ASSOCIATION OF ENVIRONMENTAL PROFESSIONALS (AEP)

CALIFORNIA COMMUNITY-WIDE GREENHOUSE GAS BASELINE INVENTORY PROTOCOL WHITE PAPER

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1.0 Introduction

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On December 30, 2009, the Natural Resources Agency adopted amendments to the California Environmental Quality Act (CEQA) Guidelines for greenhouse gas (GHG) emissions. The updated CEQA Guidelines, which became effective March 18, 2010, include a new section on tiering and streamlining the analysis of GHG emissions (CEQA Guidelines Section 15183.5).

Public agencies can choose to analyze and mitigate significant GHG emissions in a plan for the reduction of GHG emissions (e.g., a "climate action plan," [CAP] a "GHG emission reduction plan"). The Guidelines go on to detail that the plan should include a quantified analysis of GHG emissions resulting from activities within a defined geographic area but do not provide guidance as to how to organize or categorize GHG emissions sources or delimit geographic boundary considerations.

The purpose of this white paper is to provide recommendations to jurisdictions (cities and counties) on what could be included within a community-wide GHG emissions baseline inventory and methodology for determining the geographic/jurisdictional boundary.

1.1 FILLING THE GAPS

The magnitude of GHG emissions between similar-sized cities can vary substantially depending on what GHG sectors are included and the methodology used to calculate GHG emissions. After preparing numerous community-wide emissions inventories for local agencies, it has become apparent to the members of the Association of Environmental Professionals' (AEP) Climate Change Committee that it would be helpful if the methodology for conducting a community-wide GHG emissions inventory was standardized. This White Paper only addresses the baseline and does not discuss methods of preparing future year inventories. However, methodology and models used in preparation of the baseline inventory will ultimately set the stage for how future inventories are determined and should vary by sector.

The AEP Climate Change Committee was formed in 2008 to provide information and guidance to AEP members on climate change issues and offer comments to state agencies on the implementation of climate change legislation. The committee consists of members of AEP, most of which are CEQA environmental consultants.[1]

[1] Based on the current membership of AEP's Ad Hoc Committee.

This white paper is not intended to present every acceptable methodology, but rather to lay out a reasonable approach for considering GHG emissions sectors to include in a community-wide baseline emissions inventory. In addition, this white paper does not outline what should be included in a GHG reduction plan/climate action plan. Other organizations, including the California Air Pollution Control Officers Association (CAPCOA), are leading separate efforts that will assist lead agencies in calculating GHG reductions from individual actions.

1.2 CONNECTING THE DOTS

Thus Spoke Zarathustra: The Origin of the Local GHG Reduction Target

The California Air Resources Board's (ARB) Climate Change Scoping Plan (Scoping Plan) (2008) establishes the foundations for how the State will achieve the GHG emissions targets in Assembly Bill 32 (AB 32). AB 32 requires that the State reduce emissions to 1990 levels by the year 2020. ARB prepared a 1990 and 2020 GHG inventory and identified that the State will need to reduce GHG emissions by approximately 30 percent from business as usual (BAU) by 2020 to achieve the 2020 target of AB 32, which correlates to approximately a 15 percent reduction from existing conditions at the time the Scoping Plan was adopted (2002–2004 emissions inventory). Because local land use decisions affect how people relate to their environment, ARB (2008) recommends that cities and counties adopt a similar GHG reduction goal. Actions taken by ARB and other state agencies, including, but not limited to, the California Energy Commission (CEC) and Public Utilities Commission (CPUC), are the primary drivers behind the statewide mandatory GHG reduction measures that are being implemented to date. While actions of counties and cities were not calculated, or included in the list of actions to achieve the target of AB 32 in the Scoping Plan, local actions are important to success of long-term GHG reductions in the state.

Local Connection to the Regional Plans to Be Set Forth Under Senate Bill 375

Reducing GHG emissions from the transportation sector will be critical to the success of statewide GHG reductions. Transportation emissions account for 38 percent of the statewide GHG emissions inventory, and passenger vehicles account for 74 percent of the total transportation sector emissions (ARB 2008). While transportation planning takes place on a regional level, land use changes on a local level can improve transportation and reduce GHG emissions. Based on this principle, Senate Bill (SB) 375 was adopted to reduce passenger vehicle miles traveled and associated GHG emissions. GHG reductions associated with SB 375 are under the purview of California's 18 Metropolitan Planning Organizations (MPOs). GHG reduction targets of 7 to 8 percent in 2020 and between 13 and 16 percent in 2035 from the 2005 base year for the MPOs were adopted by ARB on September 29, 2010.

MPOs are required to identify strategies to reduce passenger vehicle miles traveled (VMT) and trips that achieve these targets in a Sustainable Communities Strategy (SCS). If the SCS is unable to achieve the regional GHG emissions reduction targets, than the MPO is required to prepare an Alternative Planning Strategy (APS) that shows how the GHG emissions reduction target could be achieved through alternative development patterns, infrastructure, and/or transportation measures. MPOs have no land use authority at the local level, as the majority of land use decisions are vested with local governments. Therefore, local-level participation in regional efforts will be critical to the success of any SCS or APS.

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2.0 Defining Geographic/Jurisdictional Boundaries

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Establishing the boundaries of the analysis is a crucial first step in establishing the inventory for a baseline GHG emissions inventory. There is much debate over which GHG sectors, or categories, a jurisdiction needs to include in its GHG emissions inventory. Currently, the Bay Area Air Quality Management District (BAAQMD) is the only air district in the state to establish protocols for conducting a qualified GHG emissions inventory in its jurisdiction (BAAQMD 2010). To identify the appropriate boundaries for defining a local communitywide emissions inventory, we could look to how ARB defined boundaries in its Scoping Plan and other adopted protocols.

The Scoping Plan inventory is defined by both a geographic boundary (emissions occurring within California) and a jurisdictional boundary (emissions that occur outside California but are directly related to California's emissions inventory) (ARB 2008). While the former category is easier to comprehend, the latter is equally important because it sets a precedent for how local agencies can look at their emissions inventory. To assist local governments, ARB has also released protocols for local jurisdictions for conducting a municipal inventory that justify an approach of using jurisdictional boundaries to identify sources of GHG emissions. The protocol strongly encourages local governments to utilize operational control when defining their organizational boundary (ARB 2008).

The municipal inventory typically comprises a very small percentage of a communitywide emissions inventory. Sources within the jurisdiction's "operational" control are also narrowly defined in these protocols as "direct" operational control.

It is clear that the community-wide inventory falls somewhere between the broad scale of the statewide inventory and the narrow focus of a municipal inventory. Because a GHG reduction plan/climate action plan typically identifies feasible GHG reduction measures that the local agency intends to implement, it is recommended that a community-wide GHG emissions inventory be defined broadly enough to encompass all sources identified in the local agency's GHG reduction measures. While local agencies are encouraged to include GHG emissions based on the level of control the agency has over actions, the community-wide inventory should encompass emissions within both the local agency's direct and indirect control, such as land use decisions and policies. Further, nothing should preclude a jurisdiction from considering emissions sources that are outside its land use authority.

Many baseline GHG emissions inventories are based on a combination of both geographic and jurisdictional control. The model used to estimate GHG emissions may determine which method (operational control or geographic boundary) a jurisdiction is able to use. In most cases, a city's or county's land use authority is contiguous with its jurisdictional boundaries. However, there are exceptions. For example, cities do not have land use authority over land that is owned by state-operated school districts. In addition, some jurisdictions encompass other lands (e.g., federal, tribal, airports), where land use jurisdiction is not in the sole authority of the city/county.

A jurisdiction's land use authority typically applies to land use and policy decisions for new development (e.g., landscaping, building energy efficiency, infrastructure, design) and policy decisions and programs adopted for existing development within the jurisdiction. Furthermore, because a CAP/GHG reduction plan lays the policy/implementation framework for the jurisdiction to reduce GHG emissions, in most instances the inventory itself should be based on those emissions that are within the purview of the city's or county's discretionary actions and regulatory authority. Therefore, it is recommended that a baseline GHG inventory include GHG emissions for sources that may not be in the jurisdiction's direct control, but for which the local agency has some degree of policy-land use control (e.g., indirect control). Factors that influence a local agency's consideration of appropriate emissions may vary by sector; for instance, Section 5.0 (Water and Wastewater) details methodologies for local agencies to include emissions from water that fall outside of local regulatory control but not outside of the impact of local activities. Alternately, a planned expansion of geopolitical boundaries may support the inclusion of emissions from land outside of current jurisdictional boundaries such as land within a jurisdiction's general plan area or sphere of influence.

3.0 Mobile Sources

CHRIS GRAY – FEHR & PEERS

GHGs related to transportation typically account for a significant portion of the emissions generated within a community. Within many California cities and counties, transportation is the single largest source of emissions, responsible for one-half or more of all GHG emissions. Analysis of transportation emissions can be problematic given the lack of consensus regarding potential approaches and other methodological issues discussed below. Furthermore, many jurisdictions are limited by the lack of available data and access to appropriate analytical tools.

Transportation-related GHG emissions are associated with fuel consumed by passenger vehicles, trucks, airplanes, trains, and boats/ships. However, the primary sources of GHG emissions for a community-wide GHG emissions inventory within a city/county jurisdiction are passenger vehicles and trucks. Therefore, other (i.e., trains, boats/ships, and airplanes) transportation-related GHG emissions are not typically included in a community-wide inventory. Nonetheless, nothing prohibits a jurisdiction from including these other sources within their community-wide GHG emissions inventory. For the purpose of this white paper, the transportation component of the GHG emissions inventory will focus on recommendations regarding passenger vehicles and trucks.

Developing GHG estimates accruing from transportation, which is defined as the movement of automobiles and trucks along a roadway network, is often a complex exercise for a variety of reasons including:

- **Metrics Measured:** There is a legitimate question regarding the metrics that are used to estimate GHG emissions resulting from vehicles. As an example, many studies estimate VMT to use as a basis for estimating GHG emissions. However, a case could be made that another measure such as vehicle hours traveled (VHT) or the actual emissions themselves might be more accurate than simply estimating how much vehicular travel occurs in terms of distance.

- **Multiple Vehicles per Household:** Unlike stationary sources where there may be a handful of locations where emissions are produced, most homes have multiple vehicles.

- **Trip Length:** A further complication is that persons extensively travel throughout the day. In California, it is not uncommon for people's daily travel to take them across city or even county boundaries.

- **Multiple Trips per Day:** Vehicular travel occurs throughout the day and occurs for a variety of reasons. For example, it is not uncommon for a person to drive to work, conduct errands during the day, make additional shopping trips while on the way home, and then return to their home.

- **Models Not Calibrated Based on VMT:** Many jurisdictions do not collect vehicle miles traveled data on a regular basis. While many cities and counties might collect regular traffic counts on major roadways, estimates of VMT were traditionally only performed by transportation agencies such MPOs.

- **Through Trips:** Many communities have through trips, where vehicles travel through a community without stopping. For communities with major roadways, these through trips can represent a significant portion of the communitywide VMT, with few options available to reduce the volume of this through traffic.

- **Estimating VMT:** There is no consistent approach to developing VMT estimates in terms of overall assumptions or analytical tools. Therefore, a variety of methods have been used to estimate VMT in community inventories.

Factors to Consider in Developing the Inventory

It is important to note that developing an inventory is usually the first step in an extended process. Most communities which complete inventories proceed to develop future GHG forecasts and identify reduction strategies that reduce community-wide GHG emissions.

These considerations can have a significant effect on the manner in which the inventory is conducted for the following reasons:

- Since VMT estimates will need to be prepared for future scenarios, an inventory method should not only be able to represent existing conditions, but future conditions.

- It is critical that the same methodology be used for both the existing and future conditions. The use of one analytical method for the inventory and a second for future conditions can lead to significant inconsistencies.

- The inventory method should also reflect the potential emission reduction strategies that might be developed. As an example, if the VMT forecasts include a large amount of through travel, it is unlikely that an individual city or county could enact policies to reduce through travel effectively.

3.1 JURISDICTIONAL ISSUES

One item which also touches on the VMT estimating process is the issue of jurisdictions. In preparing inventories, there are typically two different approaches to jurisdiction for the inventory which include:

- Land Use Control – Under this first approach, only those areas for which a city or county has land use controls are included. Areas which are typically outside of the land use control for cities and counties include universities, military bases, national parks, tribal lands, and other similar facilities.

- Geographic Limits – In this second approach, all of the land within a city or county boundary is included in the inventory.

In evaluating the jurisdictional issues, there are a couple of considerations to note including:

- The ability of a jurisdiction to apply reduction strategies. As an example, a city or county may have a limited ability to affect VMT associated with a military base, so including this type of facility in the inventory could mean that some portion of the VMT estimates is not subject to reduction strategies.

- The ability to accurately estimate VMT. A related issue is one of data availability. It can sometimes be difficult for a local jurisdiction to obtain accurate land use information on some areas not within their control, such as military bases and other similar areas. Including these areas where there is limited data available could complicate the inventory.

3.2 WHAT VMT IS COUNTED AND HOW IS IT COUNTED?

In developing VMT estimates for jurisdictions, it is important to note that there are two overarching issues that need to be considered. These issues include accounting rules and analytical tools. The accounting rules refer to the overall approach employed to estimate transportation emissions. The analytical tools refer to the models or data source used to estimate emissions, once the accounting rules have been identified. Each of these issues is discussed in detail below.

It should be noted that the accounting rules and analytical tools are strongly interlinked. Depending on the accounting rules selected, certain analytical tools may be required or conversely precluded. It is generally recommended that the accounting rules be identified first and then an appropriate analytical tool selected.

Accounting Rules

Accounting rules refer to the process by which various travel markets and trip types are segregated in estimating VMT. Some specific questions addressed by accounting rules include:

- How are internal trips (those beginning and ending within the city/county) treated?
- How are external trips (those beginning inside the city/county that might leave the city/county or those that might enter the city/county from outside) addressed?
- How are through trips (those not beginning or ending in the city/county) dealt with?

Most community inventories completed previously apply one of two potential approaches to deal with accounting rules including a geographical-based approach or an origin/destination approach.

A recent development related to GHG and VMT estimates is the implementation of SB 375, which convened an advisory panel called the Regional Targets Advisory Committee (RTAC) to review issues related to the modeling of VMT and available tools. One of the major conclusions of the RTAC was to recommend the following approach to estimating VMT:

- VMT estimates should include 100 percent of all travel which both begins and ends within a jurisdiction
- VMT estimates should include a portion of travel (50 percent) which either begins or ends within a jurisdiction
- VMT estimates should exclude travel which neither stops or ends within a jurisdiction

While these recommendations applied to MPOs, this same methodology can also apply to cities and counties conducting inventories. Information regarding this approach is outlined in the recommendations of the RTAC pursuant to SB 375 (September 2009). The RTAC approach reflects a specific application of origin/destination-based approach discussed below and represents an attempt to address jurisdictional issues identified above.

3.3 GEOGRAPHICAL-BASED APPROACH

One common approach is to estimate VMT based on geographical boundaries of a jurisdiction. As an example, a number of inventories completed to date at the citywide or countywide basis have used jurisdictional boundaries. This approach has both positive and negative aspects as listed in the table below.

Table 3-1: Comparison of Geographical-Based Approach to Vehicle Miles Traveled

Pro	***Con***
It is often relatively easy to identify the jurisdictional boundaries for a city or county, as these limits are legally defined.	This approach makes it difficult to exclude through travel. In cases of those cities or counties with large amounts of through travel when a major freeway or roadway is located within the jurisdiction, the use of this approach may overestimate transportation emissions. Including these vehicles in the inventory can be problematic given the limited ability of a city or county to influence through traffic VMT.
It is often relatively easier to calculate VMT using this approach, as a number of the analytical tools discussed below report VMT geographically.	Most importantly, this approach excludes travel that might leave the jurisdictional boundary, which ignores the common realities of travel whereby people often live, work, and shop in different locations.

3.4 ORIGIN/DESTINATION APPROACH

A second approach looks at trip origins and destinations. This approach considers vehicular travel in terms of where trips start and end instead of limiting the analysis to jurisdictional boundaries. The table below lists the positive and negative aspects of this approach.

Table 3-2: Comparison of Origin/Destination Approach to Vehicle Travel

Pro	***Con***
This approach is more consistent with the emerging consensus on VMT estimating, as outlined in the RTAC report.	Calculating VMT by origins/destinations can be more technically challenging, depending on the availability of data and analytical tool used.
This approach excludes through travel, which has been noted to be particularly problematic and difficult to effectively address by most cities and counties.	It may be difficult to determine the appropriate boundary to limit the tracking of trips. As an example, in Southern California, there are recorded instances of commutes that cross multiple city and county boundaries.

3.5 ANALYTICAL TOOLS

There are at least five potential analytical tools that could be employed to estimate existing VMT as described below.

- Regional Travel Demand Model

- Local Travel Demand Model
- Published Sources
- Air Quality Analysis Tools
- Travel Surveys

3.5.1 Regional Travel Demand Model

One commonly used tool is a regional travel demand model. Regional travel demand models are generally developed by MPOs to analyze existing and future travel behavior. Regional travel demand models include residential uses, nonresidential uses (e.g., office, retail, and industrial), and transportation networks (e.g., highways and sometimes transit facilities) as inputs to the model. Some regions with travel demand models include the Southern California Association of Governments (SCAG), San Diego (SANDAG), Sacramento (SACOG), and Santa Barbara County (SBCAG).

Some positive and negative aspects to the use of a regional travel demand model in this context include those shown in the table below.

Table 3-3: Regional Travel Demand Model

Pros	***Cons***
Regional models can track trips throughout a region, allowing the analysis to include vehicles entering or leaving a jurisdiction, thereby implementing the origin/destination approach identified above.	May require some level of technical assistance from technical experts (such as private consultants or regional agency staff) versed in the use of the regional travel model, as some manipulation of the model outputs is required.
Can be used to segregate through trips from any VMT estimates.	Some regional agencies restrict use of their models to agency staff; therefore, all requests for the use of the model have to be made through the regional agency.
Can also be used to implement a geographical approach if desired.	As regional models generally cover either a county or several counties, these models may not be as detailed as required, particularly for a smaller city located within a larger region.
Regional agencies typically have both existing and future year models, simplifying the forecasting process.	

3.5.2 Local Travel Demand Model

Many cities or counties have elected to develop their own travel demand model throughout the State of California. These models typically include more detail than the regional model, with more refined land use and greater detail in the transportation network. In some cases, these travel models were developed using the regional model as a base, while in other cases, the travel models include the areas within the jurisdiction of the city or county.

There are hundreds of locally developed travel demand models within the State of California including such varied locations as Los Angeles, Santa Monica, Irvine, Pasadena, West Hollywood, and Davis.

Some pros and cons to the use of local travel models are listed in the table below.

