones from the MORGEN study [37]. It seems that adequate sleep is important in protecting against a range of CVDs which result when arteries of different sizes are compromised: large (coronary, cerebral) arteries in heart attacks and stroke, small arteries (arterioles) in heart failure. The mechanisms are obscure, but it is known, for example, that exposing mice to stress activates [38] hematopoietic stem cells, *i.e.* affects the immune system and accelerates atherosclerosis.

All of these studies share the weakness that they are "observational" as opposed to "experimental" and, as such, their results do not constitute "proof". The results from the experimental study of sleep deprivation of fairly short durations [26], which affected the expression of a large range of genes, sheds light on the

"Wind Turbine Syndrome (WTS)", a cluster of symptoms which includes sleep disturbance, fatigue, headaches, dizziness, nausea, changes in mood and inability to concentrate [39]. In this condition, Infrasound is a likely causal agent. Another report from HUNT has examined insomnia in almost 25,000 persons and has demonstrated [40] it to be a robust risk factor for incident physical and mental disease, which included several features of WTS.

This group has now shown, in another small intervention study, that mistimed sleep desynchronized from the central circadian clock has a much larger effect on the circadian regulation of the human transcriptome (*i.e.*, a reduction in the number of circadian transcripts from 6.4% to 1% and changes in the overall time course of expression of 34% of transcripts). This may elucidate the reasons for the large excess of cardiovascular events associated with shift work [27]. The results demonstrate that any interference in normal sleeping patterns is inimical to cardiovascular health.

The old admonition that "What you can't hear won't harm you" sadly isn't true. It is now known [41] that the organ of Corti in the cochlea (inner ear) contains two types of sensory cells: one row of inner hair cells which are responsible for hearing; and three rows of outer hair cells which are more responsive to low frequency sound. Another function of the outer hair cells is that, due to their extensibility, they can modify the sensitivity of the cochlea. This has relevance to low frequency hearing and also to detecting higher frequencies which are amplitude-modulated at lower, if not infrasonic, frequencies. The Infrasound produced by wind turbines is transduced by the outer hair cells and transmitted to the brain by Type II afferent fibres. The purpose is unclear as it results in sleep disturbance. This may well be the group which is also liable to travel sickness, which is a sizeable proportion of the population. Schomer and his colleagues have since advanced [42] the theory that as wind turbines increase in size they increasingly emit Infrasound with a frequency below 1 Hz (CPS). Below this frequency the otoliths in the inner ear respond in an exaggerated way in a susceptible minority who will suffer symptoms of WTS. Previously it was thought that the brain was only under the control of electrical and biochemical stimuli, but there is new evidence [43] that it is sensitive, in addition, to mechanical stimuli.

There were important studies carried out in the 1980s which appear to have been forgotten and which give a clue to the mechanisms involved. Danielsson and Landström carried out [44] a study in 20 healthy male volunteers who were bombarded with Infrasound for varying periods. Just 30 minutes' bombardment with 125 dB at 16 Hz resulted in a mean 8 mm increase in diastolic blood pressure. On the other hand, systolic BP was not affected, whereas the Pulse Pressure decreased. This could have important effects in those exposed to environmental Infrasound, for although the intensity may not be profound, chronic exposure might raise blood pressure a little. From a population perspective, this could raise the burden of CVD. Scientists at the University of Toronto Institute for Aerospace and the University of Waterloo found [45] variability in response in volunteers exposed to Infrasound under laboratory conditions using Infrasound of 8 Hz. The adverse responses of some individuals closely resembled motion sickness. They postulated that individual differences in the reaction to Infrasound might be explained by variability of inner-ear structure or central adaptive mechanisms.

As far back as 1996, the International Standards Organisation acknowledged [46] that motion sickness arises from low frequency oscillatory motion below 1 Hz. The report cites: "…a range of microscopic organs (mechano-receptors) distributed in the living tissues throughout the body that variously signal changing pressure, tension, position, vibratory motion, etc." This is highly intriguing as it seems extremely plausible that the same effect obtains for Infrasound in the same frequency range and this requires urgent clarification. Indeed, the incidence of motion sickness can be predicted from the magnitude, frequency, and duration of vertical oscillation [47]. There is also mounting evidence that jet engine Infrasound can induce Vibro-acoustic Disease [48]. It is recognized [49] that around 15% - 20% of individuals are seriously affected by the Infrasound and low frequency noise produced by aircraft, particularly jets.

