



## **Staff Report**

### **California 1990 Greenhouse Gas Emissions Level and 2020 Emissions Limit**

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## EXECUTIVE SUMMARY

The Global Warming Solutions Act of 2006 (the Act or AB 32, Nunez, Statutes of 2006, chapter 488) requires the Air Resources Board (ARB or Board) to determine the statewide greenhouse gas emissions level in 1990 and to approve a statewide greenhouse gas emissions limit, equal to that level, to be achieved by 2020. ARB staff is recommending that the Board approve 427 million metric tonnes of carbon dioxide equivalent (MMTCO<sub>2e</sub>) as the total statewide aggregated greenhouse gas 1990 emissions level and 2020 emissions limit.

This staff report discusses the development of the 1990 statewide emissions level and provides a summary of the key emissions sources, the methodologies used to calculate the emissions, and the sources of data. More detailed documentation is provided on-line at <http://www.arb.ca.gov/cc/ccei/emsinv/emsinv.htm>.

The Act establishes a comprehensive program to reduce greenhouse gases by 2020 and identifies several major requirements that ARB is or will be implementing:

- Adopt and implement a list of discrete and early action greenhouse gas reduction measures (done);
- Approve a statewide 1990 emissions level that becomes California's statewide 2020 emissions limit (due January 2008);
- Adopt mandatory greenhouse gas reporting rules for significant greenhouse gas sources (due January 2008);
- Adopt a Scoping Plan for greenhouse gas emission reductions to achieve the 1990 emissions level by 2020 (due January 2009); and,
- Adopt emission regulations to achieve the maximum technologically feasible and cost-effective reductions.

In January 2007, Assembly Bill 1803 transferred responsibility for developing and maintaining the State's greenhouse gas inventory from the California Energy Commission (CEC) to ARB. Using the CEC greenhouse gas inventory as a starting point, ARB staff determined the State's 1990 greenhouse gas emissions level by conducting a comprehensive review of all greenhouse gas emitting sectors. The seven sectors are: Transportation, Electricity Generation, Industrial, Residential, Agriculture, Commercial, and Forestry.

ARB staff gathered data from State and federal agencies, international organizations, and California industries to estimate the total statewide 1990 greenhouse gas emissions level. California facility-specific information for 1990 emissions was used where available.

Upon approval by the Board, the 1990 emissions level becomes the 2020 emissions limit, which represents an aggregated emissions limit for California.

For purposes of the AB 32 Scoping Plan, it serves as the target to be achieved by 2020.

For purposes of Scoping Plan development, ARB staff has estimated the State's greenhouse gas emissions in 2020 without the implementation of additional greenhouse gas reduction strategies. This 2020 "business-as-usual" estimate is approximately 600 MMTCO<sub>2</sub>e and is based on economic forecasts that use growth factors to project emissions. The difference between the 2020 business-as-usual estimate and the 1990 emissions level is California's emission reduction goal. The 2020 business-as-usual forecast will be further refined as the Scoping Plan is developed.

The 2020 emissions limit, as defined by the 1990 emissions level, remains in effect until amended by the Board. If additional information becomes available that would significantly alter the total emissions for 1990, staff will bring a revised 1990 emissions level back to the Board for consideration.

## **I. STAFF RECOMMENDATION**

The Global Warming Solutions Act of 2006 (AB 32, Nunez, Statutes of 2006, chapter 288) requires the Air Resources Board (ARB or Board) to approve by January 1, 2008, the statewide greenhouse gas emissions limit for 2020 based on the 1990 emissions level. Over the past year, ARB staff has undertaken a comprehensive review and update of the 1990 emissions estimates using the best available scientific, technical, and economic information. These emissions estimates were developed through an extensive public process, including technical workshops.

ARB staff has estimated the statewide 1990 emissions level to be 427 MMTCO<sub>2</sub>e and is recommending the Board approve this level as the statewide 1990 greenhouse gas emissions level to be achieved by 2020. Once adopted, the 2020 emissions limit will remain in effect until amended. If new information becomes available that would significantly alter total emissions for 1990, staff will bring a revised 1990 emissions level to the Board for consideration.

## **II. BACKGROUND**

The Global Warming Solutions Act of 2006 (the Act) establishes a comprehensive program to realize real, quantifiable, and cost-effective reductions in greenhouse gas emissions by 2020. The Act directs ARB to:

- Adopt and implement a list of discrete and early action greenhouse gas reduction measures (done);
- Approve a statewide 1990 emissions level that becomes California's statewide 2020 emissions limit (due January 2008);
- Adopt mandatory greenhouse gas reporting rules for significant greenhouse gas sources (due January 2008);
- Adopt a Scoping Plan for greenhouse gas emission reductions to achieve the 1990 emissions level by 2020 (due January 2009); and,
- Adopt emission regulations to achieve the maximum technologically feasible and cost-effective reductions.

This staff report discusses the development of the 1990 emissions level that sets the statewide greenhouse gas emissions limit for 2020. It is an aggregated statewide limit that provides the target level that must be achieved through regulatory measures, market mechanisms or other actions that will be contained in the Scoping Plan. The Scoping Plan is scheduled to be taken to the Board in late 2008.

### **III. OVERVIEW OF THE DEVELOPMENT OF THE 1990 EMISSIONS LEVEL**

The statewide 1990 greenhouse gas emissions level of 427 MMTCO<sub>2</sub>e is based on the net amount of greenhouse gases emitted to and removed from the air. The gross statewide emissions in 1990 were 433 MMTCO<sub>2</sub>e with forestry sinks offsetting approximately 7 MMTCO<sub>2</sub>e, resulting in net emissions to the atmosphere of approximately 427 MMTCO<sub>2</sub>e (see Table 2). The 1990 emissions level is a compilation or inventory of the amount and type of greenhouse gases emitted by different sources on an annual basis. In addition to setting California's 1990 emissions level and 2020 emissions limit, ARB now has overall responsibility for the State's annual greenhouse gas emissions inventory.