Table 3-4: Local Travel Models

Pro	***Con***
Local travel models are likely to have very detailed information regarding land use data and roadway networks for a local jurisdiction.	It may be difficult to account for persons traveling outside of the city/county boundary unless adjustments are made to the model.
Local travel models can segregate through traffic as needed.	Some technical assistance will be required, as some manipulation of the model inputs and outputs would be required.
Local travel models are usually either maintained by in-house staff or transportation consultants and may be more accessible to those persons preparing the inventory as compared to a regional travel demand model.	
Local city travel demand models typically have both existing and future year versions, simplifying the forecasting process.	

3.5.3 Published Sources

One common way to obtain VMT data are to review published sources that provide VMT data for existing communities. A common source is the Highway Pavement Monitoring System (HPMS), which is maintained by the California Department of Transportation (Caltrans) (Caltrans 2010).

The HPMS data estimates VMT based on traffic counts and roadway length. In other instances, the VMT data are taken from a study of a larger area. For example, there are instances where the VMT estimates for a city were derived from countywide data published in a previous study by applying some proportional reduction, such as the ratio of population in the city to the countywide total. Several positive and negative aspects of this approach are identified in the table below.

Table 3-5: Highway Pavement Monitoring System

Pros	***Cons***
Compared to other methods, this method is relatively easy to apply.	It is generally not possible to segregate through trips in these VMT estimates.
Does not necessarily require the expertise of persons with specialized knowledge in transportation planning and engineering.	The method generally is not consistent with the origin/destination accounting rule and would only be applicable if the analysis was limited to jurisdictional boundaries.
	It is difficult to generate future forecasts without some form of extrapolation process.

3.5.4 Air Quality Analysis Tools

Another option to estimate transportation emissions is one of several available air quality analysis tools, which include the California Emissions Factor Model (EMFAC), the Urban Emissions Model (URBEMIS), and the California Emissions Estimator Model (CalEEMod). Additional information regarding each of these items is provided below.

EMFAC

EMFAC was developed by the California Air Resources Board (ARB) (2007) to provide emission factors for vehicles operating on public roadways in California.

EMFAC provides VMT data for the various counties within California and can be used to estimate VMT and GHG emissions for various areas of the state including air basins and the counties. However, default information is not provided in EMFAC for sub-areas below the county level.

URBEMIS/CalEEMod

URBEMIS and the newly released CalEEMod are commonly employed air quality analysis software, typically applied to analyze project-level emissions. URBEMIS and CalEEMod have a transportation component which estimates VMT based on land use data and trip length data (Rimpo and Associates 2007; SCAQMD 2011).

There are some positive and negative aspects of using these software tools in a community inventory, as outlined in the following table:

Table 3-6: Use of Air Quality Analysis Tools to Estimate Transportation Emissions

Pros	***Cons***
In the case of EMFAC, a single number can be obtained if the area of analysis is an entire county.	EMFAC, URBEMIS, and CalEEMod have extensive amounts of pre-coded data, which may or may not be appropriate for an individual community.
URBEMIS, CalEEMod, and EMFAC are widely used throughout California by environmental consultants, creating a large pool of available persons who are well versed in their use.	In the case of EMFAC, a significant amount of post-processing would be required to obtain VMT estimates for an individual jurisdiction within a county. For example, using the EMFAC data for VMT estimates for an individual city could be obtained by proportioning the VMT based on the ratio of city to county population, although this approach is not generally recommended if others are available.
EMFAC does provide future VMT forecasts at the county level.	URBEMIS and CalEEMod require the input of future land use data to develop forecasts.
EMFAC, URBEMIS, and CalEEMod can be customized by users.	Applying URBEMIS and CalEEMod on a citywide level would require that individual land uses be input into URBEMIS and CalEEMod. While this process is relatively easy for an individual project, it would be quite complicated for a mid- to large-size city. URBEMIS and CalEEMod use trip generation rates that account for trips coming and going to a particular land use; therefore, on a citywide basis it tends to double-count trips and emissions.
	As both programs have data and assumptions coded into the models, it would be difficult to account for some of the various accounting rules. For example, if there was a desire to exclude through traffic, then it would not be possible to exclude through traffic from the EMFAC outputs.

3.5.5 Travel Surveys

One function of transportation agencies is to conduct periodic surveys of travel behavior. Most often, these surveys are directed at households and ask questions such as the number of trips per day, the purpose of these trips, the origins and destinations of various trips, vehicle occupancy, and other related items. Travel surveys are currently available for the United States, California, and most metropolitan regions (Caltrans 2000). As an example, the current national household travel survey can be found here: http://nhts.ornl.gov/

One item that can be obtained from travel surveys is VMT by household. In the absence of other analytical tools, the VMT by household as established by the survey can be applied to the number of households within a jurisdiction to estimate total VMT. This approach is generally not recommended for most jurisdictions and would likely only be applicable when other analytical methods are unavailable. Various positive and negative aspects of this approach are detailed in the table below.

Table 3-7: Periodic Surveys of Travel Behavior

Pros	*Cons*
Can provide VMT for a jurisdiction quickly with little analytical effort.	Does not include employment data, which could understate VMT if the jurisdiction has employment in addition to households.
Can be used when other analytical efforts are unavailable.	Aggregate travel statistics may not be reflective of travel within a community. For remote areas, average trip length could be much longer or shorter than statewide or national averages.
Can produce VMT results that are consistent with the origin/destination accounting rule identified above.	

3.6 REASONABLENESS CHECKS

To determine whether the inventory produces reasonable VMT estimates, it is recommended that several reasonableness checks be applied, which are described in detail below.

- **Check #1: Comparison to Statewide Average –** One quick check is to compare the overall percentage of city or county emissions which are attributed to transportation. Overall, the statewide contribution of transportation to overall emissions is approximately 40 percent. For many cities, it is reasonable to assume that transportation would contribute at least 40 percent, if not more, to the overall emissions. The first check should see if the estimated VMT results in a share of overall emissions that is at least equal to the statewide average. While it is possible for a community's transportation emission to be less than the statewide average, it would be unlikely and should be investigated further. Those values which are significantly higher than the statewide average, such as 70 percent or more, should also be investigated further.

- **Check #2: Comparison to Regional Values** – Statewide, California MPOs are responsible for preparing VMT estimates for a variety of uses including SB 375 compliance and air quality analyses. As these estimates cover either individual counties or regions of several counties, they estimates can be used as a second source of verification. One potential check would be to compare the portion of an individual city's service population (residents and employees) to the regional service population. It is reasonable to expect that the VMT would be consistent with this proportion as well. For example, if a city included 10 percent of the region's service population, then it is reasonable to expect that the VMT for that individual city should be about 10 percent of the regional VMT. Significant variations, such as a city having 20 percent of the region's service population but 50 percent of the regional VMT, would be a cause for additional scrutiny.

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4.0 Stationary and Area Sources

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Community inventories may include some or all sources identified as stationary and area sources. Individual and readily identifiable sources of air pollution that are not mobile are called stationary sources. Examples include oil refineries, power plants, and cement plants. An area source is a group of many small air pollutant sources spread over a large area that may be substantial when added together, such as leaking refrigerants and the use of natural gas. The decision on which stationary and area sources to include will depend on whether the inventory is strictly a geographic-based emission inventory that accounts for all emissions within a jurisdiction's boundaries or a control-based inventory that focuses on emissions that the jurisdiction has authority to regulate or the ability to influence. The indirect emissions from stationary sources such as power plants not located within the community are included in most community GHG inventories. Power generated at a local power plant could be consumed anywhere in the grid and should not be counted in community inventories since it would result in double-counting of these emissions. Most area sources are included in community emission inventories since the sources are local and have the potential for local control in many cases.

4.1 PERMITTED SOURCES

Some stationary sources are required to obtain permits from regulatory authorities. Examples of permitted sources include the following:

- Refineries: 6.1 percent of 2020 ARB forecast GHG inventory (ARB 2008);
- Oil and gas extraction: 2.4 percent of 2020 ARB forecast GHG inventory;
- Cement plants: 2.1 percent of 2020 ARB forecast GHG inventory; and
- Select agricultural operations (see Section 8 of this white paper).

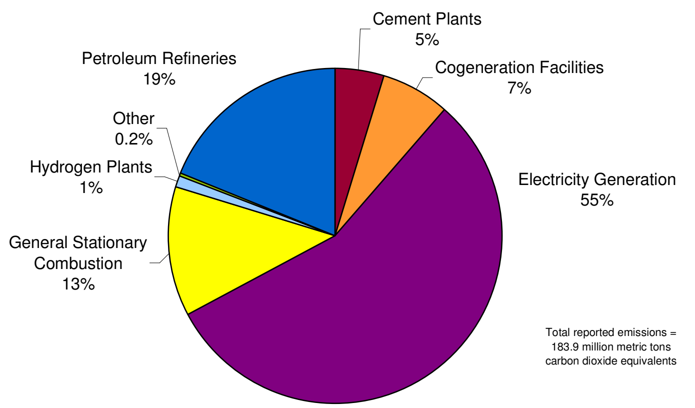
The United States Environmental Protection Agency (EPA) and ARB have adopted regulations that require some facilities meeting specified criteria to report their GHG emissions. This is viewed as a first step in implementing permitting requirements and a cap-and-trade program for large GHG sources.

Title V of the Clean Air Act requires some sources of air pollution obtain permits. Most Title V permits are issued by state and local permitting authorities, such as air pollution control/management districts. Permits for sources on tribal lands are issued by EPA. Permits are legally enforceable documents that clarify what sources must do to control air pollution, such as application of best available control technology.

In May 2010, EPA issued a rule that also requires permits for high-GHG-emitting stationary sources. As of January 2011, facilities currently subject to Clean Air Act permitting requirements with increases of GHG emissions of 75,000 tons per year or more would need to include GHGs in their permits. In July 2011, new sources with GHG emissions over 100,000 tons per year and modifications to existing facilities that increase GHG emissions by at least 75,000 tons per year will also require permits. Therefore, larger GHG emitters would be required to quantify GHG emissions, and this data would be available in the future for use in jurisdiction baseline inventories.

In California, a mandatory GHG reporting regulation became effective in January 2009. Examples of sources subject to the regulation are those that emit more than 25,000 metric tons of carbon dioxide ($MTCO_2$) per year, use more than 471,520 million metric British thermal units (MMBtu) of natural gas, use more than 12,000 short tons of coal, or generate more than 1 megawatt (MW) of electricity and emit more than 2,500 $MTCO_2$ from generation activities. Therefore, post-2008 data for these regulated sources are available through the ARB database. Emissions reported for 2008 were 183.9 million metric tons of carbon dioxide equivalents ($MMTCO_2e$) with the primary reporting sectors as shown in the chart below:

Figure 4-1 Reported Stationary Sources in California



Data source: California Air Resources Board. Mandatory Greenhouse Gas Reporting. 2008 Reported Emissions. www.arb.ca.gov/cc/reporting/ghg-rep/ghg-reports.htm.
Chart prepared by: Michael Brandman Associates

The general stationary combustion category contains emissions from oil and gas extraction, natural gas distribution, water supply and irrigation systems, sewage treatment plants, food manufacturing, dairy manufacturing, poultry processing, breweries, wineries, wood product manufacturing, paper manufacturing, other various manufacturing industries, and waste treatment and disposal. Many of these categories would be accounted for in a jurisdiction's emissions in other sectors. For example, emissions from electricity generation would be accounted for through the electricity used by the land uses in the jurisdiction (see Section 6.0 of this paper for more information). If a power plant is located within a jurisdiction's boundary, the emissions from that power plant should not be included in the baseline GHG inventory. If a jurisdiction were to include emissions from a power plant in its inventory, that could result in double-counting because the emissions are being included in city and county inventories all over the state. Additionally, cities and counties typically do not have the authority to control or influence those sources.

Most GHG emissions from industrial sources are caused by fuel combustion used in industrial processes and water heating. The utility service providers may be able to provide rates of natural gas consumption for commercial and industrial sources, but do not provide data for individual facilities. Community inventories that include natural gas combustion from commercial and industrial sources using utility data cover the vast majority of emissions from permitted sources.

In summary, a jurisdiction should use discretion when including emissions from stationary sources and should make sure such emissions are not already accounted for elsewhere, such as in another sector of its inventory or another jurisdiction's inventory.

4.2 NATURAL GAS AREA SOURCES

Natural gas is used for area heating, cooking, water heating, and industrial uses. When natural gas is burned, it emits carbon dioxide, methane, and nitrous oxide. Residential, commercial, and industrial natural gas fuel use consists of 5.1 percent, 2.1 percent, and 2.0 percent, respectively, of the ARB 2020 forecast inventory, totaling 9.2 percent.

In a jurisdictional approach to estimating natural gas emissions, only sources of emissions the jurisdiction has control are included, which are new users of natural gas. Air districts have control over large users that require permits. The jurisdiction has control over new users that have to go through environmental review; the jurisdiction may be able to require an increase in energy efficiency to decrease natural gas usage. Some may think that existing natural gas users are within the jurisdiction's control; however, just because existing buildings could be renovated to become more energy efficient does not mean that the jurisdiction has control over the sources, as it is the owner's decision whether or not the building is renovated.

In the geographic approach, all sources within the jurisdiction's geographic boundaries are estimated. Local governments can control this source of emissions through building codes and/or time of sale ordinances. Natural gas usage is usually provided by utilities for residential, commercial, and industrial uses; but if it is not, Table 4-1 provides alternate methods for estimating usage.

Table 4-1: Natural Gas Estimation Methods for Geographical Approach

Method	*Pros*	*Cons*
Actual Data Natural gas usage data and GHG emission factors can be obtained from the natural gas provider.	This method is the most accurate; it is simple to obtain the data.	None.
County Data The California Energy Consumption Data Management System (ECDMS) contains natural gas usage for counties (ECDMS 2010).	If actual data are unavailable, this data will provide a rough estimate.	The data are not as accurate as actual data.
Per Capita Data Natural gas consumption per capita for California is available from the United States Energy Information Administration (EIA) (EIA 2008).	If actual data are unavailable, this data will provide a rough estimate.	The data are not as accurate as actual data.

Note: GHG emission factors to convert natural gas usage to GHG emissions are available in the California Climate Action Registry (CCAR) General Reporting Protocol (Tables C.7 and C.8 of CCAR 2009).

4.3 OZONE-DEPLETING SUBSTANCE SUBSTITUTES

In some cases, high global warming potential gases have been substituted for ozone-depleting substances (ODS) in refrigeration and manufacturing processes. These ODS substitutes can leak into the atmosphere from various sources within a jurisdiction and should be considered for inclusion in the community inventory.

ODS are being phased out pursuant to the Montreal Protocol because they cause chemical destruction of the ozone in the stratosphere (a layer of air in the upper atmosphere). Ozone in the stratosphere is good because it absorbs ultraviolet radiation, which can cause skin cancer, cataracts, and other health problems in humans. Stratospheric ozone is not to be confused with ozone in the troposphere (the layer of air that we breathe), which is an air pollutant that results in health effects.

ODS substitutes can be released into the atmosphere when they leak out of refrigeration and air conditioning equipment contained in stationary and mobile applications. ODS substitutes are also used in solvent cleaning, foam production, sterilization, fire suppressants, and aerosols. Emissions of ODS substitutes consisted of 2.9 percent of California's GHG inventory in 2008 and are anticipated to increase to 7.5 percent by 2020. The United States is forecasting emissions of ODS substitutes to increase by 168 percent between 2005 and 2020 (USDS 2010).

Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are used as ODS substitutes, which have high global warming potentials. The global warming potential is the potential of a gas or aerosol to trap heat in the atmosphere compared with the reference gas, carbon dioxide, which has a global warming potential of one. The Intergovernmental Panel on Climate Change (IPCC) (IPCC 2007) categorizes 11 gases as HFCs and 11 gases as PFCs. There are at least

19 ODS with a global warming potential that are not considered GHGs because they are being phased out under the Montreal Protocol.

On December 9, 2009, ARB adopted the Management of High Global Warming Potential Refrigerants for Stationary Sources in the California Code of Regulations. Beginning in 2011, the rule will require leak inspection, repairs, required service practices, and recordkeeping for large commercial and industrial systems that use more than 50 pounds of refrigerant for a single unit, about the equivalent of the refrigerant found in 100 household refrigerators. This regulation is anticipated to reduce approximately 8.6 $MMTCO_2e$ in California by 2020 (ARB 2009c).

ODS substitutes have the potential for local control and for actions that support ARB's regulations of high global warming potential gases. Jurisdictions could reduce new emissions of ODS substitutes by creating policy that requires low global warming potential gases to be used, such as carbon dioxide or ammonia. Energy efficiency and heat mitigation policies can reduce the need for air conditioning and refrigeration; however, if those appliances are installed, they still may leak refrigerants. EPA's Significant New Alternatives Policy Program contains more information on ODS substitutes.

Table 4-2 contains potential approaches for accounting for ODS substitutes in a baseline jurisdiction inventory.

Table 4-2: Ozone-Depleting Substance Substitutes Approaches

Approach	*Pros*	*Cons*
Interpolation Based on ARB Inventory In its 1990–2004 GHG Emissions Inventory, ARB (2009a) estimated emissions from ODS substitutes by apportioning national emissions on the basis of population. Therefore, the ARB inventory could be interpolated and applied on the basis of population for the jurisdiction. For example, emissions of ODS substitutes were 13.89 $MMTCO_2e$ in California in 2008 (ARB 2010). The population in California in 2008 was 38,239,893 (interpolated from 2005 and 2010 data) (ARB 2009b). Therefore, emissions of ODS substitutes in 2008 would be 0.363 $MTCO_2e$ per person.	The approach is quick. The calculations are based on ARB's inventory, which promotes consistency across the state.	The estimations do not take into account jurisdiction-specific data and climate. The estimates are based on the population of a jurisdiction—the residents—which may not take into account large users of refrigerants (large supermarkets, office buildings, schools, etc.).
Estimate Based on Jurisdiction Data In this approach, ODS substitutes are estimated based on data from the jurisdiction, similar to a project-specific analysis or an estimation of municipal operations. There are references available to assist in estimating emissions, if usage data are available (i.e., ARB et al. 2010).	If usage data are known, this approach can provide a more accurate estimation.	Usage data can be difficult to estimate.
No Estimation The jurisdiction may decide that existing sources	None	Future reductions from regulations are not

are outside of its jurisdiction.	accounted for; the need for additional reductions is unknown.

4.4 WOOD-BURNING APPLIANCES

Some jurisdictions, such as rural or mountain communities that do not have natural gas service, may have relatively high emissions from wood-burning appliances (fireplaces and woodstoves).[2] Overall in the state, however, the category residential "other fuels" has relatively low emissions—0.3 percent of the 2020 forecast. These emissions are biogenic emissions because they are generated during combustion or decomposition of biologically based material. Emissions from wastewater treatment are also considered a biogenic source and are included in this paper.

Wood-burning appliances are typically used for residential heating. The jurisdictional and geographical approaches could be considered the same because the jurisdiction could pass an ordinance banning or restricting wood burning and/or requiring that existing old wood stoves be replaced with a more efficient appliance (e.g., natural gas, EPA-certified wood stove). Wood-burning appliances in new development could also be prohibited or limited.

Table 4-3 provides details on the approaches for estimating or not estimating emissions from wood-burning appliances.