A recent economic assessment of US environmental noise as a cardiovascular health hazard suggested that a reduction of 5 dB would reduce hypertension by 1.4% and coronary heart disease by 1.8%, with an annual economic benefit of USD3.9 billion. The threshold for the noise-exposed group was >55 dBA LDN, though there is evidence in the literature that there may be important impacts at even lower levels of noise exposure [50]. Invariably in assessing noise exposure the average sound levels are assessed, whereas it may be that it is the peaks of sound which do the damage. In a study of seals kept in captivity, it was shown [51] that repeated elicitation of the acoustic startle reflex led to sensitization, subsequent avoidance behavior and induced fear conditioning. The data indicated that repeated startling by anthropogenic noise sources might have severe effects on long-term behavior.

An Iranian paper has lately reported [52] sleep disturbance in wind turbine workers, 53 of whom fell into three groups: mechanics, security staff and officials. The results showed that there was a positive and significant relationship between age, workers' experience, equivalent sound level, and the severity of sleep disorder. When age was constant, sleep disorders increased by 26% for each 1 dB increase in equivalent sound level. In situations where the equivalent sound level was constant, an increase in sleep disorder of 17% occurred for each year of work experience. There was a difference in sound exposure between the different occupational groups: the effect of noise in mechanics was 3.4 times greater than in the security group and about 6.5 times greater than in the official group. Sleep disorder caused by wind turbine noise was almost twice as high in the security group in comparison to the official group. It was concluded that the noise generated by wind turbines has health implications for everyone exposed to it.

In a study reported [53] from Japan, 15 subjects were experimentally exposed to various sound stimuli, including recorded aerodynamic noise and Infrasound, along with synthetic periodic sound, and were evaluated by electroencephalography. The induced rate of *alpha*1 rhythm decreased when the test subjects listened to all the sound stimuli and decreased further with reducing frequency. In particular, the induced rate of *alpha*1 rhythm, when the sound stimulus lay in the frequency band of 20 Hz, produced the lowest rate of all. It was concluded that the subjects cannot relax comfortably when exposed to Infrasound.

The European Metrology Research Programme (EMRP) has now established that everyone, at least all 16 of the healthy 18 - 25-year-old volunteers studied, can perceive Infrasound down to 8 Hz [54]. This was the lowest frequency investigated and it is likely that even lower frequencies can be perceived. 'Perception' was assessed using functional magnetic resonance imaging (fMRI) and a significant response was detected which was localized within the auditory cortex and which was present down to 8 Hz. The signal strength of the blood-oxygen-level dependent (BOLD) signal showed a minimum at 20 Hz, so a further investigation of BOLD-signal's dependence on the loudness was carried out. A decreasing dynamic range of hearing in this frequency range was noted, accompanied by the finding that even sound signals with sound pressure levels only slightly above the threshold will be registered as annoying.

Several details in the brain imaging results suggested that, at frequencies around about 20 Hz, the perception mechanism might change or is realized by a combination of different processes. One hypothesis is that a somatosensory excitation of the auditory cortex contributes at these frequencies [54]. Thus, the idea is floated that we are perceiving Infrasound directly through our body surface. This fits in with the concept of the vibration of body structures espoused by Persinger [6]. In the Cape Bridgewater study, in which turbines were intermittently turned on and off, the subject who could best predict whether or not the rotors were in motion or not was profoundly deaf [55].

The latest EMRP study conducted on 14 subjects has demonstrated [56], using fMRI, that Infrasound of 12 Hz administered at sound pressure levels just below the hearing threshold can induce changes in neural activity across several brain regions. Some of these regions are known to be involved in auditory processing, while others are recognized as playing key roles in emotional and autonomic control. Paradoxically, these effects were not observed when subjects were exposed to Infrasound of 12 Hz above the hearing threshold, because, apparently, the brain can adjust to it. These findings provide intriguing evidence that continuous exposure to subliminal Infrasound may be harmful to the human brain. Such physiological or even psychological effects could be mediated via a subconscious processing route. The transient up-regulation of these brain regions in response to Infrasound at this level may therefore reflect an initial stressor response, with symptoms becoming established through constant exposure.

The EMRP authors observe [56] that a large part of the Infrasound that we are exposed to in our daily environment is produced by continuous sources such as wind-turbines and traffic. They argue that it is these sources of constant and subtle Infrasound, which may not attain a level exceeding the threshold of perception, which exert influences on the nervous system. Thus it seems that low levels of Infrasound really are capable of getting in 'under the radar'. It is this very level of Infrasound which authorities such as Leventhall state cannot harm you and which WHO dismisses as having no physiological or psychological effects [56].

In addition, wind turbines can, and do, cause accidents by collapsing, blade snap, ice throw, and even going on fire. They induce stress and psychological disorder from shadow flicker, which also has implications for certain types of epilepsy and autism. Even the current planning process, with its virtual absence of consultation, is stress inducing, as is the confrontation between landowners, who wish to profit from erecting turbines, and their neighbours, who dread the effects on their health. Finally, wind turbines considerably reduce the value of dwellings nearby and this has a negative long-term effect on their owners' and their families' health [57]. On top of this, increasing numbers of families will be driven into fuel poverty by spiralling electricity costs which are subsidizing wind energy.