In September 2000, the Legislature passed Senate Bill 1771. It required the California Energy Commission (CEC) to determine the statewide greenhouse gas emissions inventory by January 2002 and update it every five years thereafter. In 2006, Assembly Bill 1803 transferred responsibility for updating the statewide greenhouse gas inventory to ARB commencing January 1, 2007.

In January 2007, ARB staff began an intensive review of the CEC's California greenhouse gas emissions inventory for the years 1990 to 2004, with particular focus on the 1990 emissions estimates. Staff has updated and evaluated the 1990 emissions inventory and ensured its consistency with national and international guidelines for greenhouse gas inventories.

The remainder of this section summarizes the key components of the 1990 emissions inventory. A supplemental document titled "California Greenhouse Gas Emission Inventory, 1990 to 2004" will discuss emissions estimates for 1990 to 2004.

#### **A. Which gases are included?**

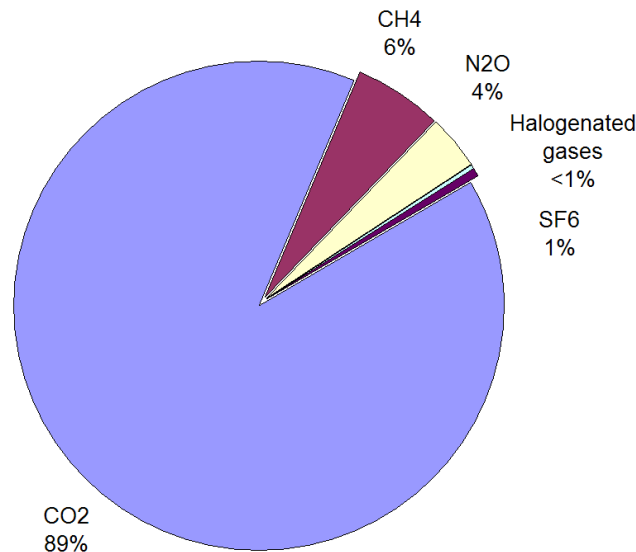
Pursuant to the Act, the inventory includes the following Kyoto greenhouse gases: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), sulfur hexafluoride (SF<sub>6</sub>), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs). These greenhouse gases are referenced in the international guidance on the development of national inventories provided by the Intergovernmental Panel on Climate Change (IPCC), the authoritative scientific body on climate change.

The greenhouse gases included in the inventory absorb infrared radiation, directly impacting the atmosphere's ability to trap heat. Three of these greenhouse gases, CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O, may be emitted naturally or through human activities (e.g., the combustion of fossil fuels). The other three, SF<sub>6</sub>, HFCs, and PFCs, are synthetically produced for industrial purposes.



Almost 90 percent of the total greenhouse gas emissions in the 1990 inventory were in the form of CO<sub>2</sub>, as shown in Figure 1. Carbon dioxide accounted for 389 MMTCO<sub>2</sub>e of the total statewide gross greenhouse gas emissions of 433 MMTCO<sub>2</sub>e. Gross greenhouse gas emissions estimates only include the greenhouse gases emitted to the atmosphere, and exclude removals from the atmosphere. The remaining emissions were comprised of CH<sub>4</sub>, N<sub>2</sub>O, halogenated gases (including substitutes for ozone-depleting substances (ODS)), and SF<sub>6</sub>. Methane and N<sub>2</sub>O emissions totaled 24.9 MMTCO<sub>2</sub>e and 16.1 MMTCO<sub>2</sub>e, respectively. Emissions of SF<sub>6</sub> were 2.6 MMTCO<sub>2</sub>e. Halogenated gas emissions were minimal in 1990, estimated at approximately 0.6 MMTCO<sub>2</sub>e. Many of the halogenated gases are substitutes for ODS, which are being phased out under the Montreal Protocol on Substances that Deplete the Ozone Layer. Because the Montreal Protocol came into force only shortly beforehand in 1989, emissions of ODS substitutes were relatively small in 1990.

**Figure 1. 1990 Gross Emissions by Greenhouse Gas**



**B. Which global warming potentials are used?**

Each greenhouse gas has a different capacity to trap heat in the atmosphere, with some more effective at trapping heat than others. To account for this difference, IPCC developed the metric of a global warming potential (GWP) for each gas. The GWP allows comparison of the global warming influence of different greenhouse gases relative to CO<sub>2</sub>. Total greenhouse gases can then be expressed as CO<sub>2</sub> equivalents or CO<sub>2</sub>e.

In developing the greenhouse gas inventory for 1990, staff used the GWPs in IPCC's Second Assessment Report for consistency with national and international inventories. All international inventories, including the U.S. inventory, use GWPs from the Second Assessment Report per international

consensus (USEPA 2007). The GWPs used to estimate the 1990 emissions level are referenced in Table 1.