[2] Emissions from natural gas fireplaces are covered under natural gas area sources. Emissions from biomass burning for cogeneration or power generation are reported to ARB and should not be included in the GHG baseline inventory because the emissions are covered in indirect electricity emissions for jurisdictions throughout the state.

Table 4-3: Wood-Burning Appliances Approaches

Approach	***Pros***	***Cons***
Estimation of Emissions from Wood-Burning Appliances First, the number of residential units with wood-burning appliances must be estimated. Jurisdiction staff may be able to provide an estimate. Alternatively, the information can be gleaned from a survey given to jurisdiction residents. Many air districts have developed emission inventories to support their attainment plans and rule development processes that include wood-burning data. Rules adopted by air districts to prohibit wood-burning appliances include estimates of the number of fireplaces and amount of wood burned as supporting documentation for the rule development package. These rules typically prohibit wood-burning appliances in new development, although some air districts also have "no burn" days, which might reduce emissions. Once the number of residential units that have wood-burning appliances has been estimated, the emissions can be estimated. URBEMIS and CalEEMod contain assumptions that include the amount of wood burned and pounds in a cord of wood and emission factors for different wood-burning devices.	An estimation can provide insight regarding whether wood-burning appliances contribute a substantial amount of the jurisdiction's emissions.	The assumptions used in the calculations can be difficult to estimate.
No Estimation The jurisdiction may determine that existing sources are outside of its jurisdiction.	Emissions may be minor; emissions are biogenic.	Any emissions would not be included in the baseline inventory.

4.5 MINOR SOURCES

There could be a variety of minor stationary or area sources that represent a very small fraction of the total emissions. For example, landscape maintenance emissions can consist of less than 0.03 percent of a community's emissions. Electricity grid sulfur hexafluoride losses and semiconductor manufacturing are relatively minor sources of high global warming potential gases, together contributing less than 0.3 percent of the state's 2020 forecast emissions. Quantification of minor emissions is often not helpful, unless it is to demonstrate that reductions from those sources would be negligible.

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5.0 Water and Wastewater

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The water use cycle — from supply to wastewater treatment — results in significant direct and indirect GHG emissions. By including water-related GHG emissions in a community-wide inventory, jurisdictions are able to explore the full impact of their community's water consumption and conservation efforts.

It is important to note that water is inherently tied to GHG emissions and climate change. As GHG levels rise, it is likely that precipitation will decrease, droughts will increase, and California's overall water supply will shift or deplete. It is therefore necessary that all levels of government address water conservation and water system efficiency, not only from a GHG standpoint but to ensure the availability of this essential resource for generations to come.

Approximately one-fifth of the electricity and one-third of non-power-plant natural gas consumed in California is associated with water delivery, treatment, and use (ARB 2010b). In addition to indirect emissions from energy, wastewater treatment facilities directly emit methane (CH_4) and nitrous oxide (N_2O) during the treatment process. This chapter explores both indirect and direct emissions at each point in the cycle of California's water system and outlines decision criteria to determine which emissions are appropriate for inclusion in a community-wide inventory.

5.1 GREENHOUSE GAS EMISSIONS AND THE CALIFORNIA WATER USE CYCLE

GHG emissions are produced at each stage of the water use cycle. The water use cycle includes collecting, conveying, treating, and delivering water to end-users, using the water, and finally collecting, treating, and disposing of wastewater (CEC 2005). For the purposes of GHG analysis, water-related sources can be separated into the following categories:

- Water supply, conveyance, and treatment – The energy consumed to convey, treat, and deliver water to the end-user.
- End-use energy – The energy consumed by the end-user for water-related activities such as agricultural irrigation, water heating, and industrial activities.

- Wastewater treatment – The direct nitrous oxide and methane emissions released from the treatment of wastewater, as well as the energy consumed for its collection, treatment, and disposal or recycle.

Each category reveals a different source of energy consumption per unit of water, also known as the energy intensity of water. Table 5-1 below shows the amount of water-related energy consumed in California in 2001. Energy use related to water was responsible for over 19 percent of all electricity and 32 percent of all natural gas consumed in California.

Table 5-1: Water-Related Energy Use in California, 2001

	Electricity (GWh)	*Natural Gas (Million Therms)*	*Diesel (Million Gallons)*
Water Supply and Treatment			
Urban	7,554	19	--
Agricultural	3,188	--	--
End-Uses			
Agricultural	7,372	18	88
Residential Commercial Industrial	27,887	4,220	--
Wastewater Treatment	2,012	27	--
Total Water-Related Energy Use	48,012	4,284	88
Total California Energy Use	250,494	13,571	--
Percentage	19%	32%	--

Source: CEC 2005

The energy intensity of water supply and conveyance varies widely depending on the source and destination of water. Gravity-fed systems, such as the system used to convey water from the Hetch Hetchy reservoir in Yosemite National Park to San Francisco, consume little to no energy. On the other hand, many areas of Southern California are forced to pump water over mountains or long distances from the Sacramento Delta or Colorado River. The energy intensity of water supply and conveyance is therefore generally higher in Southern California than in Northern California.

The energy intensity of water treatment depends on the source of water. Some water sources, like the Hetch Hetchy reservoir, require little treatment because the water quality is relatively close to drinking water standards. Other sources, such as groundwater or seawater desalination, require an energy-intensive process for water treatment. The ultimate end-use is also a factor in energy intensity. Recycled water requires much less energy to treat than potable water and can be used in some agricultural and industrial activities.

Water-related end-uses account for 58 percent of overall water-related electricity and 99 percent of water-related natural gas (CEC 2005). Agricultural end-use energy is the result of additional water pumping or distribution on the farm using diesel or natural gas engines. A considerable amount of energy is used by farms to pump groundwater for irrigation. Urban end-use energy is the result of water heating, steam systems, clothes washing, pumping water in high-rise buildings, car washes, and other related uses.

Wastewater treatment requires energy for both transport and the treatment process. Wastewater systems primarily rely on the force of gravity to transport wastewater from the source to the treatment plant; however, lift stations are necessary when moving the wastewater from a lower elevation to a higher elevation. As wastewater is collected, it is transported to a central treatment facility, the wastewater treatment plant. Before wastewater can be released into groundwater, rivers, lakes, and oceans or reused as recycled or reclaimed water, it must be treated to reduce pollutants to an acceptable level. Wastewater treatment plants are regulated by federal, state, and regional water quality agencies to ensure the treated water is safe to release into the environment.

Wastewater treatment plants may have three phases of treatment: (1) primary, (2) secondary, and (3) tertiary. Primary treatment is the initial treatment when the influent first enters the treatment plant, removing large debris and biosolids. Secondary treatment uses biological processes to remove dissolved biosolids and other pollutants. The final or tertiary stage in wastewater treatment is the removal of any remaining pollutants, nutrients, and sediment. The final treatment stage can be completed using biological, chemical, or physical processes.

It should also be noted that some residences—generally those in more rural areas—treat their wastewater on-site using septic tanks. Because these systems are located in close proximity to the source of domestic wastewater, very little energy is required to transport the wastewater through the system.

The wastewater treatment process not only consumes energy, it also emits a considerable amount of direct GHG emissions in California, as displayed in Table 5-2.

Table 5-2: California Greenhouse Gas Emissions from Wastewater Treatment, 2001

	Million Metric Tons CO_2e
Domestic Wastewater Treatment and Discharge	1.92
Industrial Wastewater Treatment and Discharge	0.68
Total	**2.6**
Percentage of Gross California Emissions	0.5%

Source: ARB 2010a

There are two classifications of wastewater: domestic and industrial. Domestic wastewater is produced in homes and businesses. Industrial wastewater is a higher strength of wastewater and contains byproducts of industrial processes such as hard metals. While industrial wastewater requires more intense treatment, domestic and industrial wastewater can be treated in the same system. Therefore, it is difficult to distinguish emissions resulting from each wastewater classification.

As organic matter breaks down during the wastewater treatment process, methane (CH_4) is released. Depending on the wastewater treatment plant design, the methane can be captured and flared or captured and converted to energy to power the plant. Alternatively, the methane may not be captured and simply released into the atmosphere.

Nitrous oxide (N_2O) emissions are a byproduct of the nitrification and denitrification processes of wastewater treatment. Nitrification and denitrification are used to remove additional nutrients from wastewater before it can be safely released into the environment. Nitrification is a biological process to convert ammonia to nitrite and nitrate. Denitrification is the process to convert nitrate to gaseous forms of nitrogen (EPA 2007).

5.2 WATER-RELATED EMISSIONS IN A JURISDICTIONAL COMMUNITY-WIDE BASELINE INVENTORY

Water-related GHG emissions have not historically been included as a separate sector in community-wide baseline GHG inventories. This exclusion is due to the considerable amount of overlap between water-related emissions, energy emissions, and municipal emissions. The information below outlines how to determine the energy and direct GHG emissions attributed to community water consumption and how to eliminate overlap with other sectors.

5.2.1 Benefits and Uncertainties

In general, there are two methods of estimating water-related GHG emissions:

1) If water facilities are municipally operated, create an estimate of GHG emissions attributed to the jurisdiction’s water consumption using local consumption and emission data.

2) If water facilities are not municipally operated, then create an estimate of GHG emissions attributed to the jurisdiction's water consumption using estimated emission factors created by the state.

At minimum, a local jurisdiction can separate the community-wide energy that is consumed by municipal water facilities and serves the community in question. This data are usually available in jurisdiction utility bills or through utility providers. Distinguishing water-related emissions in an inventory in this manner has a high degree of accuracy. Additionally, the jurisdiction will have the benefit of being able to address water-related GHG emissions, not only through water conservation efforts but from operational changes at its treatment facility.

For those water categories outside of the jurisdiction's service area, a methodology is provided below to create an estimate per California water source and region. Including these up-source emissions creates consistency between those jurisdictions that own or operate their water facilities and those that do not. It also allows jurisdictions to calculate the GHG benefit of water conservation programs like landscaping ordinances and low-flow faucet and/or showerhead programs. Like the solid waste sector, a level of uncertainty exists when estimating the efficiency of facilities out of the jurisdiction's control. As such, it is important to classify these up-source emissions as Scope 3 or as an information item.

5.2.2 Determining a Community's Water Consumption

The first step in calculating water-related GHG emissions is to determine community-wide water consumption. Jurisdictions that maintain control of their community's water supply will likely have this information readily available. If this is not the case, jurisdictions should be able to request community-wide water consumption from the water district, water association, conservation agency, or utilities district.

If water consumption data are not available for a community, an alternative approach estimates water consumption based on county-specific per capita figures from the United States Geological Survey (USGS) or California per capita figures (see Table 5-3).

Table 5-3: Water Consumption Calculation Methodologies

Data	***Source/Method***	***Pros/Cons***
Measured water consumption	Water supplier or water agency	This method is the most accurate, but the data may require time to gather.
Estimated water consumption based on per capita figures	Per capita water consumption figures based on USGS water consumption per county data or California per capita coefficients	This top-down approach is not as accurate as measured water consumption, but it is a substitute if no measured data are available.

5.2.3 Water Supply, Conveyance, and Treatment

The water supply, conveyance, and treatment process is often shared by multiple jurisdictions and agencies. This section provides a chart of the embedded energy per unit of water per source; however, it is first important to determine if any of these processes are controlled by the local government. For instance, if a jurisdiction owns a water treatment facility and is aware of what portion of treated water is sent to its community versus others, then the jurisdiction can calculate a more accurate estimate of water treatment energy use for its community. Following is a discussion of the ways in which a jurisdiction can calculate emissions related to water supply, conveyance, and treatment, and how to classify emissions based on operational control.

5.2.4 Municipal Water Treatment Facilities and Conveyance

Many jurisdictions own or operate water treatment facilities, lift stations, pumps, and other water-related facilities. The facilities can be owned by the jurisdiction and located inside or outside of the jurisdiction boundary. The facilities can also be within the jurisdiction's control if the jurisdiction has significant operational influence over the facility through a joint powers authority (JPA) or district/agency governance structure.

If municipally operated water facilities are located inside the jurisdictional boundary, they will be included in the community-wide energy data. A jurisdiction can request municipal energy data related to their water facilities and subtract it from overall community-wide energy to make a distinction between general energy use and water-related energy use. The energy emissions from municipal water facilities can be subtracted from the Scope 1 (natural gas) and Scope 2 (electricity) commercial/industrial emissions and reclassified as Scope 1 and Scope 2 water emissions, respectively.

It is important to note that jurisdictions should only distinguish the energy from municipally operated water facilities in a community-wide inventory if that energy is directly attributed to their community-wide water consumption. Water pumps and lifts can generally be attributed to the jurisdiction's water use. Conversely, the jurisdiction may own water treatment facilities that serve other cities or areas not in the jurisdiction's operational control. In this case, the energy from water treatment facilities should be separated based on service area. For instance, if City X owns a water treatment facility that serves its community and two other cities, City X would divide its water treatment facility energy consumption by total water treated and then multiply that factor by its community-wide water consumption only.

If the facilities are located outside of the jurisdiction in question, their energy will not be included in the community-wide energy data. A jurisdiction can include the portion of energy from these facilities attributed to the jurisdiction in a community-wide GHG inventory. These emissions would be classified as Scope 3 emissions.

5.2.5 Non-Municipal Water Treatment Facilities and Conveyance

Although much of the energy related to water supply, conveyance, and treatment may be consumed outside of the jurisdiction, it can be attributed to the jurisdiction since the energy would not be consumed without the jurisdiction's water demand. CEC provides factors for each water source and California location in its 2005 paper entitled the Water-Energy Relationship. These estimates were later refined in the 2006 staff report, "Refining Estimates of Water-Related Energy Use in California." Local governments can use these figures to estimate the up-source energy for supply, conveyance, treatment, and distribution processes that are not operated directly by the jurisdiction. The GHG emissions resulting from this up-source energy consumption will be classified as Scope 3 similar to the solid waste stream. Table 5-4 shows the range of energy intensity per segment of the water use cycle.

Table 5-4: Range of Energy Intensities for Water Use Cycle Segments

Supply		***Conveyance***		***Treatment***		***Distribution***	
Source	**kWh/ MG**	**Source**	**kWh/ MG**	**Source**	**kWh/MG**	**Source**	**kWh/MG**
Surface Water	0	SWP LA Basin	8,325	EPRI Avg.	100	EPRI Avg.	1,200
Groundwater	4.45/ foot	SWP Bay Area	3,150			Recycled Water	1,200–3,000
Ocean Desalination	13,800	SWP Central Coast	3,150				
Brackish Water Desalination	1,240–5,220	SWP San Joaquin Valley	1,510				
Recycled Water	0	CRA LA Basin	6,140				
		Hetch Hetchy - Bay Area	0				
		Mokelumne Aqueduct	160				
		Local/ Intrabasin	120				

Source: CEC 2006

It is important to eliminate overlap between non-municipal and municipal energy consumption related to water supply, conveyance, and treatment. For instance, if a jurisdiction owns a water treatment facility that supplies 80 percent of its community's water, the jurisdiction would only want to use the "treatment" factor for the remaining 20 percent of its community's water consumption.

The energy intensity of groundwater is not only a factor of gallons, but also of the depth of the well. If this information is unavailable or any other factor is uncertain, CEC provides averages for Northern and Southern California as shown in Table 5-5.

Table 5-5: Recommend Adjustments to WER Table 1-3, Electricity Use in Typical Water Systems

Segment of Water-Use Cycle	*Northern California (kWh/MG)*			*Southern California (kWh/MG)*		
	WER	*Adjusted*	*w/Losses*	*WER*	*Adjusted*	*w/Losses*
Water Supply and Conveyance	150	1,811[a]	2,117[b]	8,899	8,324[c]	9,727[d]
Water Treatment	100	n/a[e]	111[f]	100	n/a[g]	111[h]
Water Distribution	1,200	n/a[i]	1,272[j]	1,200	n/a[k]	1,272[l]
Total	1,450	1,811	3,500	10,199	8,324	11,110

Source: CEC 2006

Notes:

a. Adjusted estimated is based on a representative weighted average of SWP deliveries to the San Francisco Bay area, Central Coast, and San Joaquin Valley.
b. Based on system loss estimates of 5% for conveyance, 5% for water treatment, and 6% for water distribution.
c. Adjusted estimated is based on a weighted average intensity of the two SWP branches, net 0 of hydro generation on the conveyance system of the Metropolitan Water District of Southern California.
d. Based on system loss estimates of 5% for conveyance, 5% for water treatment, and 6% for water distribution.
e. No change from WER estimate, other than adjustment for losses (note 2).
f. Based on system loss estimates of 5% for conveyance, 5% for water treatment, and 6% for water distribution.
g. No change from WER estimate, other than adjustment for losses (note 2).
h. Based on system loss estimates of 5% for conveyance, 5% for water treatment, and 6% for water distribution.
i. No change from WER estimate, other than adjustment for losses (note 2).
j. Based on system loss estimates of 5% for conveyance, 5% for water treatment, and 6% for water distribution.
k. No change from WER estimate, other than adjustment for losses (note 2).
m. Based on system loss estimates of 5% for conveyance, 5% for water treatment, and 6% for water distribution.

Table 5-6: Pros and Cons of Water-Related Energy Methodologies

Data	***Source/Method***	***Pros/Cons***
Energy from municipally operated water facilities	Local water-related energy will be included on a jurisdiction's or agency's utility bill as water pumps, lifts, or similar account listings. Water-related energy can be converted to GHG emissions using the appropriate coefficients as presented in Section 6 of this paper.	The energy consumption in this category is from municipally owned facilities that serve the community. It is possible to separately account for these emissions because local governments have access to this information. There is a possibility that private treatment and conveyance systems could be located in the community, but there is no way of accessing this information.
Embedded energy from supply, treatment, and conveyance for non-municipally operated water facilities	Multiply water consumption by the energy intensity of the jurisdiction's water supply. The energy intensity of each California watershed is explored in the California Energy Commission report and the Natural Resources Defense Council report cited in this paper. Water-related energy can be converted to GHG emissions using the appropriate coefficients as presented in Section 6 of this paper.	Calculating upstream emissions from water will better convey the energy intensity of water and its variability between different areas of California. It also allows jurisdictions to calculate the benefit of providing for recycled or greywater systems in their community.

5.2.6 End-Use Emissions

End-use water emissions are embedded within the commercial, residential, and industrial energy use data for each community. It is difficult to separate the energy from water-related activities since water is ingrained in many day-to-day residential, commercial, and industrial activities. Jurisdictions that own and operate their own utility may have access to energy consumption by Northern American Industry Classification System (NAICS) codes, which would allow an inventory to determine the amount of energy dedicated to irrigation and other water-related processes. However, investor-owned utilities are currently unable to provide energy use by NAICS code.

When calculating the benefit of GHG reduction measures, a methodology exists to estimate the amount of household and commercial energy dedicated to water heating. While this is a useful estimation methodology to calculate the cost and benefit of energy efficiency programs, it is not recommended as an inventory methodology due to lack of accuracy.