2.4. Controlling Wind Farm Noise

Another aspect is that the instruments and methods used to assess the cut-points may be inappropriate or inaccurate. The United Kingdom's Batho Report of the Noise Review Working Party in 1990 identified [58] low frequency noise as having a serious effect on those exposed to it. It also commented that the use of the A-weighted scale to assess low frequency noise was not appropriate. The A-weighted scale was in fact designed to reflect the normal human auditory range for many common urban/suburban noise sources. The rationale for this derives from work published by Fletcher and Munson [59] in 1933 using pure tones and ear-occluding headsets (headphones) with the object of increasing the distance over which the human voice could be transmitted by telephone wire. The tests were therefore conducted in a setting intended to mimic the use of an ear-occluding headset, *i.e.*, a telephone. The use of occluded ears and pure tones is a totally artificial situation and not directly comparable to "free-field" hearing. Normal hearing occurs in "free field", without occluding the ear, and in the presence of many other background sounds.

When a noise emits more Infrasound and low frequency energy than usual, the use of A-weighted thresholds and measurements is not protective. If unweighted Infrasound measurements had been used to investigate Sick Building Syndrome, its generally accepted cause, Infrasound and low frequency rumble, could have been detected much earlier [60]. It has been known for a long time that fans turning inside buildings can make people sick [61] and there are questions remaining about the effects of even larger fans turning outside buildings [60], *i.e.* wind turbines.

The problem of Infrasound and low frequency noise was well-recognized in a Report by Casella Stanger, commissioned by DEFRA in 2001 [62] with the statement that: "It should not be regarded as formal guidance from DEFRA", but what is unclear is just when this advice was added. The Report advises, "For people inside buildings with windows closed, this effect is exacerbated by the sound insulation properties of the building envelope. Again, mid and high frequencies are attenuated to a much greater extent than low frequencies." It continued: "As the A-weighting network attenuates low frequencies by a large amount, any measurements made of the noise should be with the instrumentation set to linear." It drew heavily upon the Batho Report of 1990 [58]. In fact, these problems had already been elucidated and the measurement issues addressed in a trio of papers by Kelley and his colleagues in the 1980s [63] [64] [65]. Kelley and his colleagues began investigating a single turbine at Boone, North Carolina, in late 1979 when around 12% of families within 3 km where impacted by noise emissions from a single wind turbine. The 237-ft high 2 MW turbine with four cylindrical legs was perched "atop Howard's Knob" and the passage of the rotors past the legs caused low frequency pressure pulsations to be propagated into the structures in which the complainants lived. The situation was aggravated further by a complex sound propagation process controlled by terrain and atmospheric focusing. The report runs to 232 pages and is certainly comprehensive [64].

The annoyance was described as an intermittent "thumping" sound accompanied by vibrations. A "feeling" or "presence" was described, felt rather than heard, accompanied by sensations of uneasiness and personal disturbance. The "sounds" were louder and more annoying inside the affected homes. Some rattling of loose objects occurred. In one or two instances, structural vibrations were great enough to cause dust to fall from high ceilings and create an additional nuisance. The noise was found to be more persistent and perhaps more severe at night. Moreover, it was noted as being worse in small rooms, usually bedrooms. The impulsiveness of the emitted low frequency acoustic radiation was identified as a major factor in determining not only the level of potential annoyance to residents within a structure, but perception as well. Various recommendations were made concerning noise reduction [65].

Kelley and his colleagues' research was promoted at conferences on wind turbine noise but seems to have been ignored or forgotten, so the problem continues to be seriously underestimated. When measured using a tool which can detect it, levels of Infrasound and low frequency noise are disturbingly high, with 'sound pressure levels' greater than previously thought possible [66]. It has also been demonstrated that infrasonic noise interferes with the micro-mechanics of the human inner ear [67].

In February 2003, the UK Department of Trade and Industry launched [68] 'Our Green Energy Future,' which committed the country to wind energy. Despite the existence of the Casella Stanger Report warning about Infrasound and low frequency noise and its caveats about how it should be assessed, the Government used another Report dated May 2003 which told a rather different story [5]. Although a lot more comprehensive than the Casella Stanger Report [62], it was aligned with the ETSU-R-97 recommendations [69] (see below). This is all rather reminiscent of the allegedly "Dodgy Dossier" which the then Prime Minister, Tony Blair, used to launch the UK's involvement in the Iraq war the same year. It was published by the same Government Department which had published the Casella Stanger Report two years before. This looked remarkably like the Government commissioning the report which would facilitate its energy policy.