**Table 1. Global Warming Potentials (GWPs)  
IPCC Second Assessment Report (SAR)**

Greenhouse Gas	SAR GWP (100 years)
CO2	1
CH4	21
N2O	310
HFC-23	11,700
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-32	650
CF4	6,500
C2F6	9,200
SF6	23,900

Source: IPCC Second Assessment Report

Since GWPs are indexed to CO<sub>2</sub>, they allow for the conversion of different greenhouse gas emissions into the same emission unit, carbon dioxide equivalents (CO<sub>2</sub>e). Carbon dioxide equivalents represent the total impact (radiative forcing) of greenhouse gases in the atmosphere, making it possible to determine the climate change impact of one greenhouse gas versus another. The 1990 greenhouse gas emissions level is expressed in total CO<sub>2</sub>e. It is calculated as follows:

$$\text{CO}_2 \text{ Equivalent in million metric tonnes} = (\text{Million metric tonnes of a GHG emitted}) * (\text{GWP of the GHG})$$

**C. What types of emissions are included?**

The inventory includes emissions of the six greenhouse gases from all known anthropogenic and biogenic sources within California, as well as emissions from imported electricity and transmission and distribution line losses as required by the Act. The total emissions for any given year is the net sum expressed in CO<sub>2</sub>e emissions to the atmosphere (“positive” emissions) and removals from the atmosphere (“negative” emissions) due to sequestration of carbon by forests and rangelands within the State’s boundaries.

Anthropogenic emissions are emissions resulting directly from human activities, such as the combustion of fuels in transportation and industrial activities, as well as process emissions from industrial activities. They are also the result of human influence on natural processes and processes subject to human control. The burning of fossil fuels is the largest single source of anthropogenic greenhouse gas emissions in California. Because increases in anthropogenic greenhouse

gas emissions have substantially increased atmospheric greenhouse gas concentrations, anthropogenic emissions are the primary focus of the inventory (IPCC 2007).

Biogenic emissions are emitted as part of the natural biogeochemical cycling of carbon. These emissions include, for example, CO<sub>2</sub> released as plants decompose or burn. Natural processes, such as photosynthesis, remove CO<sub>2</sub> from the atmosphere and may store carbon in plant tissues for long periods of time (sequestration). In the 1990 inventory, forest-related biogenic emissions and removals are tracked in the Forestry sector. The difference between the biogenic CO<sub>2</sub> emissions to and removals from the atmosphere, known as the net flow of atmospheric CO<sub>2</sub>, indicates whether Forestry is net source or sink of CO<sub>2</sub>. Biogenic CO<sub>2</sub> flux estimates, or the net flow of atmospheric CO<sub>2</sub>, are detailed in Appendix B.

#### **D. What key sectors and categories were reviewed and updated?**

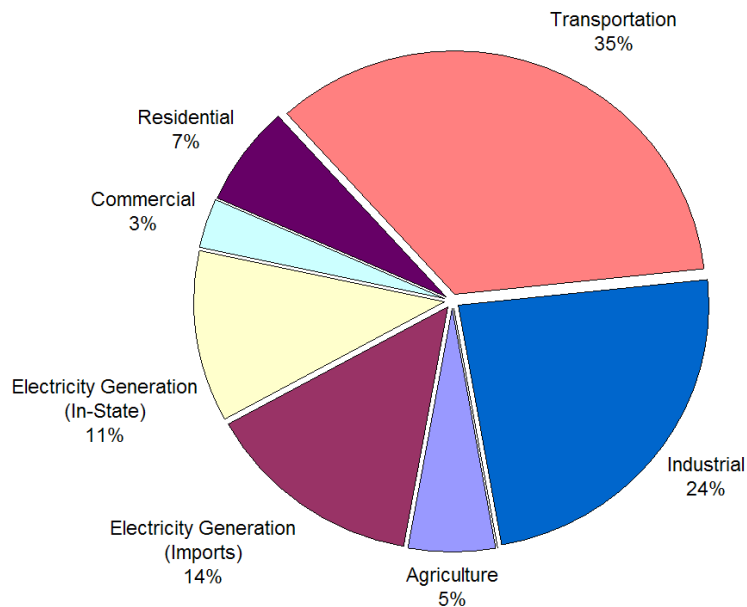
The 1990 emissions level is the sum total of emissions and removals from all sectors and categories in the inventory. The inventory is divided into seven broad sectors defined by areas of economic activity within California. These sectors include: Agriculture; Commercial; Electricity Generation; Forestry; Industrial; Residential; and, Transportation. Each sector contains different types of emission sources called categories. For example, the Industrial sector contains the cement, landfills, and petroleum refining categories. Roughly 85 percent of California's greenhouse gas emissions in 1990 can be found in three sectors: Electricity Generation, Industrial and Transportation.

Staff primarily focused their review and update efforts on five sectors (Agriculture, Electricity Generation, Forestry, Industrial, and Transportation) and three categories within the Industrial sector (cement, landfills, and petroleum refining). Emissions from all seven sectors are listed below in Table 2 and Figure 2. A detailed discussion of the review of the seven sectors is described in Section IV.

**Table 2. Greenhouse Gas Emissions by Sector in 1990<sup>1</sup>  
(433 MMTCO<sub>2</sub>e Gross Emissions)**

Sector	Total Emissions (MMTCO <sub>2</sub> e)	Percent of Total Gross Emissions
<b>Agriculture</b>	<b>23.4</b>	<b>5%</b>
<b>Commercial</b>	<b>14.4</b>	<b>3%</b>
<b>Electricity Generation</b>	<b>110.6</b>	<b>26%</b>
<i>In-State</i>	<i>49.0</i>	<i>11%</i>
<i>Imports</i>	<i>61.6</i>	<i>14%</i>
<b>Forestry (excluding sinks)</b>	<b>0.2</b>	<b>&lt;1%</b>
<b>Industrial</b>	<b>103.0</b>	<b>24%</b>
<i>Cement</i>	<i>8.1</i>	<i>2%</i>
<i>Landfills</i>	<i>6.3</i>	<i>1%</i>
<i>Petroleum Refining</i>	<i>32.8</i>	<i>8%</i>
<b>Residential</b>	<b>29.7</b>	<b>7%</b>
<b>Transportation</b>	<b>150.7</b>	<b>35%</b>
<b>Forestry Sinks</b>	<b>- 6.7</b>	<b>--</b>

**Figure 2. 1990 Greenhouse Gas Emissions by Sector<sup>2</sup>  
(427 MMTCO<sub>2</sub>e Net Emissions)**



The majority of 1990 emissions are tied to fuel use activities, ranging from transportation to electricity generation to heating buildings. In fact, emissions from fuel combustion comprise more than 80 percent of overall 1990 statewide

<sup>1</sup> The remaining 1.3 MMTCO<sub>2</sub>e are from unspecified fuel combustion and ODS substitute use, which could not be attributed to an individual sector. Percents may not total 100 due to rounding.