5.2.7 Wastewater Treatment

There are two types of wastewater treatment emissions: (1) emissions from energy consumed by wastewater treatment activities, and (2) direct point source emissions released from the breakdown of organic matter in the treatment process. Both emissions sources may be controlled by the jurisdiction and included in an inventory of government operations. If so, these emissions can be translated to the community-wide inventory by determining the portion of emissions attributed to the community, excluding any emissions that serve outside communities. As with water supply and treatment, the inclusion of these emissions allows the jurisdiction to create a realistic GHG estimate of community-wide water consumption. It also allows the jurisdiction to track the GHG benefit of water conservation programs and upgrades to wastewater treatment facility efficiency.

If wastewater facilities are not within a jurisdiction's control, this section provides a mechanism for estimating the energy and point source emissions attributed to a community's water consumption using emission factors. The benefit of this exercise is to allow the jurisdiction to fully measure the GHG impact of water consumption and reduction efforts. However, as with water supply and treatment, there is a level of uncertainty in calculating emissions out of the jurisdiction's control.

5.2.8 Wastewater Treatment Energy

For municipally operated wastewater treatment facilities, jurisdictions should follow the methodology outlined in the section entitled "Municipal Water Treatment Facilities and Conveyance" to determine the energy attributed to the community. If wastewater treatment is out of the jurisdiction's control, the CEC has calculated general per unit energy factors as shown in Table 5-7. The resulting energy can be converted to GHG emissions using utility-specific conversion factors.

Table 5-7: Range of Energy Intensities for Wastewater Use Cycle Segments

Wastewater Collection		***Wastewater Treatment***		***Wastewater Disposal***	
Source	**kWh/MG**	**Source**	**kWh/MG**	**Source**	**kWh/MG**
Aggregated within treatment	140	Trickling Filter	955	Gravity Discharge	0
		Activated Sludge	1,322	Pump Discharge	400
		Advanced	1,541		
		Advanced with Nitrification	1,911		

Source: CEC 2006

If the type of wastewater treatment or wastewater disposal is unknown, the CEC provides an average kilowatt hour per million gallons (kWh/MG) figure for both Northern and Southern California. These figures, shown in Table 5-8, should only be used if region-specific indicators cannot be found.

Table 5-8: Recommend Adjustments to WER Table 1-3, Electricity Use in Typical Water Systems

Segment of Water-Use Cycle	*Northern California (kWh/MG)*			*Southern California (kWh/MG)*		
	WER	*Adjusted*	*w/Losses*	*WER*	*Adjusted*	*w/Losses*
Wastewater	2,500	1,911	1,911	2,500	1,911	1,911

Source: CEC 2006

5.2.9 Direct Wastewater Treatment Emissions

Direct wastewater treatment emissions include those from wastewater treatment plants and septic tanks. Methodologies are provided for calculating wastewater treatment plant emissions attributed to a community's water consumption in two ways. In addition, direction is provided for calculating the impact of septic tank operation. It should be noted that some wastewater facilities are used to create energy through gas-to-energy projects; however, since GHG inventories are not to account for emission sinks, these activities should only be discussed qualitatively.

The first approach to calculating emissions uses measurable data obtained from the plant operator. This methodology is recommended for municipally operated facilities. Quantifying direct wastewater treatment emissions requires the use of formulas included in the Local Government Operations Protocol (LGOP) v.1.1 Chapter 10 (ARB et al. 2010). If the jurisdiction is a member of ICLEI-Local Governments for Sustainability, they may have access to a wastewater treatment plant Excel-based tool that automates the LGOP calculation. Depending on the plant type and design, the following information is required:

- Amount of biochemical oxygen demand (BOD) 5 produced per day;
- Percentage of BOD5 removed at primary treatment;
- Percentage of BOD5 removed in overall treatment;
- Percentage of methane in digester gas; and
- Nitrogen discharged from plant.

The percentage of CH_4 in digester gas and the amount of nitrogen discharged from the plant will not apply to all wastewater treatment plants and should only be included in the analysis when applicable to the individual plant. Entering this information into the ICLEI wastewater treatment plant Excel-based tool or by using the equations provided in LGOP v.1.1 Chapter 10 will produce the total annual emissions resulting from the wastewater treatment process. If the treatment facility serves more than one area, the jurisdiction should only include those wastewater emissions attributed to the jurisdiction in question.

The second approach to calculating direct wastewater emissions is by population. This methodology is recommended if wastewater facilities are out of the jurisdiction's control or if the number of wastewater facilities serving the jurisdiction would make individual calculation time-prohibitive. Using default averages provided by LGOP, emissions can be calculated using the domestic and industrial populations served by the wastewater treatment plant. This approach is recommended if measurable data are not available. It should be noted that this approach does not include plant-specific operations.

Lastly, fugitive septic tank emissions can be estimated using equations provided in LGOP. The number of permitted, on-site septic systems is usually available from the local public health department or in the jurisdiction's services or infrastructure section of the general plan. If this information is unavailable, it may be possible to estimate the number of systems by requesting the service population (households) from the jurisdiction's wastewater treatment plant and then calculating the number of homes not served by the plant. LGOP provides two equations to calculate fugitive GHG emissions from septic tanks: one where the jurisdiction is aware of its average BOD load, which may be available from permit information, and an alternate equation that can be used if site-specific information is unavailable.

Table 5-9: Pros and Cons of Wastewater-Related Energy Methodologies

Data	***Source/Method***	***Pros/Cons***
Population	Total population served by the wastewater treatment plant can be used in conjunction with LGOP default coefficients to estimate point source emissions from the plant.	The default coefficients provided by LGOP are considered to be national averages for a range of wastewater treatment plant systems and designs. Local conditions and specific plant operations are not taken into account. Therefore, it is likely these emissions will be under- or overstated.
Measurable Data	Data obtained from plant records and inserted into ICLEI's Excel-based calculator or LGOP equations.	Total emissions will be more accurate and take into account local conditions and specific plant operations. Will be able to compare emissions before and after plant upgrades. Data may not be available. Requires cooperation from operating agency.
Local Energy Consumption for Wastewater Treatment	Local water-related energy will be included on a jurisdiction's or agency's utility bill. If the facility is shared, only the portion of energy attributed to the jurisdiction's water consumption should be included.	The energy consumption in this category is from municipally owned facilities that serve the community. It is possible to separately account for these emissions because local governments have access to this information. There is a possibility that private treatment and conveyance systems could be located in the community, but there is no way of accessing this information.

5.3 CONCLUSION

As California's water supply becomes more constrained, it becomes more tied to GHG emissions and climate change. Including water-related emissions as a separate source of GHG emissions will give local governments a tool to explore future water system efficiencies and to motivate community-wide water conservation efforts.

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6.0 Purchased Electricity

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One of the largest sources of GHG emissions in a community inventory is the electricity sector. Electricity generation is the process of creating electricity from other forms of energy. Some forms of energy, such as natural gas or coal, emit GHGs when combusted to generate electricity. Some renewable energy—such as solar, wind, and low-impact hydroelectricity—do not emit GHGs during electricity generation. Other renewable energy, such as biogas and biomass, emit GHGs when combusted but are using carbon that would have been emitted anyway during fires or decomposition. Community inventories usually include emissions from electricity generation for electricity consumed by residences, commercial development, and industrial development.

Usage data and emission factors are required to estimate the emissions from electricity generated to provide power to the jurisdiction. Each electric utility provider has its own unique mix of generation sources and its own GHG emission factors. Emission factors vary year to year due to variations in the availability of power and the need to import power from out of state.

6.1 JURISDICTIONAL ISSUES

Emissions from electricity generation should be reported at the user level instead of at the point of production. A jurisdiction may have electricity-generating facilities located within its geographical boundary. To include emissions from both the power-generating facilities within the geographical boundary and at the user level would lead to double-counting of emissions because these emissions are reported as residential and commercial electricity consumption in both the subject jurisdiction and other jurisdictions.

Reporting electricity consumed at the user level instead of at the point of production is advantageous because the ability of the jurisdiction to influence emissions is at the user level through energy conservation and efficiency programs. Including emissions from power plants themselves in the inventory might also skew results since these plants might supply power for other jurisdictions.

Local jurisdictions have limited to no control over the emissions at the utility but they do have land use permitting authority, so permits for power plants can be denied if incompatible with neighboring land uses due to noise, hazards, odor, toxics, or other impacts. In addition, utilities are already subject to state mandates such as the Renewable Portfolio Standard, Renewable Electricity Standard, and future cap-and-trade regulations.

Emissions from power plants located within the jurisdiction that sell all of the electricity to the utility provider can be noted in the report, without being included in the inventory. California's mandatory GHG reporting program provides GHG emissions inventories for oil refineries, hydrogen plants, large stationary combustion facilities that emit more than 25,000 metric tons of carbon dioxide equivalent ($MTCO_2e$) per year, and electricity generating and cogenerating facilities that generate more than 1 megawatt of electricity and more than 2,500 $MTCO_2e$ per year. Public emissions inventories are available beginning from 2008 (ARB 2010b).

A jurisdiction may own or operate a cogeneration plant that uses natural gas to generate electricity and heat. If the jurisdiction uses all of the electricity in its facilities without selling any of it back to the local utility, then those emissions can be categorized as "natural gas" (see Section 4.2 of this paper). However, if the jurisdiction does not use all the electricity and sells some of it to the utility provider, it is in essence a power plant. To include those emissions in the natural gas sector would be double-counting the emissions, since the electricity that is generated is sent via the utility provider to jurisdiction electricity users. Therefore, any electricity provided to the utility should be subtracted out of the inventory.

Some jurisdictions have large industrial sources that produce products consumed outside of the jurisdiction. Thus, some of the upstream emissions for the product are included in the jurisdiction's inventory. The electricity emissions for the large industrial sources should be included in the jurisdiction's GHG inventory.

6.2 USAGE DATA AVAILABILITY

Electric utilities (e.g., Southern California Edison, Pacific Gas & Electric [PG&E]) are the best source of data for electricity consumption. The level of detail for emission inventories using electricity consumption data is dependent of the level of detail available from the utility providers. Typically, only aggregated data are provided. This data are adequate to provide a community baseline, but does not identify neighborhoods or individual buildings that consume higher amounts of electricity than average.

Fine-grained data would better identify opportunities for focused retrofit program controls and would aid in estimating potential emission reductions. However, under existing rules, such as Rule 15/15, utilities are not allowed to provide individual customer data due to privacy practices. Utilities may be able to provide neighborhood-level data, but this would require substantial work on the utility's part and may be difficult to obtain.

As an alternative to using fine-grained consumption data, communities can use age of housing stock and commercial buildings as an indicator of the energy consumption rate to identify potential reductions. Title 24 energy efficiency standards have evolved since their first adoption in 1978: they are now more stringent. Structures built prior to 1978 can be assigned an average electricity usage rate, and structures built while each version of Title 24 was in effect can be assigned lower average rates with each successive version.

The benefits of Title 24 have been offset to some degree by increases in the use of power-consuming devices like televisions and computers and by increases in home size. Most areas of the United States have seen increasing electricity consumption, while rates in California have remained flat.

The utilities are the primary source of commercial and residential energy consumption statistics for communities. Some communities are served by more than one utility. In those communities, the inventory would need data from all providers with emissions calculated separately to reflect the current power portfolio of each utility. Direct access electricity is electricity that is purchased from a power provider but is delivered via power lines operated by the major utilities. Direct access power is subject to Rule 15/15 privacy protections that preclude disclosure of electricity consumption data from this source. It may be feasible for the utility to provide the information in a consolidated inventory, but that would prevent the use of a utility-specific emission factor based on the emissions from their actual generation facilities.

Utilities need adequate time to respond to data requests, anywhere from three weeks to a few months. Sometimes the jurisdiction's manager or high-ranking official is required to sign a data request form. Usage data obtained from the utility is preferred. If for whatever reason the utility is not able to provide the data, residential electricity consumption (EERE 2008) or per capita data (i.e., obtaining total electricity used in the state and dividing by the population) could be used, though it is not recommended.

6.3 EMISSION FACTORS

Utilities have unique blends of power plants and renewable power. For example, PG&E currently uses renewable energy generated by biofuel, biomass, digester gas, geothermal, hydro, solar biomass hybrid, solar PV, solar thermal, and wind. This mix of sources can vary year to year and yield differences in the overall emission factor for the utility. The emission factor is a measure of the average emission rate of a pollutant relative to the intensity of an activity; for example, pounds of CO_2 per megawatt hour.

Emission factors for CO_2, CH_4, and N_2Oitrous oxide exist. These are GHGs that are emitted during combustion of fuels. Utility-specific electricity delivery metrics provide the most accurate emission factors. Emission factors are available in the Local Government Operations Protocol (ARB et al. 2010). Emission factors are also available through the United States Environmental Protection Agency's Emissions and Generation Resource Integrated Database (eGRID). eGRID2002 provides emission factors for 1996, 1997, 1998, 1999, 2000 (EPA 2002), while eGRID2010 contains emission factors for the years 2004, 2005, and 2007 (EPA 2011). Emission factors for 2007 will be available soon through eGRID2010. The CCAR (2009) General Reporting Protocol reports eGRID emission factors by region for the years 2000 and 2007. Emission factors may also be available directly from the utility provider.

Sulfur hexafluoride is a GHG that is used in electricity transmission. It is used in electrical power systems as an insulator and arc quencher in medium and high voltage gas insulated switchgears and can leak out of those applications. Sulfur hexafluoride has a global warming potential of 23,900 and an atmospheric lifetime of 3,200 years. There is currently no published sulfur hexafluoride emission factor. To calculate the emission factor for sulfur hexafluoride, the California sulfur hexafluoride emissions from transmission lines (ARB 2010a) can be divided by the total electricity generated in California in 2008 (CEC 2010), resulting in 0.0033 $MTCO_2e$ per megawatt-hour or 0.00031 pounds of sulfur hexafluoride per megawatt-hour.

6.4 SUMMARY

Accurately estimating emissions from electricity consumed by a jurisdiction can be accomplished when a variety of conditions are considered. The most straightforward approach to estimating emissions from electricity consumed by a jurisdiction is to obtain electricity data for that jurisdiction by the utility and use the utility-specific emission factors.

7.0 Municipal Solid Waste Related Emissions

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Two emission sources associated with municipal solid waste are addressed in this chapter: landfills and composting. Emissions associated with wastewater treatment are addressed in Section 5.0 of this paper. Emissions associated with waste hauling would be captured with other vehicle miles traveled as mobile emissions, which are discussed in Section 3.0 of this paper.

After municipal solid waste (MSW) is placed in a landfill, waste (such as paper, food scraps, and yard trimmings) is initially decomposed by aerobic bacteria. After the oxygen has been depleted, the remaining waste is available for consumption by anaerobic bacteria, which break down organic matter into substances such as cellulose, amino acids, and sugars. These substances are further broken down through fermentation into gases and short-chain organic compounds that form the substrates for the growth of methanogenic bacteria. These methane-producing anaerobic bacteria convert the fermentation products into stabilized organic materials and biogas consisting of approximately 50 percent carbon dioxide (CO_2) and 50 percent methane (CH_4), by volume. Significant CH_4 production typically begins one or two years after waste disposal in a landfill and continues for 10 to 60 years or longer (EPA 2010). Composting of organic waste releases CO_2 and limited amounts of CH_4 and nitrous oxide (N_2O).

Solid waste management accounted for approximately 2 percent of United States GHG emissions in 2006 and approximately 1.4 percent of California GHG emissions in 2008 (ARB 2010a).

In addition, local municipalities have GHG reduction opportunities through their role in reduce, reuse, recycle programs and often through their role as solid waste authorities (e.g., when they own/operate a solid waste landfill). Thus, inclusion of solid waste emissions in a baseline GHG inventory is important for accounting for diversion, waste reduction, and landfill control practices in a climate action plan.

7.1 LANDFILL AND WASTE DATA AVAILABILITY

Methane emissions from a landfill are a function of several factors, including:

- The total amount of waste in the landfill;
- Characteristics of the landfill receiving waste (i.e., composition and age of waste in place (WIP), size, climate);
- The amount of CH_4 that is recovered and either flared or used for energy purposes; and
- The amount of CH_4 oxidized in landfills instead of being released into the atmosphere.

7.1.1 Waste Generation

Jurisdictions are required by California state law to estimate their annual amount of waste generation and diversion. Data for waste generation for a jurisdiction is usually available from CalRecycle (officially the Department of Resources Recycling and Recovery, formerly known as the California Integrated Waste Management Board). Annual reports of waste generation are available at: http://www.calrecycle.ca.gov/LGCentral/Reports/DRS /default.aspx. Reports are also available identifying the facility where a jurisdiction's waste was sent by year.

Waste stream profiles are often available from the local solid waste authority and/or landfill operators. Alternatively, California conducted a waste stream analysis in 1999 for all jurisdictions in the state, which is available at: http://www.calrecycle.ca.gov /WasteChar/. The LGOP provides default waste stream profiles for the United States and California if such data are not available for a jurisdiction.

7.1.2 Landfill Characteristics

Landfill open and close dates, composition, and age of WIP are sometimes available from the local solid waste authority and/or landfill operators. The LGOP provides a default method in case such data are not available. EPA's Landfill Methane Outreach Program (LMOP) may also have data on the amount of MSW disposed of at a particular landfill (EPA 2007). A fundamental piece of data for this calculation is the age of the waste in the landfill, which is calculated based on the year the landfill opened and closed. If data on age is unavailable, 19 years can be used as a proxy based on the average lifespan of a landfill.

7.1.3 Landfill Gas Control

The largest active landfills are equipped with landfill gas management systems. These systems include active flaring or landfill gas-to-energy (LFGTE) projects. CalRecycle or the EPA's LMOP should be accessed to determine if there is an active project at the landfill, and the amount of methane collected from that project (EPA 2007). Landfill gas capture rate estimates are sometimes available from the local solid waste authority and/or landfill operators. The EPA recommends a default of 75 percent when a gas capture system is in place and the capture rate has not been otherwise estimated. Jurisdictions with more detailed site-specific data on landfill gas collection system efficiencies should adjust the estimates accordingly.

7.1.4 Oxidation Rates

Landfill gas that is not collected or vented to the atmosphere passes through cover soils before being released to the environment. Bacteria near the landfill surface consume methane and other volatile hydrocarbons that are produced by decomposition in the underlying waste by reacting it with oxygen. The bacteria harness the energy from these enzyme-catalyzed chemical reactions to fuel their respiration. The EPA currently recommends a default methane oxidation rate of 10 percent. Jurisdictions with more detailed site-specific data on methane oxidation rates should adjust the estimates accordingly.

7.1.5 Uncertainties

There are uncertainties in some of the data used to estimate landfill GHG emissions. For example, at present there is no widely accepted methodology to be recommended for directly measuring fugitive methane emissions from solid waste. As a result, the measurement of landfill gas capture is also subject to uncertainty. Research is under way to develop methodologies to more accurately measure emissions and the effectiveness of capture technology. The use of proxy data (i.e., waste age, waste profiles, assumption of deposition timing, decay rates, and gas capture systems) is a pragmatic approach until it is technically feasible to more directly determine landfill emission rates and thus to determine capture efficiencies.