The Report by Leventhall [5], who has acted as a noise consultant to wind companies, actually states, "The effects of Infrasound or low frequency noise are of particular concern because of its pervasiveness due to numerous sources, efficient propagation, and reduced efficiency of many structures (dwellings, walls, and hearing protection) in attenuating low frequency noise compared with other noise," but it seems that this was the work of a co-writer. Despite this, the message conveyed is that modern wind turbines are not an important source of Infrasound and the use of A-weighting is entirely adequate. The report also states that "Infrasound exposure is ubiquitous in modern life." This may be so, but Persinger makes [6] the point that naturally occurring Infrasound, including that produced within our own bodies, is random, whereas wind turbine Infrasound is pulsatile; and it is this quality which causes health problems.

The message concerning the appropriateness of using A-weighting in assessing sound has recently been reasserted by Leventhall and three of his fellow acousticians [70]. This was in spite of the fact that three of them had previously recommended, in joint and separate statements and publications, that Infrasound should be viewed as a source of adverse effects.

2.5. Wind Farm Guidelines

In the UK, the construction of wind farms is predicated on ETSU-R-97 which was organized by the wind industry, ably assisted by acousticians and others associated with the industry, without a single Sleep Physician, in 1996-1997 [69]. The authors state in the executive summary: "This document describes a framework for the measurement of wind farm noise and gives indicative noise levels thought to offer a reasonable degree of protection to wind farm neighbors, without placing unreasonable restrictions on wind farm development or adding unduly to the costs and administrative burdens on wind farm developers or local authorities." Despite these lofty ideals, a recent review observed [71]: "Exposure to wind turbines does seem to increase the risk of annoyance and self-reported sleep disturbance in a dose-response relationship. There appears, though, to be a tolerable level of around L_{Aeq} of 35dB. " This is about 6 dB less than the permitted ETSU-R-97 night time level, implying a doubling of the setback (assuming a decay of noise level of 6 dB per doubling of distance). The ETSU-R-97 recommendations were based on the turbines of the mid 1990s which had a hub-height of 32 m, whereas today's turbines are several times taller with blades that are much longer and more flexible.

Applying the ETSU-R-97 methodology, which is still in force, setback distances for human habitation from modern 2.5 - 3 MW turbines are in the region of 500 - 600 m. There are good reasons for believing that these setbacks are woefully inadequate. A 2013 Marshall Day Acoustics 'Examination of the significance of noise in relation to onshore wind farms' [72], commissioned by the Sustainable Energy Authority of Ireland, reproduces a graph from the Møller and Pedersen paper of 2011 [73]. This shows how the noise emitted by a turbine increases with size. In fact, a doubling in turbine generating capacity from 1 MW to 2 MW may result in slightly more than a doubling of the overall A-weighted sound power level, that is, an increase of more than 3 dB. Also, for a range of turbines with the same power generating capacity, sound level output can vary by several decibels. Moreover, it was noted that while audible sound increased with increasing turbine size, the emission of low frequency sound was disproportionally greater. Shifting the acoustic energy into the lower frequencies renders A-weighted measurements and guidelines even less applicable. These data applied to turbines up to 3.6 MW, but are expected to apply to even larger ones. It was noted that the relationship is not necessarily statistically significant, which may well be the case, but it is almost certainly biologically significant.

In Ireland, the current setback, introduced in 2006, is a mere 500 m, although there have been repeated promises by government to increase it [74]. There are also concerns about the use of average noise levels as these smooth out the peaks. It is these sound pressure peaks which may be sensitizing people to noise, as has been shown in the case of seals [51]. Averaging only serves to conceal important characteristics which exert adverse effects on living things.

In 2008, the distinguished American acoustic engineers, George Kamperman and Richard James, posed [75] the question: "What are the technical options for reducing wind turbine noise emission at residences?" They observed that there were only two options: i) increase the distance between source and receiver; or ii) reduce the source sound power emission. They added that neither solution is compatible with the objective of the wind farm developer to maximize the wind power electrical generation within the land available. They also highlighted the fact that Vestas' employees are not allowed to go within 400 m of a turbine while it is in motion. Turbines can produce Infrasound even when they are not running when wind excites the tower and blades. Long-range measurements from two different wind farms over a distance of 80 km have shown that Infrasound below 6 Hz has a propagation loss approximating to 3 dB per doubling of distance [76].

Lastly, carpeting the Irish landscape with wind turbines has led to a proliferation in power lines which come with their own health risks. An association between living close to high voltage power lines and the development of childhood leukemia has been consistently observed [77]. Recent epidemiological studies are in agreement with earlier findings of an increased risk of childhood leukemia with estimated daily average exposures above 0.3 to 0.4 μT. Although no mechanisms have been identified and consequently causality cannot be ascribed [77], in view of its serious nature the association cannot simply be ignored.