<sup>2</sup> Percents do not total 100. Less than one percent of the inventory is due to unspecified fuel combustion and ODS substitutes, which is not attributed to an individual sector (1.3 MMTCO<sub>2</sub>e in 1990).

greenhouse gas emissions. The primary fuels combusted were natural gas and gasoline.<sup>3</sup> In-state Electricity Generation, Residential and Industrial sectors accounted for almost 90 percent of the natural gas combusted statewide in 1990, while the Transportation sector consumed almost all (98 percent) of the State's gasoline in 1990.

California's economy and population have grown since 1990, resulting in increases in greenhouse gas emissions for some sectors. Table 3 and Figure 3 reflect the relative contributions of each sector to the State's overall greenhouse gas emissions in 2004.

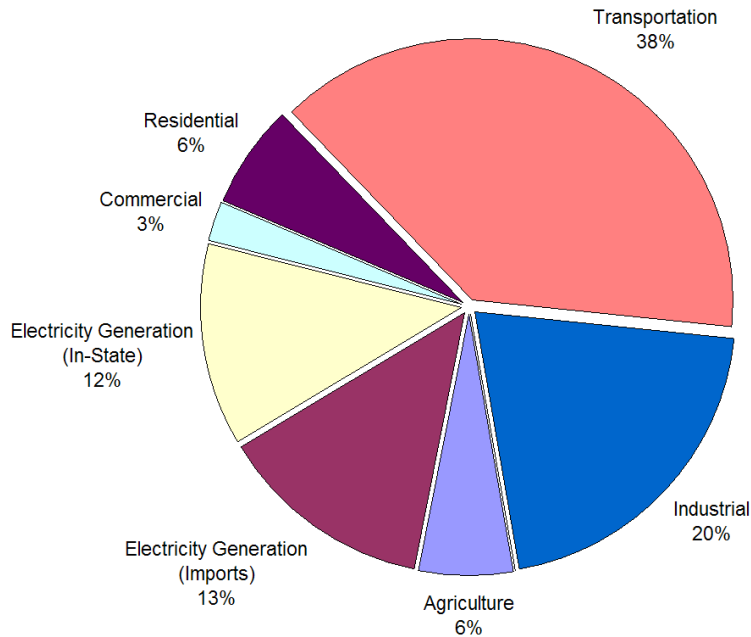
**Table 3. Greenhouse Gas Emissions by Sector in 2004<sup>4</sup>**  
(484 MMTCO<sub>2</sub>e Gross Emissions)

Sector	Total Emissions (MMTCO <sub>2</sub> e)	Percent of Total Gross Emissions
<b>Agriculture</b>	<b>27.9</b>	<b>6%</b>
<b>Commercial</b>	<b>12.8</b>	<b>3%</b>
<b>Electricity Generation</b>	<b>119.8</b>	<b>25%</b>
<i>In-State</i>	<i>58.5</i>	<i>12%</i>
<i>Imports</i>	<i>61.3</i>	<i>13%</i>
<b>Forestry (excluding sinks)</b>	<b>0.2</b>	<b>&lt;1%</b>
<b>Industrial</b>	<b>96.2</b>	<b>20%</b>
<i>Cement</i>	<i>9.8</i>	<i>2%</i>
<i>Landfills</i>	<i>5.6</i>	<i>1%</i>
<i>Petroleum Refining</i>	<i>34.9</i>	<i>7%</i>
<b>Residential</b>	<b>29.1</b>	<b>6%</b>
<b>Transportation</b>	<b>182.4</b>	<b>38%</b>
<b>Forestry Sinks</b>	<b>- 4.7</b>	<b>--</b>

<sup>3</sup> Comparison among fuels uses heat content (e.g., BTUs/scf natural gas; BTUs/gal gasoline) as a common metric among different fuels. Heat content factors are primarily from the California Energy Balance (CALEB) database, EIA and U.S. EPA.

<sup>4</sup> The remaining 16.0 MMTCO<sub>2</sub>e are from unspecified fuel combustion and ODS substitute use, which is not attributed to an individual sector. Percents may not total 100 due to rounding.

**Figure 3. 2004 Greenhouse Gas Emissions by Sector<sup>5</sup>  
(480 MMTCO<sub>2</sub>e Net Emissions)**



**E. How does the proposed 1990 emissions estimate differ from previous California estimates?**

The 1990 emissions level is based on the most recent data and methodologies available. The CEC and Climate Action Team (CAT) also produced estimates of the 1990 emissions level based on the best available data at the time their estimates were made. The CEC estimated the level to be 413 MMTCO<sub>2</sub>e (duVair 2007). Per Executive Order S-3-05, the CAT, which is made up of representatives from several state agencies, was required to implement greenhouse gas emission reduction programs and report on the progress made toward meeting the statewide targets specified in S-3-05. The CAT sponsored development of a 1990 level using similar estimation methods and data sources to the CEC, with some slight differences in the input data. The CAT's estimated 1990 level was 426 MMTCO<sub>2</sub>e, which is similar to ARB's updated 1990 level (CAT 2006).