7.2 WASTE EMISSIONS ESTIMATION DECISION SUPPORT

There are several key choices in quantifying solid waste landfill GHG emissions for inventory purposes:

1. Site-Based vs. Waste-Generation Based Emissions – Whether to only include the waste emissions at landfills within (or that are controlled by) the jurisdiction OR to include the GHG emissions due to waste generation within the jurisdiction, regardless of where the waste is landfilled.

2. Waste in Place (WIP) Emissions vs. Life-Cycle Emissions – Whether to only include emissions from waste in place (WIP) at the landfill, or quantify the life-cycle GHG reductions due to production, manufacturing, recycling, and the future emissions from the waste in the landfill.

3. Carbon Dioxide Emissions from Landfill Flaring – Whether to include CO_2 emissions from flaring of landfill gas.

4. Composting Emissions – Whether to include fugitive emissions from composting.

7.3 SITE-BASED VERSUS GENERATION-BASED WASTE EMISSIONS ESTIMATION APPROACHES

The following methodology presents two options for estimating landfill emissions for a jurisdiction: (1) site-based emissions (e.g., direct emissions from a specific landfill regardless of where the waste originated) and (2) population-based emissions (e.g., indirect emissions associated with waste generated in the jurisdiction, regardless of where that waste is disposed).

Both approaches can provide information about opportunities to reduce emissions related to waste management. If there is a landfill within the jurisdiction, planners may wish to estimate emissions both ways (taking pains not to double-count) by including direct and indirect emissions in the final inventory results. For example, estimating emissions from a landfill in the jurisdiction and simultaneously estimating emissions associated with waste generated by households in the region that send their waste to the same landfill gives a full picture of these sources. If a landfill does not exist within a particular jurisdiction, the population-based estimates can be used to estimate emissions associated with disposal of waste generated in the region, regardless of where the waste is actually disposed.

The site-based approach can identify landfills that may be candidates for methane flaring or capture. The population-based estimates can identify opportunities for waste reduction measures through source reduction, recycling, or composting. In both methodologies, the first-order decay equation presented in the first-order decay model described by the Intergovernmental Panel on Climate Change (2006) can be utilized. This type of equation calculates the emissions from waste disposal over a period of time. The results of both approaches may be reported in the jurisdictional inventory for informational purposes.

For municipal emissions inventories (as opposed to a community inventory), landfill GHG emissions from a landfill owned or operated by a municipality are considered to be Scope 1 emissions according to the LGOP. Methane emissions from waste generated by a jurisdiction but disposed of outside its organizational boundaries are considered to be Scope 3 emissions or “optional,” according to LGOP. The LGOP recommends that these Scope 3 emissions be included in the emissions inventory because doing so provides an opportunity for innovation in GHG management.

7.3.1 Calculating Solid Waste Landfill Emissions Using a Site-Based Approach

The site-based approach calculates landfill emissions for the inventory year based on the landfills located within the geographic boundaries of the jurisdiction, regardless of when the waste was disposed. This method is also known as waste in place, or WIP, and is a suitable method for calculating the amount of landfill gas available for flaring, heat recovery, and energy generation.

Methane emissions from landfills for a single year can be calculated using a first-order kinetics[3] model that takes into account climatological factors that influence the decay rate of the waste in the landfill. The first-order decay model is described by the Intergovernmental Panel on Climate Change (2006). For a particular amount of WIP at a landfill, it can be assumed that the waste was deposited in the landfill in equal installments for each of the years the landfill was open.

The LGOP also provides equations that can be used to make a first-order kinetics estimate of landfill methane emissions. The California Air Resources Board (ARB) (2010b) has released a spreadsheet tool for landfill emissions estimation (for landfills that do not have a gas collection system), based on the IPCC first-order delay model, in support of the LGOP guidelines. ARB's spreadsheet tool provides default values for many of the landfill characteristics, allows the user to input landfill-specific data, and accounts for WIP at the landfill. Although ARB's tool is intended for landfills that do not have a gas collection system, the resulting emissions can be adjusted to account for a gas collection system, as described below. ICLEI's Clean Air Climate Protection (CACP) 2009 software also includes a WIP method for calculating direct landfill emissions.

For landfills with gas collection systems, the LGOP recommends using actual system data for the fugitive emissions. However, if this data collection for inventory purposes is overly burdensome or is not available, the quantity of CH_4 collected, oxidized, and flared can be subtracted from the "potential" CH_4 emissions. Potential landfill methane emissions are estimated given the amount of WIP and the characteristics of the waste, as described above. Likewise, CH_4 that is collected and used to generate electricity in LFGTE projects is also subtracted from the potential CH_4 emissions. Potential landfill emissions can be adjusted by the assumed gas collection system efficiency and methane oxidation rate of 75 percent and 10 percent, respectively. These are default values, but jurisdictions with more detailed site-specific data on landfill gas collection system efficiencies and/or methane oxidation rates could adjust the estimates accordingly.

7.3.2 Calculating Solid Waste Landfill Emissions Using a Waste-Generation-Based Approach

This approach calculates baseline landfill emissions based on the amount of current annual waste generated within a particular jurisdiction and the landfills where the waste is deposited, regardless of whether the waste is deposited in a landfill within the inventory jurisdiction. This approach discloses the annual landfill emissions associated with annual waste generation.

[3] Refers to chemical kinetics, which is the study of chemical reaction rates.

The waste generated within a jurisdiction can be identified based on local reporting, solid waste authority data, or CalRecycle data for the inventory year. It is necessary to identify the jurisdiction's waste characteristics. While the majority of jurisdictions report information regarding community waste characteristics (i.e., waste type and amount, for both commercial and residential waste), in some cases this data may not be available. In those cases, if data are available at a county level, it can be apportioned by population to provide an approximation of the waste characteristics at the jurisdiction level.

Next, a profile of the landfills (including landfill gas control/oxidation rates, climate) where the jurisdiction's waste is deposited needs to be developed. ARB's first-order decay model can also be used to estimate emissions for this approach, once the amount of waste, its characterization, and the landfill characteristics are determined. For a full accounting of emissions associated with the landfill operating years, a per capita waste estimate may need to be developed, based on Department of Finance or other historical population information.

7.3.3 Waste in Place Versus Life-Cycle Emissions

As described above, WIP includes landfill emissions during the inventory year, regardless of when the waste was disposed. However, life-cycle GHG emissions (and associated reductions) of waste result from the production and manufacturing of the raw materials and recycling of the used materials, as well as the future emissions from the waste in the landfill. Below, we evaluate several components of the GHG emissions life cycle of waste and describe the implications for accounting for these components in a GHG emissions inventory.

7.4 RECYCLING

There is a difference between making a product with virgin inputs and making a product with recycled raw material inputs. Recycling means that the virgin inputs that would have been necessary to create the specific material are no longer required because this material is being recycled. As a result, recycling and reuse of materials (that would otherwise be landfilled) reduce the GHG emissions associated with production using virgin material. The EPA has developed a Waste Reduction Model (called WARM) that can be used to estimate the difference in recycling material compared to production from virgin materials, as well as to calculate the benefits of source reduction, waste combustion, and composting. The model calculates the life-cycle emissions avoided through application of different alternative disposal methods.

While the WARM model and other life-cycle approaches are useful tools for evaluating the potential benefit of reduce, reuse, recycle measures, using such approaches is not recommended for use in developing a baseline of GHG emissions. A baseline GHG emissions inventory, by definition, needs to be bound by definitive boundaries. A life-cycle analysis, by definition, must cross numerous geographic boundaries to account for both upstream and downstream supply chain emissions. For example, large amounts of recycled material are actually exported to China for use in production there; thus, a life cycle's geographic domain can literally be global A further concern for using life-cycle analysis in a baseline inventory is that one would be incorporating reduction calculations within a single emission factor (often negative), which can mask the remaining landfill emissions that may still be occurring. For this reason, EPA (2009) states that the use of the WARM model is inappropriate for GHG inventories.

7.4.1 Methane Commitment

The methane generation potential over the degradation period of a single year's waste is known as the "methane commitment." This life-cycle approach accounts for emissions from waste generated in a single year, regardless of when those emissions occur, and is a useful metric for accounting for the total emissions impact of one year's waste. It is a useful metric if no historic information regarding waste disposal can be obtained. This parameter also provides a metric against which to measure the impact of recycling and other waste diversion measures. The LGOP recommends that the methane commitment emissions be considered Scope 3 because the emissions occur over the lifetime of the waste and not in the inventory year.

The methane commitment for a single year's waste is an option in ICLEI's CACP 2009 software (WIP is another option). The methane commitment can be calculated based on first-order decay and by assuming the future methane collection efficiency and landfill modeling parameters over the generation lifetime of the waste.

7.5 LANDFILL FLARING CO_2 EMISSIONS

Although the composition of landfill emissions is estimated to be about 50 percent CH_4 and 50 percent CO_2 by volume, CO_2 emissions from anaerobic digestion of solid waste in landfills are considered to be of biogenic origin. The LGOP and IPCC recommend that biogenic emissions be reported only as an informational item (ARB et al. 2010; IPCC 2006). CO_2 emissions from combustion of recovered landfill gas (i.e., flared methane) are also not typically reported, as the CO_2 emissions are considered to be of biogenic origin. Consequently, inventories only need to report landfill flaring CO_2 emissions as an information item and should not include them as part of the base GHG inventory.

It should be noted that under mandatory reporting rules, qualifying facilities are required to report both CO_2 and CH_4 emissions. However, this paper is concerned with the preparation of community GHG baseline inventories, not compliance with mandatory reporting.

7.6 COMPOSTING EMISSIONS

Composting of organic waste is common in some California communities. Composting releases CO_2 and limited amounts of CH_4 and N_2O. The CO_2 released is biogenic in origin and like CO_2 from landfills, should not be included in a community inventory (but may be disclosed as an informational item should a jurisdiction desire).

Composting is an aerobic process, and a large fraction of the degradable organic carbon in the waste material is converted into CO_2. CH_4 is formed in anaerobic sections of the compost, but it is oxidized to a large extent in the aerobic sections of the compost. The estimated CH_4 released into the atmosphere ranges from less than 1 percent to a few percent of the initial carbon content in the material. The range of the estimated N_2O emissions varies from less than 0.5 percent to 5 percent of the initial nitrogen content of the material (ARB et al. 2010).

Because of the lack of existing data and guidance for this potential emission source, the LGOP does not include standardized methodologies to estimate fugitive emissions from composting at this time. Local governments should assess the potential for emissions from composting activities based on the best available information and determine whether their quantification is meaningful on the local level.

8.0 Agriculture

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Agricultural practices vary between regions, and provide a unique sector of GHG emissions for local governments to quantify. Appropriate approaches to quantify GHG emissions and obtain the data necessary to quantify these emissions vary. Both the sources of agricultural emissions and available data differ from one jurisdiction to the next. In 2008, agriculture contributed approximately 5.9 percent of California's total GHG emissions (ARB 2010), consistent with the proportion of emissions resulting from agriculture nationwide (6.1 percent) (EPA 2010). Nationwide, agricultural activities were the single largest source of all nitrous oxide (N_2O) emissions, contributing almost 68 percent of all N_2O. Further, agriculture contributes approximately 35 percent of all CH_4 emissions nationwide (EPA 2010).

For the past 50 years, California has been the most agriculturally productive state (Natural Resources Agency 2009). It receives the highest amount of cash farm receipts of any state and is the nation's leading dairy state. It produces almost half of all United States grown fruits, nuts, and vegetables (USDA 2008), and yields over 90 percent of the nation's production of almonds, apricots, raisin grapes, olives, pistachios, and walnuts (Natural Resources Agency 2009). Agricultural practices throughout the state vary regionally. Agriculture may not be an appropriate sector for inclusion in every inventory, but in certain scenarios it may contribute a significant proportion of local emissions.

Rationale for Inclusion of Agricultural Emissions at the Local Level

An accurate assessment of agricultural emissions from local sources requires a higher level of deliberation at the local level. Several factors support the accurate local assessment of agricultural emissions:

- Relevance and Completeness. Due to agriculture's contribution to key GHG emissions, including approximately 70 percent of all N_2O and 35 percent of CH_4 (EPA 2010) in the United States, when agriculture is present, it will likely be an important source of emissions to be accounted for.

- Foundation for Greenhouse Gas Emission Reduction Strategies and Climate Action Plans. When agriculture is locally present, assessment of emissions from agriculture allows for the creation of a more powerful

CAP/GHG emission reduction strategy. Having quantified GHG emissions from agriculture, a local government is able to take credit for changes in farming practice that may occur after the baseline inventory.

- Anticipate Opportunities for Sequestration and Cap and Trade. An inventory of agricultural emissions prepares a local government to explore new opportunities for emissions credit and revenue related to cap and trade. Prepare for Climate Change Adaptation. By integrating agriculture as a sector of a climate change assessment and strategy, a local government is positioning itself to deal with long-term climate change challenges on the horizon.

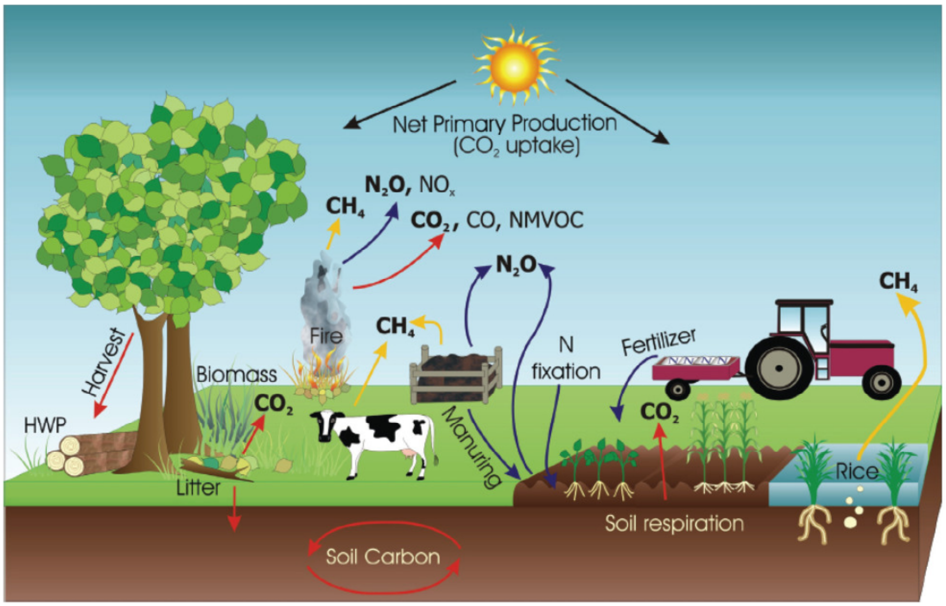
Agriculture and GHG Emissions: Determining Appropriate Sectors for Inclusion

Overview of GHGs and the Agricultural Cycle

At this time there is no adopted protocol for community-wide GHG inventories. Local governments are able to use a spectrum of approaches to assess GHG emissions from the agricultural sector. Primary approaches and tools relevant for California agriculture are based on best practices and available tools, including the IPCC Guidelines for National GHG Inventories (2006), the EPA's Inventory of U.S. GHG Emissions and Sinks (2010), and the California GHG Inventory for 2000–2008 (ARB 2010).

Understanding the context of agricultural practices helps a local government to determine optimal approaches to quantify agricultural emissions at the local level. Figure 8-1 below depicts the agricultural cycle. For the purposes of a community-wide GHG inventory, each cycle process can be grouped into three categories: (1) crop production, (2) livestock, and (3) agricultural equipment. These categories capture the primary agricultural activity or source that creates local GHG emissions, as discussed below.

Figure 8-1: Primary Greenhouse Gas Emissions Sources and Removals in an Agricultural System



Source: IPCC 2006

- Crop production includes any process emissions pertaining to the establishment, harvesting, or decomposition of crops. Crop production includes crop burning and the application of fertilizer and pesticides. Fuel combustion that is used to support crop production for the operation of farm equipment is included below under agricultural equipment. These human-induced activities result in direct emissions within a local government's geographical boundary and are classified as Scope 1 emissions.

- Livestock includes the emissions from all ruminant animals. Ruminants include cattle, sheep, hogs, goats, horses, and pigs. GHGs result from the special process of enteric fermentation that takes place within ruminant digestive systems and through manure decomposition. Once livestock exists in any given place, livestock emissions take place apart from human intervention. These are classified as Scope 3 emissions, those which the local government has an interest in but no direct control over.

- Agricultural equipment includes the combustion of fuel in all off-road agricultural equipment, including tractors and other types of fuel-powered farm machinery. Note that any agricultural facility powered by electricity would be captured with other aggregated stationary sources of emissions. Due to Rule 15/15,, a local government is unable to specifically call out any specific facility or class of facilities related to agriculture. Agricultural equipment represents a source of emissions that is not otherwise captured under other sectors of the inventory.

The following discussions on crop categories and tools for emissions quantification are based on best practices of local governments to date. Agriculture involves a diverse array of activities with a multitude of implications for GHGs. The following sections function as an abbreviated overview of primary considerations and activities to quantify. The sections present an initial approach to agricultural emissions for a local government to consider; this paper does not present the full minutia of agriculture emissions. This presentation is driven by the primary motivation of balancing a comprehensive and accurate approach with practicality and feasibility.

8.1 CROP PRODUCTION

California's agricultural GHG emissions result from a highly intensive modern industry sustained by ongoing human intervention. Crop yields are dependent on inputs of fertilizer, manure, and pesticides that both directly and indirectly release GHGs. Other practices, such as the application of lime to the soil, work to achieve targeted levels of nutrients in the soil necessary to support agriculture. As a typical agricultural practice, burning is often used as a means to eliminate crop residue that remains after harvest, a practice which also releases GHGs into the atmosphere. Practices vary by crop type, soil type, terrain, and other factors. Additional information on the contribution of these practices to GHGs is provided below.

Note that while there has been a rise in organic farming and less intensive agricultural practices throughout the state, most agricultural enterprise is nonetheless characterized by a reliance on industrial inputs. As of 2008, less than 3 percent of all California farmland was classified as organic (USDA 2010).