2.6. What Studies Should be Mounted?

Although the associations between noise pollution, particularly from Infrasound and low frequency noise, and ill health can be argued against, and there are gaps in our knowledge, there is sufficient evidence to cause grave misgivings about its safety. Further research, supported by adequate funding, remains necessary. Good and caring Government should entail acting with greater caution when its policies could jeopardize the Health and Human Rights of its people.

So what studies need to be mounted? Hessler and his colleagues, as well as upholding [70] the adequacy of A-weighting, pose the question: "Do wind turbines make people sick? That is the issue."

This paper, written by four "scientists in the wind turbine acoustical field" who "do not doubt for a moment the sincerity and suffering of some residents close to wind farms and other low frequency sources, and this is the reason all four would like to conduct, contribute or participate in some studies that would shed some light on this issue." This all sounds very laudable, but the basic contention of their paper is that there is no adverse human health effect from low frequency noise and Infrasound, provided that A-weighting is used to measure them and current guidelines are adhered to. What, precisely, qualifies them to pronounce on health issues is obscure.

They continue: "It must also be said that it is human nature to exaggerate grievances and that some qualitative measure must be made available to compensate affected residences." It is hard to assimilate the logic of this sentence, but the first part is clearly intended as an antidote to the residents' "sincerity and suffering" described earlier in the paragraph. It should be pointed out that babies, young children, and animals that are unable to "exaggerate grievances" are also seriously impacted when exposed to low frequency noise and Infrasound, eg badgers [78], pigs [79], crabs [80] and, perhaps, even plants [81]. The phrase "exaggerate grievances" is also redolent of accusing sufferers of hysteria, which is all rather cynical. A similar fate befell Myalgic Encephalomyelitis sufferers when they had their condition derisively dismissed as "Yuppie Flu", until in 2011, when it was finally accepted as a true disease entity and International Consensus Criteria were developed [82].

Some of the studies the "scientists" propose [70] are not particularly scientifically robust: e.g., National Surveys, collecting cross-sectional data which may reveal associations, which, no matter how strong, cannot establish causation, are slow, inconclusive and favor the *status quo*; and Noise Source Reduction, *i.e.* trying to reduce noise emissions from turbines, which seems welcome but oddly similar to the tobacco industry's attempts to reduce tar in tobacco while ignoring the fact that tobacco smoke contains a cocktail of noxious elements [83], as wind turbine noise certainly also does. For example, in addition to Infrasound, Amplitude Modulation related to wake interference between turbines [84] can effectively double the noise produced. This is particularly likely to occur when turbines are crowded too close together, which also reduces their output [85].

Some other suggestions are better such as Perception Testing to investigate whether receivers have the ability to detect a turbine's activity without actually seeing or hearing it. It seems that it is only a minority, albeit a significant one, which is impacted by it. Moreover, whichever pathway transmits Infrasound to the brain is immaterial as it is unquestionably registered there. As noted above, one person who is sensitive to feeling the pulsations has nerve deafness. Furthermore, published reports by acousticians who are sensitive to infrasonic pressure pulses should establish that people can feel them even when sound pressure levels are insufficient to achieve the threshold of audibility [86].

The Recommendation [70] concerning Simulation appears the most sensible, by duplicating and simulating low frequency noise and Infrasound with loudspeakers, and exposing volunteers to high and low levels, to establish threshold levels. This approach would be valid if the sound correctly reflects what is experienced by people exposed to wind turbine noise. Such is the nature of the pulsations that electronic systems employing loudspeakers cannot reproduce them accurately. This all begs the question as to why not carry out this study in the field and measure some hard endpoints?

As the authors point out: "Realistically, it is not even possible to answer the posed question to all parties' satisfaction with practical research. For examples, a direct link to adverse health effects from yesterday's tobacco and today's excess sugar can be denied forever, because any research that could actually prove a link to all parties would take longer than forever and would be totally impractical." Surely there is ample evidence that sugar consumption, as it is a rich source of calories, is associated with obesity? This, although arguably not a disease in itself, is a powerful marker for a range of diseases. In this sense obesity represents a strong "intermediate phenotype" lying on the physio-pathological pathway between health and disease. Similarly, in relation to tobacco, there are biomarkers which are elevated in people who smoke and which indicate an increased risk of lung and other associated cancers [83].

So, does Infrasound and low frequency noise emitted by wind turbines make people sick? The authors comment [70] that, "It is abundantly obvious that intense adverse response occurs at certain sites" but stop short of admitting that it does make people sick, despite their having investigated complaints reported to them by adversely affected citizens. The authors support wind energy: "Likewise, wind farm opponents must accept reasonable sound limits or buffer distance to the nearest turbine—not pie-in-the-sky limits to destroy the industry." This all depends on what is considered "reasonable."