Staff was able to characterize the CEC inventory using similar sectors and categories as the ARB inventory. However, it was not possible to do this same characterization with the available inventory information from the CAT report. Table 4 therefore presents a comparison of only the ARB and CEC inventory emissions estimates.

<sup>5</sup> Percents do not total 100. Roughly three percent of the inventory is due to unspecified fuel combustion and ODS substitute use, which is not attributed to an individual sector (16.0 MMTCO<sub>2</sub>e in 2004).

**Table 4. Differences in ARB and CEC 1990 Emissions Estimates  
for Sectors and Key Categories**

Sector	1990 Emissions (MMTCO <sub>2</sub> e)	
	ARB	CEC
<b>Agriculture</b>	<b>23.4</b>	<b>31.1</b>
<b>Commercial</b>	<b>14.4</b>	<b>15.3</b>
<b>Electricity Generation</b>	<b>110.6</b>	<b>89.2</b>
<i>In-State</i>	<i>49.0</i>	<i>45.2</i>
<i>Imports</i>	<i>61.6</i>	<i>44.0</i>
<b>Forestry (excluding sinks)</b>	<b>0.2</b>	<b>0.2</b>
<b>Industrial</b>	<b>103.0</b>	<b>79.5</b>
<i>Cement</i>	<i>8.1</i>	<i>4.8</i>
<i>Landfills</i>	<i>6.3</i>	<i>8.1</i>
<i>Petroleum Refining</i>	<i>32.8</i>	<i>27.9</i>
<b>Residential</b>	<b>29.7</b>	<b>29.6</b>
<b>Transportation</b>	<b>150.7</b>	<b>177.8</b>

While the numbers are similar, these estimates have important differences. Emissions from individual sectors differ between CEC and ARB estimates by up to 30 percent due to updated data, methodologies, and differences in included and excluded emissions. Staff treated carbon stored in landfills differently than CEC by separately tracking stored carbon instead of considering it an emission sink within a landfill. In addition, the ARB estimate only includes intrastate aviation, whereas the CEC and CAT estimates include both interstate and intrastate flights. Staff also included emissions from international shipping and related port activities in California waters, whereas the CEC and CAT excluded all emissions from international ships. If ARB treated these sectors in the same manner as the CEC, an additional 7 MMTCO<sub>2</sub>e would be added to the updated 1990 emissions level.

Additional details on differences between the CEC's and ARB's estimates of 1990 emissions are described in Section IV of the report.

**F. Is the inventory consistent with international and national guidelines?**

The 1990 California inventory is consistent with international and national guidelines and protocols to the greatest extent possible. Consistency maximizes the comparability of the inventory with inventories from other states and nations. This is important to facilitate the future linkage of California's program with regional, national, and international greenhouse gas emission reduction programs.

IPCC develops the standard international guidance for emissions inventories. Nations that have adopted the United Nations Framework Convention on Climate Change must prepare and report their emissions and sinks of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O,

SF6, PFCs, and HFCs using IPCC methodologies to ensure comparability among national inventories.

The IPCC guidelines delineate the sectors and processes for which nations must report their anthropogenic emissions and sinks, and how they should report these emissions. They also describe different methodologies to estimate both emissions and uncertainties, depending on the available data sources. The guideline documents include: *The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/UNEP/OECD/IEA 1997); *Good Practice Guidance and Uncertainty Management in National Greenhouse Inventories* (IPCC 2000); and, *Good Practice for Land Use, Land-Use Change and Forestry* (IPCC 2003), among others. IPCC recently published updated guidelines to incorporate new sources, additional greenhouse gases, and improved methodologies, *2006 Guidelines for National Greenhouse Gas Inventories* (IPCC/UNEP/WMO 2006).

The U.S. EPA is the lead agency for preparing and developing the national greenhouse gas inventory. The U.S. EPA supplements the widely applicable IPCC methodologies with more U.S.-specific and/or updated methodologies and data as feasible, and uses published emission factors and activity data when available.

ARB staff used the IPCC guidelines for its overall approach and sector-specific guidance in developing the 1990 inventory. The guidelines allow for use of state-specific data and methodologies rather than the more generic international ones when available. Staff used California-specific data and methodologies, as appropriate.

International guidance also recommends excluding bunker fuel emissions for all international aviation flights and marine vessel voyages from emissions inventories (IPCC/UNEP/WMO 2006). In an effort to be consistent, we propose to exclude these emissions from the 1990 emissions level, with the exception of marine bunker fuel use in California waters. As discussed above, we are also proposing to exclude greenhouse gas emissions from interstate flights, which is consistent with the international approach of including only those flights within a jurisdiction's borders.

California's inventory differs from the IPCC guidelines and U.S. EPA greenhouse gas inventory in two ways. The Act requires that ARB include imported electricity in the 1990 inventory. International and the U.S. inventories do not. The proposed inventory also contains emissions from all ships, including internationally-flagged ships, occurring within California waters provided that either their origin or destination is a California port.<sup>6</sup>

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<sup>6</sup> For purposes of calculating emissions from ships, California waters extend to 24 nautical miles from the coast.



### **G. What was the review and update process?**

Staff updated the inventory through an extensive process to ensure inclusion of the best available economic, technological, and scientific data. The process began when ARB received the statewide greenhouse gas inventory from the CEC in December 2006 per Assembly Bill 1803. CEC staff had developed a comprehensive detailed inventory of statewide greenhouse gas emissions for 1990 through 2004 (CEC 2006). ARB staff devoted eight months to an extensive review of this inventory, including the data sources and methodologies used for each sector and category. The process focused on four sectors (Agriculture, Electricity Generation, Forestry and Transportation) and three categories in the Industrial sector (cement, landfills, and petroleum refining). Staff made updates and improvements to the data, methodologies, and calculations in consultation with agencies and stakeholders to ensure use of the best data and methodologies and consistency with international and national guidelines.