Table 8-1: Crop Production

Activity	*Process of Contribution to GHGs*	*Percentage Contribution to California's GHG Inventory, 2008*[a]	*Factors to Consider for Inclusion*
Agricultural soil management and crop production (e.g., the application of manure and fertilizers)	• Direct introduction of nitrogen into managed soils through synthetic or organic fertilizers releases N_2O. • Direct introduction of lime into soils (to reduce soil acidity) releases CO_2. • Indirect emissions	• Fertilizer: 23.95% of Agriculture emissions; 1.42% of net emissions from all categories • Soil Preparation & Disturbances: 4.10% of Agriculture	• Extent and type of farming management practice (e.g., application of manure or fertilizer to cropland would cause emissions, whereas passive rangeland not receiving any inputs would not cause anthropogenic emissions to be

Activity	*Process of Contribution to GHGs*	*Percentage Contribution to California's GHG Inventory, 2008*[a]	*Factors to Consider for Inclusion*
	of volatilization of applied nitrogen, leaching, and runoff. • Anaerobic decomposition in rice fields releases CH_4.	emissions; 0.23% of net emissions from all categories	quantified). • Availability of data on crop farming. Relevant data includes crop types, acreages farmed, and intensity of fertilizer use. • Typical to rely on, a simplified approach is that focuses solely on emissions from fertilizer application.
Agricultural residue burn	• Burning of leftover biomass releases N_2O and CH_4.. (CO_2 emissions are biogenic and are processed in crop cycles. Consistent with standard methodology and the California Inventory, CO_2 emissions from crop burning should be excluded from an inventory.)	• Crop Residue Burn: 0.03% of Agriculture emissions; 0.02% of net emissions from all categories	• Determine if data are tracked at a local or regional scale. Use of regional or statewide data should to be cross-checked against local conditions. For instance, if local crops consist solely of established orchards with long life cycles, statewide trends of annual burn rates may not be applicable. • Without data, estimates can be created based on local insights that respond to all available regional or state information.
Pesticide Application	• Direct application of chemicals that releases assorted GHGs.	Not quantified	• Pesticide use is available through state data sets at the county scale. Additional local insight would be necessary to attribute properly to activity within a smaller geographic entity. • TheGWP of pesticides varies greatly, and detailed activity is required to accurately quantify pesticide use. .

Source: ARB 2009
Notes:
a. All capitalized phrases correspond to categories in the Scoping Plan.

8.2 LIVESTOCK

Livestock emissions largely result from ruminants, including cattle, buffalo, sheep, and goats. Enteric fermentation is a natural digestive process that occurs in livestock when indigestible carbohydrates are reprocessed into nutrients that the animal can absorb. Methane is a natural byproduct of this process. Cattle create most of the methane emissions that result from enteric fermentation in the United States. In addition, methane and nitrous oxide emissions result from the anaerobic decomposition of livestock manure (ARB 2009). Decomposition of human waste also yields GHGs, but this source of emissions is dealt with separately under wastewater emissions. Pertinent information to quantify livestock sources of GHGs is provided below.

Table 8-2: Livestock

Activity	***Process of Contribution to GHGs***	***Percentage Contribution to California's GHG Inventory, 2008***[a]	***Factors to Consider for Inclusion***
Enteric fermentation	• Direct emission of CH_4 from livestock.	• Enteric Fermentation: 31.00% of Agriculture emissions; 1.84% of net emissions from all categories	• If livestock is locally present., a head count of all livestock for the baseline year is necessary to quantify emissions. • Quantification approaches vary based on intensity of local cattle operations and available data. If cattle activities are limited to less intensive grazing, an aggregate head count will suffice. • Countywide crop reports or local agricultural agencies often have information on livestock populations, at least at a county or region-wide scale.
Manure management	• Direct emission of CH_4 and N_2O from decomposition of	• Manure Management: 27.02% of	• Emissions vary based on the type of manure and storage methods.

Activity	*Process of Contribution to GHGs*	*Percentage Contribution to California's GHG Inventory, 2008*[a]	*Factors to Consider for Inclusion*
	manure.	Agriculture emissions; 1.60% of net emissions from all categories	Even if livestock is present, manure management may not cause GHG emissions. If manure is stored in dry form or applied to rangeland, it will usually decompose aerobically and yield little GHG emissions. • Note that manure management may include emissions from animals that are not assessed for enteric fermentation (e.g., poultry).

Source: ARB 2009
Notes:
a. All capitalized phrases correspond to categories in the Scoping Plan.

8.3 AGRICULTURAL EQUIPMENT

All agricultural equipment that is not powered by electricity or natural gas would otherwise not be captured in the community-wide inventory; as off-road uses, agricultural equipment is excluded from the mobile sources sector. Agriculture equipment that generates emissions includes tractors, mowers, balers, combines, hydropower units, sprayers, swathers, and tillers.

Table 8-3: Agricultural Equipment

Activity	*Process of Contribution to GHGs*	*Percentage Contribution to California's GHG Inventory, 2008*[a]	*Factors to Consider for Inclusion*
Agricultural equipment	Emission of GHGs from fuel combustion.	General Fuel Use: 13.61% of Agriculture emissions, 0.81% of net emissions from all categories	• OFFROAD 2007 (ARB 2006) data aggregated at the county level for off-road agricultural equipment. Additional local land use information is needed to disaggregate data to a sub-county scale (i.e., acres of land designated for agriculture or similar land uses) • BAAQMD guidelines require Qualified Greenhouse Gas Reduction Programs to disaggregate OFFROAD emissions based on the percentage of countywide residents accounted for in the local boundary.

Source: ARB 2009
Notes:
a. All capitalized phrases correspond to categories in the Scoping Plan.

8.4 METHODOLOGY AND TOOLS

8.4.1 Baseline & Forecast Considerations

Consistent with existing standard practices, the same tools are generally used to determine emissions in both baseline and forecast years. Variation between baseline and forecast emissions results from unique input variables that are collected but which are often fed into the same models. Once a local government has taken stock of relevant activities and available data, it can initiate the quantification of agricultural emissions. Data that have been collected in the initial stages described above will determine the most appropriate tools to use in quantification. Often, local governments utilize a geographic approach, assessing agricultural emissions for all activities that fall within the jurisdiction's geographical boundaries of an entity. However, in some instances, anticipated changes to geopolitical boundaries merit modification to this approach to account for all relevant emissions sources. Such concerns include:

- Consistency and transparency of geographic scope between agricultural activities. Since agricultural data comes from multiple sources in multiple levels of aggregation, inconsistencies may arise regarding assumptions between agricultural sectors. Clear inputs and appropriate levels of documentation facilitate an informative and rigorous inventory.

- Consistency with other sectors. An annexation or land use designation amendment planned to take place after the baseline year may increase or decrease agricultural activities within a jurisdiction. Any changes to the geographic scope for purposes of accuracy of agriculture emissions should only be made while ensuring that methodology is consistent between other GHG emissions sectors.

- Tension of completeness and accuracy. Determinations on appropriate agricultural activities for inclusion are simply made on a case-by-case basis, given available data, best practices, and feasibility. Aiming for a complete depiction of all agricultural emissions is not necessarily a desirable goal,. Rather, resources can be allocated to ensure that time is efficiently devoted to the relevant activities that hold potential to yield accurate results, based on available data and existing best practices.

8.4.2 **Quality Control**

Once emissions from agriculture have been calculated, a local government should attempt to assess the accuracy of such figures. However, unlike other sectors, there is a high degree of variability in agricultural activities between areas. Accuracy will slowly be confirmed through multiple checks.

- Common-sense check. Use a basic understanding of the extent of agricultural activities as a general check against agriculture's overall contribution to total GHG emissions.

- Comparison to state emissions. While not always an appropriate comparison, a local government can use the published statewide inventory to generally compare agriculture's statewide contribution to GHGs to local levels of agricultural contribution. Statewide, agriculture contributes approximately 6 percent of all emissions. A breakdown of the contribution of each agricultural activity to total emissions statewide (not just to the emissions associated with agriculture) follows (ARB 2010):

    - Enteric fermentation from livestock: 1.8 percent of total emissions;

    - Manure management for livestock: 1.6 percent of total emissions;

    - Fertilizers: 1.4 percent of total emissions;

    - Crop residue burning: 0.02 percent of total emissions; and

  - General fuel use for agricultural equipment: 0.08 percent of total emissions.[4]

- Comparison to emissions from other jurisdictions. Utilizing the published inventories of other jurisdictions is another potential check for accuracy. Note that not all inventories use the same agricultural activities or methodologies. Any comparison should be based in an informed understanding of what emission figures represent

8.4.3 Tools

The following section provides detail on the available tools to quantify emissions from agricultural activities. Appropriate tools will largely be determined by activities and available data that is obtained during the initial assessment stages. While there are a multitude of tools available, this paper presents likely approaches best suited to the needs of a local government that are based on existing best practices and resources to date. This directory is intended to help a local government establish parameters for an initial game plan to assess agricultural emissions in a manner that balances accuracy with feasibility. Note that many tools are under development; over time, it is assumed that more advanced approaches and detailed data sets will become available to local governments.

Current research efforts related to the AB 32 Scoping Plan will likely yield tools that can inform the development of more accurate approaches to calculate agriculture emissions. For instance, a collaborative study led by several state agencies is focused on better understanding N_2O emissions from agricultural practices to refine the existing state inventory and inform fertilizer management practices.[5]

The discussion of each tool includes benefits and limitations which may include a discussion of tiers.

Discussion of tiers is a reference to varying degrees of complexity of the estimation methodologies provided by the IPCC, with Tier 1 methodologies serving as the most basic (ARB 2006). These tiers serve as a basis for nearly all

[4] Note that these summaries are based on the updated 2010 inventory, for which the Technical Support Document is not yet available. This document will provide detail on the inclusion of updated models for determining emissions from livestock and fertilizers. Until such data are available, the updated contribution to GHG emissions is provided here in reference to new categories, but throughout this paper and especially in discussion of available tools, reference is made to the methodologies and categories as published in the 2009 Technical Support Document. It is anticipated that some of the equations provided in the 2009 Technical Support Document will become outdated upon release of the newer version.

[5] Participating state agencies include the California Department of Food and Agriculture, California Air Resources Board, and California Energy Commission. For more information, refer to the Climate Action Team & Climate Action Portal: http://climatechange.ca.gov/climate_action_team/index.html.

GHG estimation methodologies. Generally, the higher the tier, the higher the level of accuracy and the greater the amount of data required to complete the methodology. Note that IPCC tiers are provided as guidance to national governments and that the requirements of some of the higher level tiers surpass what most local governments can provide. In many cases, local governments are able to use emissions factors developed from rigorous Tier 2 and Tier 3 estimation methodologies that have already been calculated for the State of California or the United States as a whole. In other instances when there is an absence of local data to feed tools developed for California or the country as a whole, the IPCC may provide an optimal approach through a simple Tier 1 methodology that provides the tools suited to a local government's needs.

- **Agricultural activity:** crop production

  Tool to quantify emissions: Methodologies in the California Air Resources Board (2009) Technical Support Document, California 1990–2004 GHG Emissions Inventory and 1990 Emissions Level.

  Benefits:

  - Publicly available and allows for manipulation of equations for relevance at the local level.
  - Provides a basis of appropriate Tier 1, 2, and 3 equations for California entities.
  - Provides for the capture of both direct and indirect emissions.
  - Furnishes equations for assorted crop production activities, including agricultural soil management, crop residue burning, and rice cultivation.
  - Allows for inclusion of locally relevant data, including crop type, management practices, and intensity of farming practice. Data necessary to inform these methodologies is generally accessible at the local level.

  Drawbacks:

  - Emissions vary based on crop type and local rates of fertilizer use—if this data are not locally available, the equations are not as useful.
  - Methodologies rely on a static equation and constant emissions factors that do not accurately capture the dynamics of biological processes and variations in local conditions.

Tool to quantify emissions: Process-based model tools such as DAYCENT, DNDC (Denitrification and Decomposition), or the Century ecosystem model (COMET-VR).

Benefits:

- Advanced and accurate modeling systems that calculate emissions based on biogeochemical processes, GIS data, and other sophisticated inputs. Such models have been used to inform state and national inventories.

- Allow for the use of higher tier approaches with more accurate results.

Drawbacks:

- Highly technical and largely infeasible for most local governments.

- Supplementary programs and services utilizing such tools are often cost-prohibitive.

- The USDA's publicly available Century ecosystem simulation model, COMET-VR 2.0, requires site-specific and operational inputs that may not be feasibly aggregated for a community-wide inventory.[6]

- **Agricultural activity:** livestock

  Tool to quantify emissions: Methodologies in the California Air Resources Board (2009) Technical Support Document, California 1990–2004 GHG Emissions Inventory and 1990 Emissions Level.

  Benefits:

  - Publicly available and allows for manipulation of equations for relevance at the local level.

  - Provides a Tier 2 approach to quantify all manure emissions, a Tier 2 approach for cattle enteric emissions, and a Tier 1 default IPCC approach for all other livestock.

  - Calculations account for certain state-specific factors (such as state-specific N_2O factors for manure generation), yielding higher accuracy than nationwide (see below) methodologies.

  - For livestock other than cattle, the data necessary to complete equations is usually accessible at the local level.

[6] Refer to COMET-VR 2.0 online: http://www.comet2.colostate.edu/.

Drawbacks:

- Lack of transparent emissions factors for all livestock subset groups requires additional analysis to make all equations usable at the local level.

- To complete Tier 2 manure calculations requires detailed information on livestock storage, manure handling, and rates of generation; to calculate Tier 2 cattle emissions requires details on sub-populations, including weight, age, and use. Such details may be burdensome or impossible to acquire.

Tool to quantify emissions: Methodologies in the EPA (2010) Inventory of U.S. GHG Emissions and Sinks: 1990–2008.

Benefits:

- Publicly available and allows for manipulation of equations for relevance at the local level.

- Provides a Tier 2 approach to quantify all manure emissions, a Tier 2 approach for cattle enteric emissions, and a Tier 1 default IPCC approach for all other livestock.

- Transparent provision of emission factors for all livestock subsets.

- For other livestock, the data necessary to complete equations is usually accessible at the local level.

Drawbacks:

- Loss of state-specific values that ARB methodologies may provide.

- To complete Tier 2 manure calculations requires detailed information on livestock storage, manure handling, and rates of generation; to calculate Tier 2 cattle emissions requires details on sub-populations, including weight, age, and use. Such details may be burdensome or impossible to acquire.

Tool to quantify emissions: IPCC (2006) Guidelines for National GHG Inventories, Volume 4, Agriculture, Forestry, and Other Land Use.

Benefits:

- Publicly available and allows for manipulation of equations for relevance at the local level.

- Provides simplified Tier 1 methodologies that can easily be applied and may be appropriate when detailed livestock information is not available and prohibits the use of Tier 2 methodologies provided by the California Air Resources Board or EPA (discussed above).

Drawbacks:

- Loss of locally specific values and factors that yield higher accuracy and are offered by California Air Resource Board or EPA tools.

- **Agricultural activity:** agricultural equipment

Tool to quantify emissions: OFFROAD 2007, an inventory of off-road mobile sources in California produced by the California Air Resources Board (2006).

Benefits:

- Publicly available model that provides ready-to-use data.
- Yields emissions for California-specific off-road activities that are otherwise not available.

Drawbacks:

- Data are only available at the countywide scale. For local governments, additional data are needed to make assumptions about disaggregation to the local level.

Tool to quantify emissions: University of California Cost Production Studies estimates of per acre diesel fuel use by crop. (UC Davis Agricultural and Resource Economics, 2011).

Benefits:

- Publicly available data that provides ready-to-use data. Diesel fuel use by acre per crop can be calculated for local crop types and aggregated.
- This approach depicts diesel fuel consumption and associated emissions by crop types and can inform tailored reduction measures in a climate action plan for fuel savings by crop type.
- Potential to serve as a cross-check for an approach that uses county data from OFFROAD 2007.

Drawbacks:

- This approach may require additional work and discretion on the part of the local government to determine crop acreages and relevant crops for inclusion.

- In some instances, University of California Cost Production Studies provide crop data that may not be uniformly applicable in all scenarios, including regional crop practices that vary based on tillage.

9.0 Carbon Sequestration in Natural Lands

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This section addresses the inclusion of carbon sequestration in a community baseline GHG inventory. Accounting for the carbon stored in natural lands is not necessary or appropriate for all jurisdictions. The reasons why a community might opt to inventory carbon stocks and sequestration capacity are discussed in this section followed by discussion of the available methods. Carbon sequestration is a negative value (a "sink") in an inventory, and when accounted for, it is presented as a separate line item from total emissions ("sources") in the inventory.

Carbon sequestration in the baseline inventory does not represent a credit. Rather, it is another aspect of the baseline condition, from which change is measured. Thus, baseline sequestration should not be seen as an existing offset of current emissions, but rather the base for evaluating changes over time in sequestration (positive or negative). Accordingly, it is recommended that sequestration be accounted and tracked separately from our sources of GHG emissions (combustion, industrial processes, etc.).

This is consistent with state and national GHG inventories. An associated climate action plan necessarily has the dual purpose of addressing both sources and sinks (i.e., both line items). For example, the AB 32 Scoping Plan outlines a detailed plan to reduce emissions before 2020 but also to preserve natural lands such that there is no net loss in statewide sequestration capacity. A local plan following the Scoping Plan example could have separate goals to reduce GHG emissions from combustion and industrial processes and to maintain or enhance sequestration.

9.1 CARBON SEQUESTRATION IN NATURAL LAND COVER

The term carbon sequestration is used broadly to refer to several biological, chemical, or physical processes that remove carbon dioxide (CO_2) from the atmosphere. In this section, the term sequestration refers to the biological process by which plants take up CO_2 from the atmosphere through photosynthesis and incorporate it into the structure of the plant. Within this context, two specific terms are used: (1) carbon stock and (2) carbon sequestration rate.

Carbon stock refers to the total amount of carbon stored in the existing plant material including trunks, stems, branches, leaves, fruits, roots, dead plant material, downed trees, understory, and soil organic material. Carbon stock is expressed in units of metric tons of carbon per acre (t C ac-1). Carbon stocks are not counted as GHG emissions in a baseline inventory. However, establishing a baseline of carbon stocks is necessary in order to account for the loss of carbon stocks occurring between the baseline year and future inventory years. Cutting down of trees or removal of vegetation that result from land use change (e.g., forestland to cropland or cropland to developed land) is treated as a one-time emission of GHGs, equal to a percentage of the total amount of carbon stored in the standing stock.[7] For the baseline inventory year, carbon stock can be thought of as a tank of fuel that has not yet been combusted. The unspent fuel is not a GHG emissions inventory item, but it is necessary to know the total amount of fuel in the tank in order to quantify the GHG emissions from combustion of the fuel in future years. Establishing a goal to maintain or increase carbon stocks can be an important component of a CAP.

The carbon sequestration rate is the amount of CO_2 that plant material, within a specified boundary, removes from the atmosphere within a single year. The sequestration rate is expressed in units of metric tons of carbon per acre per year (t C ac-1 yr-1) and can be included in a baseline GHG inventory or forecast as a separate line item that can be summed together with emissions to represent the "net" emissions for a jurisdiction. Different species of plants remove CO_2 from the atmosphere at rates that vary by several orders of magnitude. The rate at which plants within a single species or group take up CO_2 is also highly variable over the lifetime of the plant. The carbon sequestration rate can be thought of as the year-to-year CO_2 uptake capacity. Carbon stock and sequestration rate are directly correlated, as a loss in stock results in a loss in annual CO_2 uptake capacity. The annual sequestration rate value determined in the baseline inventory will vary greatly from community to community, dependent on the total acres covered by vegetation, the type of vegetation present, and the management practices on those lands. For all communities, the sequestration rate in the baseline GHG inventory does not represent an offset to current emissions, but serves only as an initial reference point from which future gains or losses in uptake capacity can be compared.