It is abundantly clear that sound levels involve a similar, continuous increase in risk, in a similar way that the amount of tobacco smoked determines [81] the risk of lung cancer. That is why cut-points for the levels of sound permitted were established in an attempt to protect receivers. What we have learned about cut-points in the past, for example from the asbestos scandal, is that, from the outset, cut-points are invariably placed too high and constantly need to be reduced [30].

In the late 18^{th} century, the great Scottish Anatomist, John Hunter, wrote to his protégé, Edward Jenner, asking him: "Why think? Why not do the experiment?" [87]. He was exhorting Jenner to measure the core temperature of a hibernating hedgehog. We all have remnants of the genes for hibernation but we don't express them [88]. Similarly, in common with some animals, we possibly all have the genes for reacting to Infrasound, but only some of us express them.

It would be perfectly feasible to mount an experiment, a randomized crossover trial, in which persons impacted by wind farm noise have their biomarker levels [25] [89] measured after standardized periods of exposure and non-exposure to wind turbine noise. In this way, each person would act as his or her own control. A well-devised trial could be of modest size, be cheap to conduct and deliver results relatively quickly. Assessment of the blood transcriptome [26] would increase the scope of such a trial, as would cortisol assessment [78]. This study could be augmented with the 'Simulation' study proposed by the authors to identify critical frequencies and sound levels if a test chamber and audio system can be devised which accurately reproduces the pulsations experienced in people's homes. Besides, the comparison of means makes for a more powerful statistical analysis. This sort of study will quickly indicate whether exposure to wind turbine noise is safe or not. It has a huge advantage over prospective studies which will take years to accumulate hard disease endpoints, as was the case with tobacco. For many people exposed to industrial wind turbines the question as to whether they can feel or otherwise sense them has already been answered. Could the reluctance of the wind industry to mount the appropriate studies be due to the worldwide spate of complaints from those exposed to wind turbine noise?

The Salford Report, again written [32] by a group of acousticians without any input from sleep experts, concluded that there is "… some evidence for sleep disturbance which has found fairly wide, though not universal, acceptance." The increasing weight of evidence of sleep deprivation's association with several chronic diseases is totally ignored. The authors of the Report are at pains to deny any "direct" health effects. In terms of prevention, any differentiation between 'direct' and 'indirect' is irrelevant: in 271 BC, the Roman consul Manius Curius Dentatus ordered the construction of a canal (*the Curiano Trench*) to divert the stagnant waters surrounding the River Velino in Umbria over the natural cliff at Marmore, to produce Cascata delle Marmore [90]. Romans had an aversion to drinking stagnant water and went to great lengths to "drain the swamp" because they associated it with illness. In this case the stagnant water was only "indirectly causal" but was vital to the propagation of Malaria, and hence draining the swamp abolished Malaria locally.

Governments pursuing renewable energy targets must adhere to the *Precautionary Principle* (see below). They have a duty to commission appropriate studies to ensure that the health of their rural citizens is adequately protected. It might be assumed that the wind industry would have carried out these studies as part of its "due diligence", but, to date, no such studies have been forthcoming.

3. The Public Health Perspective

3.1. Public Health and Utilitarianism

Public Health developed in different ways in different countries. In Europe, Johann Peter Frank's *System einer vollstädigen medinischen Polizey* was particularly influential [91]. Frank's epic work was published in six volumes between 1779 and 1817 and promoted the concept of "Medical Police". The word 'Police' here connotes public administration. It was taken up by Andrew Duncan (Senior) in the Edinburgh University Medical School, who published a "Memorial" in 1798 presenting an outline of what he saw as a comprehensive course of instruction in Medical Police [92]. The concept spread to Ireland, where Henry Maunsell was appointed as Professor of Political Medicine at the Royal College of Surgeons of Ireland in 1841 [93].

The concept was also adopted in England, where Edwin Chadwick wrote upon Preventive Police in 1829 [94]. Chadwick was a lawyer and "…'the bureaucratic radical'… disciple of the archutilitarian [sic] Jeremy Bentham," who in 1842 was to publish his famous *Report on the Sanitary Conditions of the Labouring Population of Great Britain*, which he wrote in his position as Secretary to The Poor Law Commissioners. As a young man, Chadwick was Bentham's assistant and he afterwards applied Bentham's Utilitarian principles to Public Health [95]. Chadwick's *Report* paved the way for the establishment of the General Board of Health in 1848, under the great Public Health Act [96]. Chadwick's work heading the Board strongly influenced the thinking of doctors such as John Simon, and this marks the birth of Public Health in England [96] and the Medical Officers of Health. Thus, in Britain, modern Public Health grew out of the Utilitarian philosophy, developed by Jeremy Bentham, which enshrined the ethos that a morally good action is one that helps the greatest number of people.

However, it now seems that economic growth, particularly during a recession, is such an important goal that other aspects, such as health, are seen as being of secondary importance. It is essential that Public Health should increase its vigilance; to do any less would be to betray its proud past.