### **H. What was the public process?**

The review and update process included four public workshops and nine technical discussions on the inventory. Staff held an initial workshop in late 2006, a preliminary technical discussion in early 2007, a workshop on updates in June 2007, and a workshop to discuss the draft inventory in August 2007. There have also been several technical workgroups on the emissions estimates associated with electricity generation, cement, landfills, and petroleum refining in conjunction with the development of the mandatory reporting regulation for greenhouse gases.

### **I. What issues were raised in the public process?**

Although many topics were discussed during workshops and technical discussions, three were particularly challenging when developing the 1990 inventory: forestry, landfills, and electricity generation.

Forestry. The 1990 forestry emissions estimate uses data on greenhouse gas emissions and sinks estimated by the CEC, which are based on the results of a remote-sensing and GIS-based analysis of forest data. These data represents the best available, peer-reviewed data for the Forestry sector. During the public review of the greenhouse gas emissions data for forestry, the U.S. Department of Agriculture – Forest Service (USDA-FS) developed a draft inventory of carbon sequestration for national forests using a different methodology. The California Department of Forestry and Fire (CalFIRE) and the USDA-FS believe the CEC-based methodology used to calculate forest carbon sequestration may underestimate the amount of vegetation statewide, and therefore underestimate CO<sub>2</sub> sinks. ARB has formed an interagency workgroup with participants from CalFIRE and USDA-FS, as well as CEC and U.S. EPA, to investigate these additional data sources and methods. The results will be incorporated in future

greenhouse gas emissions estimates and included in the Scoping Plan process as available.

Landfills. The landfill industry requested that staff alter the inventory methodology to count the carbon stored in landfills in the form of wood products and other carbon-bearing material as a sink when defining the 1990 level. Staff acknowledges that carbon is stored in landfills. However, the inventory methodology recognizes carbon sequestration at the point where carbon is removed from the atmosphere (i.e., photosynthesis in living vegetation). Counting it again when wood products are stored in landfills would constitute a double counting of sequestered CO<sub>2</sub>. Staff has proposed to calculate and track the amount of carbon stored in landfills, but not count it as a sink when calculating the 1990 emissions level.

The landfill industry and environmental organizations also recommended using different landfill gas collection efficiencies and surface cap oxidation factors than the currently used U.S. EPA default values. A wide range of estimates for these factors exist in the literature and from site-specific tests. To provide a better basis for calculating landfill emissions, staff is working with the California Integrated Waste Management Board (CIWMB) and CEC to obtain improved data on landfill gas collection efficiencies through a CEC-sponsored research study. In the meantime, the proposed inventory continues to use the U.S. EPA default values since rigorous, scientifically-based measurement data on collection efficiency and landfill cap oxidation factors are not currently available.

Electricity generation. The inventory uses the same methodology developed and used by CEC, including its fuel mix assumptions, to calculate emissions from unspecified imported power (out-of-state power from an unknown fuel type). An electric power provider recommended that the inventory use a different set of assumptions regarding the types and amount of fuel associated with unspecified imported electric power from the Pacific Northwest. ARB staff has based its final estimates for unspecified imported power in 1990 on the findings and recommendations of CEC staff. ARB staff will continue to work with the CEC and California Public Utilities Commission to obtain improved information on emissions from electricity generation for future years.

**J. What documentation is available on the methods used to quantify the emissions estimates?**

ARB staff has produced extensive documentation on the methods used to develop the emissions inventory for 1990, as well as for the years 1991 to 2004. Detailed calculations and methods can be found on-line at <http://www.arb.ca.gov/cc/ccei/emsinv/emsinv.htm>. This online documentation consists of over 12,000 pages and includes the following for every emission source estimate for years 1990 to 2004: basic calculation equations and

references to models, activity data, emission factors, GWPs, and other constants. It also includes the sources of each of these inputs.

#### **IV. ESTIMATING THE 1990 EMISSIONS LEVEL**

The amount and types of emissions in any given year are driven by California's economic and population demands. In 1990, California had over 29 million people and an economy that was one of the world's largest with a gross state product of approximately \$1 trillion, equaling 13 percent of the U.S. gross domestic product (BEA 2007). As a result, transportation and electricity demand to meet California's economic and population needs were responsible for the largest quantities of greenhouse gases, with transportation accounting for over 35 percent of total emissions and electricity demands for another 26 percent. A summary of the 1990 emissions estimates for all categories in each sector is included in Table 5. A detailed summary of the 1990 inventory and the complete 1990 emissions inventory are included in Appendices A-1 and A-2, respectively.

In estimating the 1990 emissions, staff relied on a variety of information sources, most of which provide data at the state or regional level. They used emission factors primarily from the IPCC, U.S. EPA, and stakeholders. Fuel use and electricity generation data were taken from the California Energy Balance (CALEB) report, Energy Information Administration (EIA), the CEC's Quarterly Fuel and Energy Report and Petroleum Industry Information Reporting Act Data, and stakeholder input. Staff also used models where appropriate, such as EMISSION FACTORS (EMFAC) 2007 model, which is ARB's transportation emissions model for on-road emissions, U.S. EPA models for agriculture, and the IPCC First-Order Decay model for landfills.

The 1990 emissions inventory therefore is primarily a top-down inventory since it relies on these statewide or regional data sources for its emissions estimates. For example, staff followed the top-down approach of using statewide fuel use from certain emissions sources to estimate their CO<sub>2</sub> emissions. For the categories where data was available, staff used a bottom-up approach, relying on facility-specific data to estimate emissions. Additional information on estimation methods may be found on-line in 12,000 pages of documentation in which calculations and data sources are detailed (<http://www.arb.ca.gov/cc/ccei/emsinv/emsinv.htm>).