Land types that may contain significant carbon stocks, and that can also sequester significant amounts of CO_2 on a yearly basis, include forests, natural shrub and grasslands, wetlands, rangelands, perennial and annual croplands, and urban forests. In general, forested lands have higher carbon stocks and

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[7] The most conservative estimate would assume that 100 percent of the carbon stock is released upon conversion. However, some of the carbon stock might be transferred to another storage pool, wood products for example, and not immediately released to the atmosphere.

remove more carbon on an annual basis than the other land types. Carbon stocks are lost primarily through natural disturbance (fire, pests, and severe weather damage), harvest, or development. At the national and state levels, carbon stock loss associated with natural disturbance is much larger then stock loss due to development (ARB 2010b; EPA 2010); at the local level, land use change due to development, as outlined in a general plan, may represent a significant portion of a single year's emissions.

The most recent national and state GHG inventories account for carbon stock loss and annual sequestration, although appropriate methodologies are not available for all carbon storing land cover types. The United States and California inventories capture sources and sinks associated with forested lands, grasslands, and to a lesser degree, agricultural lands. In 2008, the CO_2 uptake associated with forests and natural lands was equivalent to 13 percent of total United States emissions, even when considering GHG emissions associated with these lands. In California, CO_2 uptake in 2008 was equivalent to approximately 1 percent of the state's annual emissions (EPA 2010; ARB 2010b).

Reporting of carbon stocks, loss of carbon stocks, or annual sequestration on the aforementioned natural land cover types is not required under either the United States Environmental Protection Agency's (EPA's) Mandatory Reporting Rule for GHGs or the California Mandatory Reporting Rule for GHGs. It is included in the most recent version of the LGOP as a Scope 3 item. It is not included in commonly used GHG inventory software such as ICLEI Clean Air and Climate Protection (CACP) software. Several protocols for assessing carbon stocks and changes in stock for forests/woodlands are available for use in the voluntary carbon market (ARB 2010c). Protocols for accounting for carbon stock in grasslands and wetlands and for the preservation of carbon stock through soil management practices on croplands are in their early stages for voluntary carbon credit markets.

The following section describes the benefits and/or motivations of including carbon sequestration in natural land cover types in a community's baseline GHG inventory. Subsequent sections discuss the available methods for estimating carbon stock and annual sequestration rate for a variety of land cover types, for inclusion in a baseline inventory.

9.2 WHY INCLUDE CARBON STOCK AND ANNUAL SEQUESTRATION IN A COMMUNITY INVENTORY?

Accounting of carbon stock and annual sequestration rate is not necessary or appropriate for all communities. As a general rule, unless a jurisdiction contains a large number of forested acres, carbon stock loss will not likely represent a significant fraction of a future year's emissions. However, a jurisdiction may still opt to include carbon stock and annual sequestration rate in a baseline GHG inventory for reasons that include, but are not limited to the following:

1) Comprehensive Accounting – Including all GHG sources and sinks within a jurisdiction, regardless of magnitude and anthropogenic or biogenic origin,

represents the most comprehensive and robust approach to GHG inventorying. Accounting for more sources and sinks in the baseline inventory allows for pursuit of a more diverse portfolio of GHG reduction measures. Certain communities may choose to prioritize thoroughness and scientific rigor in an initial inventory as a means of establishing a framework that they hope to build and expand upon as science and regulatory guidance improve. Communities may also want to establish themselves as an environmental leader by readying for a more carbon constrained future. Finally, the effort to prepare a carbon stock analysis may be small for some communities if detailed forest or natural resource inventories were already prepared for another purpose.

2) Expansive Coverage of Natural Lands – For rural communities, natural lands may comprise a majority of the acres within the jurisdictional boundary. Further, smaller populations and limited or shared jurisdictional control over services may limit options for GHG reduction strategies as compared to those available to suburban or urban communities. Thus, management of carbon stocks might necessarily be a focus of a rural community's CAP.

3) High Potential for Land Use Change – If a jurisdiction anticipates that substantial[8] areas of natural lands will be converted to land cover types of lesser or no carbon storage, then land use change may represent a significant source of GHG emissions in the jurisdiction and should be disclosed in an inventory. Once carbon stocks and business-as-usual (BAU) projections[9] of stock loss have been established, a jurisdiction can take credit for all activities that preserve or expand carbon stock beyond the BAU projection. Because emissions associated with stock loss, particularly with forested areas, can be large, preservation of stock can potentially achieve a large portion of the community's GHG reduction goals. Additionally, if abandoned lands are dedicated for afforestation projects in a jurisdiction, establishing the baseline carbon stock and sequestration rate are necessary in order for the full credit for these increases in carbon stock to be accounted for.

4) Consistency with the State's GHG Climate Action Planning Goals – California, as part of the AB32 Scoping Plan, has set forth a goal of no net loss in statewide annual carbon sequestration capacity. The responsibility for achieving this goal falls largely on areas of the state that contain significant

[8] We define "substantial" in this section as conditions where GHG emissions that result from land conversion comprise 1 percent or more of the total emissions. If the land cover type is of particular interest for other ecosystem values, for example California oaks or land cover that provides habitat for threatened and endangered species or other species of concern, a community might select a lower level at which to consider the carbon impacts of land use change.

[9] The BAU projection must be based on clearly defined land use change that is part of a certified or adopted plan such as a general plan. The land use change must be described in terms of acres of each specific land use types that will be converted to another specified land use type.

agricultural land, grassland, and forest and woodland cover. Accounting for the role that agriculture, grasslands, and forests play in a jurisdiction's GHG management is an additional demonstration of conformity with state objectives.

9.3 INVENTORY METHODS FOR LAND COVER TYPES

Consistent with IPCC guidance, the United States GHG inventory accounts for changes within and among the following broad land cover types: forestland, cropland, grassland, wetlands, and settlements (EPA 2010). For a baseline GHG inventory, a community should establish, at a minimum, the standing carbon stock in the groups listed above, and in several sub-groups as data availability allows. For example, a county may have available digital area maps and acreages for specific forest groups such as oak woodland, evergreen forests such as redwoods and Douglas fir, deciduous forests, and riparian woodlands. This data may have been compiled as part of a general plan, habitat conservation plan, biological resource study, or agricultural report.

Carbon stock includes above- and below-ground biomass (trunks, stems, foliage, fruit, and roots); dead organic matter (standing or downed dead wood, litter); and soil organic matter (living and non-living). Emissions other than those due to carbon stock loss are also associated with natural land types (e.g., fertilizer use, fire, wetland methane emissions). These emissions are discussed in other sections of this paper.

Methods developed by the IPCC (2006) for the agriculture, forestry, and other land uses sectors are generally used for inventorying carbon stocks at the national and state levels. Unique approaches for local or regional inventories are not yet standard. As with other sectors, IPCC provides a tiered approach with each successive tier requiring an increasing level of data detail. For example, a Tier 1 calculation uses broad and general default factors. Tier 2 also uses default factors, but the default factors are developed from country-specific data. A Tier 3 calculation is based on location-specific measurement data or on sophisticated models developed from a large and local dataset. For most local governments, data sufficient to allow for a Tier 3 approach is not currently available. A basic Tier 1 approach is discussed here for several natural land cover types, with the understanding that the default factors can always be substituted with locally specific factors, if available. The EPA and ARB approaches to including each land cover type in national and state inventories are also provided.

9.3.1 Forest/Woodland

United States and California Inventories

The United States national GHG inventory accounts for the net flux of GHGs from forestlands, including the following sources and sinks: changes in carbon stock due to growth, death, and disturbance; non-CO_2 emissions from forest fires; application of fertilizer on timberlands; loss of converted stock when forestland is converted to another use; and carbon stored in wood products (EPA

2010). To estimate carbon stocks and stock changes on United States forestlands, the EPA accessed an extensive database of tree characteristics, the Forest Inventory and Analysis Program (FIA), compiled by the USDA Forest Service (Frayer and Furnival 1999). A second source of data is the National Resources Inventory of the USDA Natural Resources Conservation Service (Perry, Woodall, and Schoeneberger 2005). The FIA program inventories tree stands in every state on a 2- to 5-year cycle, with an initial year of 1990 for most locations. Tree measurements are used in conjunction with the equations of Smith, Heath, and Nichols (2010) to calculate carbon stock on a per hectare basis. Measurement stands are assumed to be representative of stands of a similar tree group across the state. The United States assessment of carbon stock and carbon stock change is entirely measurement based, for both the baseline and subsequent inventory years. The United States national inventory narrowly defines forests based on width, total area, canopy coverage, and other parameters. Although it is not necessary for a community inventory to match the national definition of forestlands, a community should be clear regarding what lands are included.

The California GHG inventory follows IPCC methodology to estimate the net carbon flux for forestlands and wood products in California. The California inventory accounts for non-CO_2 emissions from these lands as well as fire-related emissions. In contrast to the United States national inventory, which uses a statistically designed network of on-the-ground sampling plots, the most recent California inventory uses satellite-based measurements and empirically developed algorithms relating carbon stock to the satellite images (CEC 2004). The California GHG inventory assessed carbon stock in five broad tree groups and one grasslands group, for three California regions. The number and specificity of tree groups is less than in the EPA inventory but will likely expand in future inventories as the satellite-based technique matures. The baseline year for California carbon stocks is 1994. Loss or gain in carbon stocks as determined from the satellite measurements are relative to the 1994 baseline level (CEC 2004).

Community Inventories

Forested areas provide many co-benefits including erosion control, habitat, improved water quality, improved air quality, localized cooling, and aesthetic value. Methods for assessing carbon stocks and sequestration in non-urban forests are different from those for urban forests. Urban forests are discussed in a separate section below. Similar to United States national and California inventories, a community will need to specify the parameters that define a “forest” (e.g., dimensions, area, or canopy coverage). Forested areas of any size should be considered for inclusion in a GHG inventory because (1) the potential emissions associated with conversion of even small numbers of acres of forested land can represent a significant portion (>20 percent) of a future year’s emissions and (2) a community may already have in place programs for preservation of forested areas, and inclusion of the carbon stocks associated with these areas supports and formalizes these goals.

Carbon Stock – As a result of the United States inventory efforts, default factors for the average carbon density by carbon pool (e.g., above-ground biomass, dead wood, litter) are available for many different tree groups on a state-by-state basis (EPA 2010). To estimate baseline carbon stocks, a community would multiply the acres covered by a specific tree group, for example "Tanoak/Laurel," by the corresponding default stock factor (t C ac-1) used in the EPA's 2010 United States GHG Inventory Report. Default carbon stock factors used in California's GHG inventory are also available, although the tree classification groups differ from those used by the EPA (CEC 2004). Tree group classifications used in mapping tree group acreages at the local level will likely not be a perfect match to the classifications used either by the EPA or the CEC. A community will have to use professional judgment in selecting an appropriate default stock factor. Default factors for even more finely resolved tree groups are also available through the National Council for Air and Stream Improvement's (2010) COLE model. The COLE model draws upon an extensive database of measurements made by the United States Forest Service, and data are available at the county level. However, use of the COLE model requires adequate knowledge of parameters such as age distributions of stands, ownership, disturbance frequency, and forest stand management practices, for which a local community may not have data. EPA and CEC default factors reflect average carbon stock conditions (including disturbance, growth, and death) and can be applied broadly without knowledge of age or management specifics. A fourth source for carbon stock factors for tree groups is the scientific literature. Studies of carbon stock for specific species at the regional level are increasingly available and should be used in lieu of national or state level default factors where possible.

Carbon Sequestration Rate – To estimate baseline carbon sequestration capacity, a community will need to multiply the acres of a specific tree group type by a default sequestration factor (t C ac-1 yr-1). The EPA does not provide default carbon sequestration rate factors at the same level of detail as for carbon stock factors. Default factors are available from the CEC (2004) and the United States CCSP (2007), although only for several broad vegetation groups. Numerous studies are available in the scientific literature and can be used where applicable.

If a jurisdiction has an extensive tree monitoring program, a Tier 3 approach could be utilized for both baseline carbon stock and sequestration rate estimates. This approach might involve either developing a model based on local tree measurement data or by using the standard equations of Smith, Heath, and Nichols (2010), on which the EPA default factors are based. The advantages of a Tier 3 approach are local specificity and a more precise accounting for growth, death, and disturbance as compared to a Tier 1 approach. As mentioned previously, data sufficient for a Tier 3 approach will likely not be available for the majority of local jurisdictions, and the use of default factors will be the best option for estimating a community's carbon stock and sequestration rate. Carbon stock and sequestration are an active area of research, and it is anticipated that inventorying approaches for local jurisdictions will expand and mature as the scientific understanding, measurement techniques, and data availability improve.

9.3.2 Grassland (and Shrubland)

United States and California Inventories

The United States inventory includes an assessment of carbon fluxes on grassland, remaining grassland, and land that is converted to grassland. The national inventory does not distinguish between grass and shrublands and uses a common approach for grasslands and agricultural lands. The EPA used the Century biogeochemical model (EPA 2010; USDA-NRCS 2000; Parton et al. 1987; Parton, Stewart, and Cole 1988; Parton et al. 1994; Metherell et al. 1993) to estimate the carbon stored in soils associated with grass and croplands. The Century model simulates soil temperature, water dynamics, and cycling of C, N, P, and S[10] through various ecosystems. Because a majority of the carbon stored in these land cover types is stored in the soils, as opposed to above-ground biomass, a much larger variability exists, even in areas covered by the same grass species. Consequently, default stock factors for soil and grass are prone to large errors. Use of a Tier 3 approach, such as the Century model which uses spatially mapped local soil characteristic data, more accurately reflect the local soil carbon content.

The California GHG inventory accounts for the net flux of GHGs from shrub and grasslands including growth, death, disturbance, and stock loss due to land use change. Satellite-based measurements, as described above for forestlands, were used to measure the change in carbon stocks on these lands relative to the baseline year, 1994 (CEC 2004).

Community Method

In general, carbon stored in grasslands is less than in forestlands but is often greater than in croplands depending on crop type and practices. A community might consider accounting for the carbon stock and sequestration rate of grasslands if: (1) anticipated conversion of agricultural acres to grasslands acres is large; (2) anticipated conversion of grasslands to urban lands is substancial; (3) the community contains many acres of grasslands, plans to adopt a suite of practices to restore or maximize carbon stock, and wishes to take credit for these practices.

Carbon Stock – To estimate baseline carbon stocks, a community would multiply the acres covered by grassland, by the corresponding default stock factor (t C ac-1) used in the EPA's 2010 United States GHG Inventory Report or by the default carbon stock factors used in California's GHG inventory (CEC 2004). Separate factors for grasslands and shrublands are available for California (CEC 2004). The EPA provides only a single factor for grasslands (EPA 2010). More finely resolved regional or species-specific factors are not yet available for grasses. Although a local jurisdiction may have available soil characteristic data, it is not likely that they will have personnel or expertise to run the Century model or equivalent as was done by the EPA. The U.S. Department of Agriculture has a tool for the Voluntary Reporting of Greenhouse Gases – Carbon Management

[10] "C, N, P and S" = Carbon, Nitrogen, Phosphorus and Sulfur.

Evaluation Tool (COMET-VR) that utilizes land use data from the Carbon Sequestration Rural Appraisal (CSRA) and calculates in real time the annual carbon flux using the Century model (described above) (USDA 2011). The COMET tool is most appropriate for calculation of soil carbon sequestration or emissions of managed agricultural lands (including grazing lands).

Carbon Sequestration Rate – To estimate baseline carbon sequestration capacity, a community will need to multiply the acres of grassland and shrubland by a default sequestration factor (t C ac-1 yr-1). A common default sequestration rate factor is available for California grasslands and shrublands from Brown et al. (CEC 2004). Default factors for grasslands and shrublands are also available from the United States Climate Change Science Program (USCCSP) (2007), but these factors are not California specific. As with other land cover types, the scientific literature may also contain factors specific to local grasslands or shrublands.

9.3.3 **Croplands**

Because the fruit, foliage, and fiber of annual row crops are harvested regularly, carbon storage in herbaceous, annual crops is temporary. These components of the plant do not represent long-term storage of biomass and cannot be included in a carbon stock assessment. Consequently, soil makes up the major component of long-term carbon storage associated with croplands. Long-term carbon storage in crops is also associated with woody, perennial crops such as fruit trees, nut trees, and vines, although this is only relevant for select communities.

In general, the amount of carbon stored and taken up each year by croplands is much less than on forestlands and likely less than on grasslands. Additionally, large emissions sources such as fertilizer and equipment might also be associated with croplands, and the sequestration capacity of these lands is typically of much smaller magnitude than the emissions. Only select rural communities will have sufficient acreage of croplands for the non-tailpipe-related agricultural emissions to be relevant in comparison to other source sectors. A community may wish to quantify carbon stocks on cropland under the following scenarios: (1) Crops cover substantial[11] acreages of the jurisdiction and the jurisdiction would like to take credit for soil management practices that increase the carbon stock of the cropland soils or, at a minimum, prevent further loss of soil carbon. (2) The jurisdiction is evaluating the impacts associated with loss or gain of different land use types in future years; for example, loss of cropland to more urbanized land as outlined in a general plan or afforestation projects on abandoned cropland. (3) If rural communities do not have many options for GHG

[11] We define substantial as conditions where GHG emissions that result from land conversion comprise 1 percent or more of the total emissions. If the land cover type is of particular interest for other ecosystem values, for example California oaks or land cover that provides habitat for threatened and endangered species or other species of concern, a community might select a lower level at which to consider the carbon impacts of land use change.

reductions in other sectors, land use conversion may represent a critical piece of the community's long-term sustainability plan.

United States and California Inventories

The sequestration rate and carbon stocks of the above-ground biomass of perennial and annual crops are not included in national and international inventories (EPA 2010; IPCC 2006). Carbon stored in agricultural and rangeland soils is included in the United States national inventory. Seventeen percent of the North American carbon stock is present in soils associated with agriculture and grazing lands (USCCSP 2007). The EPA used the Century model for estimating the carbon stock in soils associated with croplands (as described above for grasslands).

The California inventory does not account for carbon stock of perennial or annual crops, citing a lack of appropriate data and a need to adapt methodologies to the wide range of California crops (ARB 2009). Unlike the national GHG inventory (EPA 2010), the California inventory does not yet account for changes in soil organic carbon (SOC) on agricultural lands, despite the fact that 11 percent of California land is dedicated to agriculture. Technical support documents indicate that ARB staff is assessing available methods and data availability and hopes to include carbon stocks associated with cropland soils in subsequent inventories. State-level estimates, if built on extensive measurements throughout California, could be a source of stock factors and stock change factors for community inventories within California.

Community Method

Methodology options for assessing the carbon stock and sequestration rate of croplands at the community level are limited. The EPA's Tier 3 methods cannot easily be adapted to a community-level inventory, and default factors appropriate for California are not yet available. Consequently, the method described by the IPCC (2006) is the best option for communities that wish to include carbon sequestration in croplands. Although lacking in local specificity, the IPCC method is typically the best option given that it is straightforward and has benefited from extensive peer review from sequestration experts.