3.2. Collateral Damage

In the United Kingdom in1853, a Vaccination Act was passed: it was a *compulsory* act which decreed that all parents had to have their infants vaccinated against Smallpox within three months of birth. It supplanted the *permissive* Vaccination Act of 1840, which simply hadn't worked. Although it was known that a small proportion of children would succumb to the effect of the vaccination, this was trifling in comparison to the number of deaths from Smallpox which would be prevented [97]. In effect, Public Health had accepted the principle of *Collateral Damage*, provided that the overall benefit was large and the damage was small. Eventually, by the 1970s, vaccination was phased out because as the eradication of Smallpox approached, vaccinia was claiming more lives than Smallpox was [98].

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3.3. The Precautionary Principle

The problem is just how much *Collateral Damage* is acceptable? When the BSE epidemic emerged in the late 1980s, the Government insisted that, providing simple measures were applied, beef was perfectly safe. The Minister of Agriculture went public and was photographed administering a hamburger to Cordelia, his four-year-old daughter [99]. Instead of applying the *Precautionary Principle* (enabling rapid response in the face of a possible danger to human, animal or plant health) [100], which should have triggered primate feeding experiments, the Government decided to tough it out, apparently for the health of the Farming Industry rather than for the health of its citizens. It compromised by having neural tissue separated from meat, seemingly oblivious of the fact that nerves innervate muscle. In effect, the experiment was being carried out on an unsuspecting populace.

In 1996, the first vCJD cases were identified and epidemiologists predicted thousands of deaths. Public Health was remarkably quiet on the issue but, to date, the disease has only resulted in 177 deaths. The reason that it has not been higher lies in the fact that there is a very specific genetic element as to who will develop the disease. There were no long-term monitoring measures put in place, but *ad hoc* studies indicate that the number of people infected with abnormal prion protein may be in the region of 30,000 [101]. Although representing only a small proportion of the total population, it still lies uneasily with Utilitarian principles in that the level of possible *Collateral Damage* was unacceptably large.

A similar population experiment seems to be underway in terms of environmental noise pollution. Governments, faced with economic recession, have been keen to increase economic activity and meet Green targets. As a result, environmental noise has increased. Public Health must maintain its position as champion of the health of the public and not just slavishly back up government policy. How can it be that environmental noise pollution continues to escalate despite the very real adverse effects it exerts on human health? A recent report from the Royal Society of Public Health has placed stress [102] on the importance of sleep to health. This is all very well, but nowhere in the 30-page document is there a mention of the role of noise in disrupting sleep, in fact the word "noise" is completely omitted. Perhaps the Royal Society was anxious not to open the noise can of worms? In her 'Notes on Nursing' in 1859 [103], Florence Nightingale was not so squeamish, because when she extolled the importance of sleep to health, she was also attuned to the deleterious effects of noise: "Unnecessary noise…is the most cruel absence of care which can be inflicted either on sick or well."

As sleep deprivation is the most important health-damaging effect of environmental noise pollution, Public Health should be treating the matter very seriously. Indeed, the United Nations Committee Against Torture (UN CAT) has explicitly identified "sleep deprivation for prolonged periods" [104] as a method of torture. In 1978, in a case taken to Europe by the Irish Government, the British Government was found guilty of applying five techniques, including subjection to noise and deprivation of sleep [57]. These were used in Ulster to 'encourage' admissions and to elicit information from prisoners and detainees. They amounted to humiliating and degrading treatment, *i.e.* torture. Although the judgment was afterwards overturned on appeal, and downgraded to 'inhuman or degrading treatment', the action is still alive. The case being taken by 'The Hooded Men' is being backed by the Irish Government [105]. This same Government, by its failure to revise the turbine setback guidelines, is imposing noise and sleep deprivation on its rural citizens.

3.4. Public Health's Responsibilities

When Public Health doctors are asked about possible health effects, they tend to dismiss the literature as either non-peer-reviewed, or if it is a review, non-systematic. If they want to read a comprehensive, thorough and systematic review, they should look no further than that by Punch and James [106]. The Public Health Agencies in the UK are now relying on a document published in April 2013 which is also not peer-reviewed [32]. As already mentioned, was written by a group of acousticians at the University of Salford, which begs the question as to why such a group was selected to pronounce on health issues. Since acousticians derive a significant proportion of their income from the wind industry, their scientific objectivity might be open to question. Similarly, if a profession which worked closely with the tobacco industry was asked to report on health, questions would be asked.