**Table 5. Emissions Inventory Categories within Each Sector**

<b>Sector</b>	<b>Category<sup>7,8</sup></b>	<b>1990 Emissions (MMTCO<sub>2e</sub>)<sup>9</sup></b>
<b>Agriculture</b>	Agricultural Energy Use	4.5
	Agricultural Residue Burning	0.1
	Agricultural Soil Management	6.7
	Enteric Fermentation	6.7
	Manure Management	5.0
	Rice Cultivation	0.4
<b>Commercial</b>	CHP: Commercial (UTO)	0.4
	Communication	0.1
	Domestic Utilities	0.3
	Education	1.4
	Food Services	1.9
	Health Care	1.3
	Hotels	0.7
	National Security	0.6
	Offices	1.5
	Retail & Wholesale	0.7
	Transportation Services	0.03
	Not Specified	5.6
<b>Electricity Generation (Imports)</b>	Specified Imports (generating plant known)	29.6
	Unspecified Imports (generating plant unknown)	31.0
	Transmission and Distribution (SF6)	1.0
<b>Electricity Generation (In-State)</b>	CHP: Commercial and CHP: Industrial	15.2
	Merchant Owned	2.3
	Utility Owned	29.9
	Transmission and Distribution (SF6)	1.6
<b>Forestry</b>	Forest and range management	0.2
<b>Industrial</b>	CHP: Industrial (UTO)	9.7
	Flaring	0.2
	Landfills	6.3
	Manufacturing	32.0
	Mining	0.03
	Oil & Gas Extraction	14.6
	Petroleum Marketing	0.02
	Petroleum Refining	32.8
	Pipelines	1.6
	Wastewater Treatment	3.2
	Not Specified	2.6
	<b>Residential</b>	Household Use
<b>Transportation</b>	Aviation	5.1
	Water-borne (Marine Vessel)	2.2
	On road	138.0
	Rail	2.3
	Not Specified	3.0

<sup>7</sup> Combined Heat and Power (CHP) refers to cogeneration units supplying electric power and/or useful thermal energy. UTO is useful thermal output from CHP.

<sup>8</sup> Emissions in each sector not otherwise accounted for are categorized as "Not Specified".

<sup>9</sup> Emissions may not add up to total gross emissions in 1990 due to rounding.

## **A. Emissions estimates and quantification methods for key sectors and categories**

The 1990 inventory emissions estimates are based on in-depth analyses of the CEC's inventory and appropriate updates by staff to include the best scientific, technological, and economic data available. The review and update process included all sectors and categories listed in Table 5. The process placed special emphasis on the sources of greenhouse gas emissions discussed below, in order of highest to lowest emissions. Emission estimates, methodologies, data sources, and updates from the CEC inventory are listed. In addition, there is a brief discussion of where inventory methods might be improved in the future as staff continues to develop annual inventories.

### **1. Transportation**

Emissions Estimate. The Transportation sector is the largest emitter of greenhouse gases, emitting roughly 35 percent of California's greenhouse gases in 1990. It includes all on-road vehicles (passenger cars, light duty trucks, heavy duty vehicles, and motorcycles), as well as airplanes, trains, and ships. Key exclusions are interstate and international flights, as well as ships operating outside of California waters.

Transportation emitted 150.7 MMTCO<sub>2</sub>e of greenhouse gases (CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O) in 1990. Passenger vehicles, which include passenger cars and light-duty trucks, accounted for more than 70 percent of all transportation emissions, emitting 108.5 MMTCO<sub>2</sub>e. Most of the transportation emissions were CO<sub>2</sub>. As a result, the Transportation sector was also the largest emitter of CO<sub>2</sub> in 1990: 143.1 MMTCO<sub>2</sub>e. This estimate does not include emissions from international and interstate aviation, as well as marine fuel use outside of California waters. Since fossil fuel combustion primarily produces CO<sub>2</sub> and relatively little CH<sub>4</sub> and N<sub>2</sub>O, transportation accounted for a small fraction of statewide CH<sub>4</sub> emissions, 1.0 MMTCO<sub>2</sub>e, despite the large volume of fossil fuels used in vehicles statewide. It is, however, the second largest source of N<sub>2</sub>O with 6.7 MMTCO<sub>2</sub>e, the majority of which is from on-road vehicles. Older technology catalysts, which were designed to reduce criteria pollutant emissions from on-road vehicles, produced N<sub>2</sub>O through incomplete reactions with combusted fuel.

Methodology. To quantify on-road emissions, staff used EMFAC 2007 and scaled the direct EMFAC outputs to fuel sales data for all emissions (notably CO<sub>2</sub>, carbon monoxide, total hydrocarbons, CH<sub>4</sub>, and NO<sub>x</sub>). Scaling EMFAC outputs to fuel sales enabled the transportation inventory to remain consistent with the top-down approach used for fuel combustion emissions in the rest of the inventory. Nitrous oxide for gasoline vehicles was determined from a linear regression correlating NO<sub>x</sub> with N<sub>2</sub>O based on tailpipe emissions test data. For diesel vehicles, N<sub>2</sub>O emissions were based on a per-gallon emission factor from diesel tailpipe emissions test data.