The IPCC recommends accounting for carbon stock and carbon stock changes associated with cropland that remains cropland and cropland that has been recently converted from another use. The change in carbon stocks on cropland that remains cropland is due to (1) growth in the plants or addition of organic material to the soils (positive [+] change) or (2) removal of material by harvesting or disturbance or loss of organic soil material (negative [-] change). IPCC's (2006) Tier 1 method assumes that deadwood, litter, and below-ground carbon storage is zero in non-forest systems. Carbon stored in the biomass of annual, row crops can also be neglected. Carbon stocks in the plant biomass of perennial crops (orchards and vines) and carbon stocks in all cropland soils should be accounted for, although biomass in perennial crops will only be relevant for select communities. The IPCC (2006) provides default initial stock (metric tons C ha-1), growth factors (metric tons C ha-1 yr-1), and loss rates (metric tons C yr-1) for four generalized climate zones.

For most croplands, soil carbon will represent the largest pool of stored carbon. The amount of this carbon can change substantially due to management practices. The IPCC Tier 1 method is based on several soil groups further broken into several general climate zones. For each inventory year, a reference carbon stock is multiplied by a default stock change factor. These dimensionless stock change factors can be associated with a change in cropland management practice, the cropland land use (e.g., change from annual crops to rice paddies), or organic matter input. The default carbon stock change factors are for a period of 20 years. A community need only provide the number of acres under a particular management type. When country, state, or regional soil organic carbon (SOC) reference values or stock change values are available, they should be used in lieu of IPCC's more general factors. As noted above, the USDA COMET model may be an appropriate tool for estimating soil carbon sequestration or emissions in agricultural cropland areas.

As described below, when agricultural practices result in the draining of wetlands, there can be CO_2 emissions due to subsequent soil subsidence and peat oxidation.

9.3.4 Wetlands

Wetlands can sequester substantial amounts of carbon in vegetation and soil under favorable conditions but can also be a source of methane (CH_4). However, because CH_4 is a far more potent GHG on a pound-for-pound basis than CO_2, in freshwater wetlands CH_4 production may overwhelm the benefits obtained from carbon sequestration (USCCSP 2007). Nitrogen cycling in wetlands can result in uptake and release of nitrous oxide (N_2O) but is still at an early stage of research to support site-specific quantification. The carbon sequestered in wetlands can be released when wetlands are drained resulting in peat oxidation and soil subsidence, which can be a substantial CO_2 source.

As described below, carbon sequestration and methane production in wetlands can be quantified on a rough basis using literature values and prior research. Rarely will such research be specific to wetlands found within a particular community baseline GHG inventory area or provide comprehensive coverage of the different types of wetlands that might be found within the inventory area. Methodologies noted in the literature could be adapted for a local community GHG inventory concerning CO_2 and CH_4; however, it should be noted that these studies are specific to the wetlands studied, and wetland conditions vary significantly. Quantification of N_2O changes in wetlands is still a subject of research and thus may not be feasible in the near term for community inventory purposes (but may become feasible as research progresses). When projects drain wetlands, there are methods available to roughly estimate soil subsidence and peat oxidation emissions. Any quantification of wetland sequestration or emissions should note the underlying certainty in any studies relied upon for the purposes of establishing a rough inventory and inform the users of inventories that quantification is not currently a precise science.

If a local community has substantial wetlands within its inventory area and there is potential for a change in land cover over time due to development or agricultural practices, then quantification of the baseline carbon sequestration and/or methane emissions associated with wetlands can be useful in characterizing the changes in net emissions that might result from different patterns of development or drainage practices. If a local community's wetland areas are already protected and no land use change is expected or only limited conversion, then a project-specific inventory may be more appropriate than a community-level inventory for those projects that would convert wetlands to other uses. If a local community is considering the effects of preserving additional areas of wetlands, then the effects of avoided conversion of those wetlands on net GHG emissions (relative to CO_2 and CH_4) could be identified through a rough inventory.

Greenhouse Gases and Wetlands

Analysis of GHG fluxes from wetlands has received a considerable amount of study in the last two decades. However, given that carbon cycling, CH_4 production, and nitrogen cycling vary substantially in different wetlands at different times of the year and because of highly site-specific physical, chemical, and biological characteristics, there is a substantial amount of uncertainty in estimating potential changes in GHG emissions and sequestration in such dynamic environments. The values derived from current research and literature sources for carbon sequestration and CH_4 production can be used illustratively, but given the level of uncertainty in the underlying supporting research, the values derived below should not be considered precise. However, the evidence does allow for a rough baseline quantification of carbon sequestration and CH_4 production.

Water salinity plays a major role in wetland carbon cycling, CH_4 production, and nitrogen cycling. Wetlands with higher salinity tend to sequester more carbon and emit less CH_4 than wetlands with lower salinity. The concentration of salts (salinity) in ocean water is approximately 33 parts sea salt per thousand parts of water (ppt, or grams per liter [g/L]) (psu), while the salinity of fresh water is near zero (USGS 2007). In estuarine environments, salinity varies depending on the tide, season, and the influence of dam releases and water withdrawals.

United States and California Inventories

The United States national GHG inventory includes emissions from managed peatlands (peatlands cleared and drained for production of peat), but does not include wetland sequestration per se (EPA 2010). The California GHG inventory does not currently account for carbon storage and sequestration capacity of wetlands (ARB 2010a).

The IPCC (2006) national inventory protocol describes methods to estimate GHG emissions from managed wetlands including peatlands cleared and drained for the production of peat and reservoirs/impoundments. The IPCC guidance does not include methodologies to estimate emissions from unmanaged wetlands.

Quantifying Carbon Dioxide Sequestration for Community Inventories

Through the process of photosynthesis, plants take up CO_2 from the atmosphere. Along with water, nutrients, and minerals, CO_2 is incorporated into the living tissue of plants to allow for development, growth, and reproduction of the plant. This is the process through which carbon is sequestered into plants and stored as carbon stock. Some portion of the carbon removed from the atmosphere is returned to the atmosphere through several processes, including respiration, decay, and disturbance. CO_2 emissions from respiration can be as much as 25 percent of "gross primary productivity," or the net rate at which plants fix and store carbon as energy.

Like other plant matter, vegetation in wetlands can capture carbon by taking in atmospheric CO_2, converting it to plant mass through photosynthesis, and then sequestering the carbon in the inundated soils that form as plant matter decomposes. Pilot studies undertaken in tule marshes in a part of the San Joaquin-Sacramento Delta have found a very high primary productivity (carbon fixation) and sequestration (C-immobilization, or long-term "storage") of below-ground carbon that would remain stable if continuously inundated. When coupled with the CO_2 emissions reduction associated with preservation of historic peat deposits, as much as 25 metric tons of carbon per acre per year may be sequestered by freshwater marshes in the Delta according to indications in these studies. The results vary widely depending on many factors such as temperature, inundation regime, and plant species (USGS 2007; USGS 2008).

Saline and freshwater wetlands can represent net sinks of CO_2. Because tidal marshes are extremely productive, they are one of the most effective environments for carbon sequestration (Chmura et al. 2003; Trulio, Callaway, and Crooks 2007; Mitsch and Gosselink 2000). Recent research estimates that carbon sequestration potential of saline marshes can range between 0.8 and 5.7 metric tons per acre per year (54 g/m^2 and 385 g/m^2/year) (USCCSP 2007; Trulio, Callaway, and Crooks 2007). Freshwater mineral soil wetlands also sequester CO_2. The first State of the Carbon Cycle Report (SOCCR) estimates the sequestration potential of freshwater wetlands to be 0.3 metric ton per acre per year (21 g/m^2/year), but it can range widely (USCCSP 2007). These values represent the net long-term storage of carbon in the system, after accounting for losses attributable to respiration. Research on sequestration in brackish wetlands is limited. Because the salinity in these environments is lower than in a salt marsh, but higher than in a freshwater marsh, it can be theorized that the carbon sequestration potential of brackish wetlands likely would fall somewhere between the range of a freshwater wetland and the range of a saltwater wetland.

Quantifying Methane Emissions for Community Inventories

While freshwater, saltwater, and brackish wetlands sequester amounts of CO_2, they also produce CH_4 through anaerobic decomposition of biomass, and CH_4 is a more potent GHG than CO_2. Approximately 76 percent of global naturally produced CH_4 comes from wetlands (EPA 2009a). CH_4 is naturally produced and emitted from wetlands by methane-producing bacteria that need anoxic conditions combined with labile organic matter.

Saline marshes, in general, often are thought to release less CH_4 than freshwater environments, but the absolute differences depend on site characteristics (Trulio, Callaway, and Crooks 2007; USCCSP 2007). Sulfates can suppress CH_4 production from CO_2 respiration (Chmura et al. 2003). Research suggests that tidal brackish wetlands can release 6.4 g/m1 to 22.4 g/m^2 of CH_4 per year, or 0.5 to 1.9 metric tons of CO_2e per acre per year (USCCSP 2007; Bartlett et al. 1987), while freshwater wetlands can release 18.7 to 91.4 g/m^2 of CH_4, or 1.6 to 7.8 metric tons of CO_2e per acre per year (USCCSP 2007).

CH_4 flux out of the marsh is controlled by numerous environmental factors, one of which is evapotranspiration. Evapotranspiration is the transport of water from soil or surfaces (evaporation) and from the open stomata of plants (transpiration) to the atmosphere.

Research on Wetlands and Nitrous Oxide Emissions

Natural emissions of N_2O result primarily from bacterial breakdown of nitrogen in soils and in the earth's oceans. Globally, tropical soils (primarily wet forest soils, but also savannas and agricultural systems) are estimated to produce 6.3 million tons (MTons) of N_2O annually, and oceans are thought to add around 4.7 MTons of N_2O annually to the atmosphere (IPCC 2007; EPA 2009b). Together, these two sources account for more than 70 percent of the natural sources. Similar microbial processes in temperate-region soils produce smaller quantities of N_2O. In some ocean areas, large areas of surface water can become oxygen-depleted, allowing active denitrification in open water. Large amounts of oceanic N_2O also can arise from denitrification in marine sediments, particularly in nutrient-rich areas such as those of estuaries.

All wetlands produce N_2O through nitrification and denitrification processes, which are the generation and diagenesis of nitrate (NO_3), respectively. However, research on N_2O production rates from wetlands is limited. In addition, the research that has been conducted has an extremely high degree of uncertainty because of the compound's complex chemistry and unknown strength of nitrifying and denitrifying processes in certain environments. As such, depending on biogeochemical characteristics of a wetland (e.g., labile carbon availability, nitrate availability, redox potential), N_2O production could vary significantly. Given the current research limitations, N_2O production quantification on a landscape level is highly uncertain.

It is important in studies of N_2O emissions to account for the various interactions between natural processes and human influences in the nitrogen cycle, because human impacts can significantly enhance the natural processes that lead to N_2O formation. For example, the nitrogen nutrient loading in water bodies attributable to fertilization and runoff to streams can enhance N_2O emissions from these natural sources, including wetlands. Human-related ammonia emissions also have been shown to cause N_2O emissions in the atmosphere through ammonia oxidation.

Quantifying Emissions associated with Peat Soil Subsidence and Oxidation due to Drained Wetlands

Globally, peat oxidation accounts for 2–3 gigatons (GTons) per year of CO_2 equivalents (one tenth of fossil-fuel emissions) with rates approximately tenfold greater in temperate and tropical soils than in boreal soils (IPCC 2007). In addition, global emissions of CO_2 from drained peatlands amounted to 1.4 GTons in 2008 (Wetlands International 2009).

Subsidence of organic soil in drained wetlands can produce CO_2 through microbial oxidation of the carbon in the organic component of the soil. Subsidence also can produce CH_4 and N_2O. According to multiple studies, subsidence is caused primarily by microbial oxidation of soil organic carbon, which produces emissions of CO_2. Subsidence also can occur through anaerobic decomposition; consolidation; shrinkage; wind erosion; gas, water, and oil withdrawal; wetting and drying of the soil; and dissolution of organic matter (Deverel and Leighton 2008). Peat soil lands in the San Joaquin-Sacramento Delta region are subsiding significantly, with an estimated subsidence rate between 0.2 and 2.5 inches per year that results primarily from the oxidation of the peat soil (Deverel and Rojstaczer 1996). Much subsidence and peat soil oxidation in the Delta occur from agricultural practices on drained wetlands. In addition, oxidation and subsidence rates depend on soil organic content, carbon content, temperature, and other factors. Understanding these characteristics improves the ability to predict net effects of hydrologic changes on peat oxidation.

A number of studies of peat soil subsidence and carbon loss in the Sacramento/San Joaquin Valley region show that carbon losses range from 0.05 gram/cm^2 to 0.15 gram/cm^2 per year (Deverel and Leighton 2008; Volk 1973; Deverel and Rojstaczer 1996).

In areas with substantial drained peatlands, quantification of ongoing emissions due to soil subsidence and peat oxidation may be warranted.

9.3.5 Urban Forests

Urban forests provide a large array of environmental and public health benefits to a community such as (Brack 2002):

- Amelioration of urban climate extremes
- Store and sequester carbon
- Energy savings due to shade
- Reduce noise pollution
- Improve water and air quality

- Lower temperatures of parked cars
- Aesthetic contribution
- Improve property values
- Architectural enhancement of buildings
- Increased privacy
- Control urban glare and reflection
- Contribute to human health and relaxation, reduce stress, increase walkability
- Attract birds and other wildlife

For these reasons, many communities already have active urban forestry programs and are eager to seek credit for GHG-related benefits also associated with these forests. ICLEI's CAPPA tool already includes the capability to account for energy and other air quality related benefits associated with shade trees; however, the carbon stock and sequestration capacity benefits are not yet accounted for. Several literature studies have examined the carbon benefits of urban forests (Brack 2002; Mc Pherson at al. 1994; Nowak 1993).

United States and California Inventories

The United States national GHG inventory does not account for carbon stock and sequestration capacity in the nation's urban forests, although it is estimated that urban forests in the United States contain 350 to 750 million tons of carbon (Nowak 1993). The California GHG inventory does not currently account for carbon storage and sequestration capacity of urban forests.

Community Method

As mentioned above, several scientific studies have examined the carbon stock and sequestration rates of urban forests. Methodologies noted in these studies could be adapted for a local community; however, it should be noted that these studies involve extensive and sustained measurements of tree morphological characteristics. Overall, the approaches use empirically derived relationships of tree characteristics, such as canopy and diameter at breast height, to carbon content. If communities are in the early stages of establishing an urban forest program, allocation of resources for measurement and monitoring should be considered such that carbon benefits can be accounted for. This will be of particular interest to communities that wish to take credit for afforestation projects and plan for a significant fraction of tree planting to happen in urban or suburban areas.

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10.0 Next Steps

HONEY WALTERS – ASCENT ENVIRONMENTAL, INC.

MICHAEL HENDRIX – ATKINS/PBS&J

The magnitude of GHG emissions between similar-sized cities can vary substantially depending on what GHG sectors are included and the methodology used to calculate GHG emissions. The AEP Climate Change Committee has provided this white paper as a discussion on how the methodology for conducting a community-wide GHG emissions inventory can be standardized. This white paper takes a comprehensive look at the types of emission sources that local jurisdictions could include in the development of community-wide GHG inventories from mobile sources to stationary, energy, water, solid waste, agriculture, and many others. Quantification methods are also presented alongside discussions of such key topics as geographic/jurisdictional issues and the inclusion of carbon sequestration of natural lands. The preparation of a baseline emissions inventory is arguably the most important part of developing a plan to reduce GHG emissions. Baseline community-wide GHG inventories are important because they become the basis for forecasting future emissions growth within the community. Baseline community-wide GHG inventories are also an important foundation in developing a plan for the reduction of GHG emissions because what is included in that baseline inventory dictates what emission sources are reviewed for reduction potential in the plan. As such, baseline community-wide GHG inventories serve as the foundation for emissions tracking and monitoring, and provide essential information about the type and relative magnitude of emissions for a given geographic area.

However, the completion of an emissions inventory is only the first step in a multi-step process. A complete plan to reduce GHGs should also include projecting future emissions, performing a gap analysis,[12] identifying a target, developing strategies with quantified reductions, and subsequent monitoring. Like with the development of a baseline emissions inventory, specific issues arise when performing these steps; from what indicators to use for accurately forecasting emissions (e.g., population) to how to determine the amount of reductions accomplished through state legislative actions (e.g., Low Carbon Fuel

[12] Gap analysis is reviewing the differential between the future inventory of emissions with GHG reductions that are anticipated to occur due to technological changes and state measures and the reduction target that the local agency is trying to achieve. That differential can be called the gap. Filling the gap with additional locally enforced reduction measures becomes the focus of a plan for the reduction of GHG emissions.

Standard, Pavley). AEP plans to tackle these issues and many more in subsequent white papers, so stay tuned!

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Abbreviations

AB 32	Assembly Bill 32 – Global Warming Solutions Act
AEP	Association of Environmental Professionals
APS	Alternative Planning Strategy
ARB	California Air Resources Board
BAU	business as usual
BOD	biochemical oxygen demand
Btu	British thermal unit
CACP	Clean Air Climate Protection
Caltrans	California Department of Transportation
CAP	climate action plan
CAPPA	Climate and Air Pollution Planning Assistant
CCAR	California Climate Action Registry
CCSP	United States Climate Change Science Program
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CPUC	California Public Utilities Commission
DNDC	denitrification and decomposition
ECDMS	California Energy Consumption Data Management System
EERE	Energy Efficiency and Renewable Energy
eGrid	Emissions and Generation Resource Integrated Database
EIA	Energy Information Administration
EPA	United States Environmental Protection Agency
FAO	Food and Agricultural Organization of the United Nations

GHG	greenhouse gas
GTons	Gigatons
HFCs	hydrofluorocarbons
HPMS	Highway Pavement Monitoring System
ICLEI	International Council for Local Governments for Sustainability
IPCC	Intergovernmental Panel on Climate Change
kWh/MG	kilowatt hour per million gallons
LFGTE	landfill gas-to-energy
LGOP	Local Government Operations Protocol
LMOP	Landfill Methane Outreach Program
MMBtu	million metric British thermal units
MMT	million metric tons
$MMTCO_2e$	million metric tons of carbon dioxide equivalents
$MMTCO_2e$	million metric tons of carbon dioxide equivalents
MPO	metropolitan planning organization
MSW	municipal solid waste
MT	metric tons
$MTCO_2$	metric tons carbon dioxide
MTons	million tons
MW	megawatt
NAICS	Northern American Industry Classification System
NO_3	nitrate
NRDC	Natural Resources Defense Council
N_2O	nitrogen oxide
ODS	ozone-depleting substances
PFCs	perfluorocarbons
RTAC	Regional Targets Advisory Committee
SB 375	Senate Bill 375

SCS Sustainable Communities Strategy

SOC soil organic carbon

t C ac-1 metric tons of carbon per acre

t C ac-1 yr-1 metric tons of carbon per acre per year

USDA United States Department of Agriculture

USGS United States Geological Survey

VHT vehicle hours traveled

VMT vehicle miles traveled

WARM Waste Reduction Model

WIP waste in place

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