Recently, a Vestas PowerPoint presentation from 2004 has surfaced [107] demonstrating that Vestas knew over a decade ago that safer buffers were required to protect neighbors from wind turbine noise. They knew their pre- construction noise models were inaccurate and that "...we know that noise from wind turbines sometimes annoys people even if the noise is below noise limits." Similarly, we are repeatedly told that modern turbines are quieter and produce less Infrasound and low frequency noise, which in reality is the reverse of the case. Denmark has been in the vanguard of wind energy development and there is a Danish initiative entitled "WIND2050" [108]. This appears to seek to promote the interests of the wind industry, particularly through encouraging "Community Ownership" of wind farms. To enable this, the project is "mapping criticism", *i.e.* assembling maps to show where rural citizens have raised any objection to wind farm development. It seems analogous to tobacco companies keeping smoking cessation clinics under surveillance.

There has been a tendency for Public Health to toe the official line that wind farms are entirely safe. This is the message promulgated by the wind industry so Public Health should be evaluating the evidence more critically. If Public Health doctors actually visited the families who have been forced to abandon their homes they might demand to see the necessary studies conducted. They would learn that some of the worst affected are small children who are very often put in the smaller bedrooms which are worst impacted by noise [64]. There is also the intriguing possibility that if Infrasound is conducted through the skin [54], young children will receive a larger dose because their surface area is greater in relation to their volume in comparison to adults. This is why small children lose heat faster than adults.

To her credit, in 2014, one Irish Public Health doctor, the Deputy Chief Medical Officer, actually stated that while turbines do not represent a threat to Public Health, "there is a consistent cluster of symptoms related to living in close proximity to wind turbines which occurs in a number of people in the vicinity of industrial wind turbines" and that "These people must be treated appropriately and sensitively as these symptoms can be very debilitating" [109]. The Irish Wind Energy Association promptly rounded on her with the accusation of her "having focused on out-of-date information," but she stood her ground admirably.

In view of the foregoing considerations, and because Public Health's apparent official view is that there are no important health effects caused by exposure to wind turbine noise, a reappraisal of the evidence is overdue. Public Health doctors should be conducting focused epidemiological studies, but this is something that they haven't displayed much aptitude for of late. Apart from anything else, Public Health should be rigorously applying the *Precautionary Principle* or *Primum non nocere* (First, do no harm) ideal, putting monitoring and evaluation in place and then undertaking the appropriate studies. A recent review of peer-reviewed studies published between 2000 and 2015 concluded [110] that the estimated pool prevalence of high subjective annoyance was around 10%. This figure is very close to that found by Kelley [64] and his colleagues cited above, although the true figure may well be higher. The authors observed that epidemiological research on low frequency noise is scarce and suffers from methodological shortcomings. They added that low frequency noise in the everyday environment is an issue which requires more research attention, particularly for people living in the vicinity of relevant sources.

Environmental noise pollution, particularly when it deprives people of sleep, is especially related to the development of CVD, as a recent paper concluded that: "... the public health impact of sufficient sleep duration, in addition to the traditional healthy lifestyle factors, could be substantial" [36]. Public Health must take its responsibilities seriously to protect the Health and Human Rights of all citizens. Despite a desire to meet various Renewable Energy targets, Government must ensure that the appropriate studies are undertaken in order to protect the sizeable minority of the exposed population which suffers adverse effects. In fact, Jeremy Bentham shrewdly anticipated the necessity for Government support for research in both theory and practice [111]. In the 19^{th} century, Public Health acted to protect the health of town dwellers, thrown together by the Industrial Revolution. People had moved from the country into towns where they were exposed to industrial pollution. We are now witnessing the reverse process, a second Industrial Revolution, in which large industrial machines are being imposed on rural dwellers, and Public Health must act to see that sufficient safeguards are put in place so that rural citizens' health is fully protected.

As Bradford Hill observed [112] over half a century ago: "The lessons of the past in general health and safety practices are easy to read. They are characterised by empirical decisions, by eternally persistent reappraisal of public health standards against available knowledge of causation, by consistently giving the public the benefit of the doubt, and by ever striving for improved environmental quality with the accompanying reduction in disease morbidity and mortality". Quite so, it is high time that Public Health gave the public the benefit of the doubt.

4. Conclusion

So has Public Health become too utilitarian? All the available evidence indicates that an important minority of local inhabitants is severely impacted by noise emitted by wind farms sited too close to their homes. This degree of *Collateral Damage* is too large to accept in terms of Utilitarianism. Public Health must exercise the *Precautionary Principle* and retain as much independence from government as possible in assessing the health effects of national policies. The Health and Human Rights of rural-dwelling citizens are every bit as important as those of the rest of society. In fact, in terms of wind energy, the overall benefit is fairly modest [113] [114] and the adverse effect on people's health is far from small. It is essential that separation distances between human habitation and wind turbines are increased. There is an international consensus emerging for a separation distance of 2 km; indeed some countries are opting for 3 km and more. Furthermore, the appropriate, focused studies should be undertaken as soon as possible.

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