For CO<sub>2</sub> emissions from airplanes and trains, staff followed the 2006 IPCC methodology, which multiplies the amount of fuel purchased within California by its energy content, carbon content, and a combustion efficiency assumption (IPCC/UNEP/WMO 2006). Staff used a similar approach for CH<sub>4</sub> and N<sub>2</sub>O emissions from airplanes and trains, applying the latest U.S. EPA emission factors to available fuel data. More specific data was available for the marine vessel inventory, which staff calculated using activities and emission rate data for ship emissions that occurred in California waters (within 24 miles of California's coastline) including en transit, port, harbor, docking, and other activities. Appropriate Second Assessment Report GWPs were used in all calculations to determine final emission estimates.

Updates from CEC Inventory. Scaling EMFAC 2007 outputs to the original fuel sales data was a significant update to the previous statewide inventory compiled by CEC, resulting in a vehicle-class-specific inventory for most on-road emissions. Further updates include the recalculation of N<sub>2</sub>O emissions improvements in marine vessel estimates, which now use ARB's high resolution goods movement data to determine emissions occurring in California waters, instead of following a strictly fuel sales-based approach.

Data Sources. Staff obtained on-road gasoline, on-road diesel, and aviation gasoline fuel sale numbers from the State Board of Equalization. Fuel sales data generally correlate fairly well with fuel use. These numbers are also referenced in the Federal Highway Administration Highway Statistics annual reports and CALEB. Nearly all other fuel data (carbon content, fuel use, etc.) are from the CALEB report, which cites EIA's State Energy Consumption, Price, and Expenditure Estimates database, as well as EIA's Petroleum Marketing reports. Carbon dioxide calculation methodologies for airplanes and trains are from IPCC guidance, while on-road source emission factors come from EMFAC. For airplanes and trains, N<sub>2</sub>O and CH<sub>4</sub> emission factors are from the U.S. EPA ship statistics and emissions currently included the inventory (fuel use as well as CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O) are from ARB's goods movement information database.

Future Improvements to Annual Inventories. Staff is investigating the feasibility of updating EMFAC 2007 to directly calculate emission outputs for on-road vehicle N<sub>2</sub>O emissions. Staff is also considering updating airplane, train, and ship emissions based on new activity and emissions data.

## **2. Electricity Generation**

Emissions Estimate. The Electricity Generation sector is the next largest emitter of greenhouse gases in 1990, emitting 110.6 MMTCO<sub>2</sub>e. It consists of power plants and cogenerators that generate electricity for on-site use and for sale to the power grid. Power plants typically produce electrical power to serve the grid. Cogenerators produce electricity and non-electricity useful thermal outputs, such as steam and/or hot air. The Act specifically requires that estimates shall include

greenhouse gas emissions from both in-state generated power and the generation of imported electricity delivered to and consumed in California. Emissions from transmission line losses of electricity, as well as SF6 emissions from transmission equipment, are also included.

Almost 30 percent of the electricity produced in-state in 1990 used renewable energy sources, such as biomass, solar, wind, hydropower, and geothermal (Schnapp 2007). The remainder relied on fossil fuels and nuclear power. California imported 40 percent of its electricity in 1990 to meet statewide demand. Imported electricity emitted more than 50 percent of the CO2 emissions from this sector, 60.3 MMTCO2e versus 47.3 MMTCO2e from in-state generation. Electricity generation was a relatively minor source of CH4 and N2O, emitting 0.1 MMTCO2e of CH4 and 0.4 MMTCO2e of N2O. This sector uses SF6 as an electrical insulator in the transmission and distribution of electricity. The quantities of SF6 released to the atmosphere during these applications are small, but its GWP is the highest of the greenhouse gases in the inventory. As a result, in 1990, statewide SF6 emissions from electricity generation were 2.6 MMTCO2e.

Methodology. Emissions from the Electricity Generation sector are based primarily on fuel use data obtained from the EIA. Emissions of SF6 from leaks in electrical transmission equipment are from the U.S. EPA national emissions inventory, prorated to California based on electricity generation. Staff calculated fuel combustion emissions by multiplying the heat content of fuel by its relevant emission factors and constants.

For imported power, staff used plant-specific data for known (specified) imports. The remaining unspecified imports are based on region-specific emission factors assumptions for the Pacific Northwest and Pacific Southwest regions. Staff used CEC assumptions about fuel use for both regions.

Cogeneration facilities, also known as Combined Heat and Power (CHP) plants, use some fuel for electricity generation and the rest to generate steam and other useful thermal outputs. To reflect this practice, staff only used the fraction of the fuel that each cogeneration facility reported as combusted for electricity generation to estimate electric power emissions. Emissions associated from the combustion of the remaining fuel are listed as Useful Thermal Output in the inventory and not counted under the electricity generation sector.

Updates from CEC Inventory. Significant updates from the earlier CEC inventory were the inclusion of geothermal and additional waste-to-energy data for calculating emissions from in-state power, line losses in the calculation of greenhouse gas emissions from imported power, and gross imported electricity used instead of net imports (gross imports minus exports).

Data Sources. All fuel use data is from the EIA. National SF6 emissions are from the U.S. EPA. Emission factors, fuel heat content, and GWPs are from U.S. EPA, EIA and IPCC.

Future Improvements to Annual Inventories. SF6 emissions estimates can be improved with California-specific data, which staff is currently working to obtain. Staff is also developing better methods for dividing the cogeneration emissions between respective uses. Staff is working with CEC, CPUC, and other stakeholders to improve the estimate of emissions from unspecified imports of electricity.

### **3. Petroleum Refining**

Emissions Estimate. The petroleum refining category emitted 32.8 MMTCO<sub>2</sub>e in 1990. More than 99 percent of these emissions were CO<sub>2</sub>, including 32.6 MMTCO<sub>2</sub>e, from fuel combustion and fuels used as feedstocks. Methane and N<sub>2</sub>O emissions were relatively small, 0.2 MMTCO<sub>2</sub>e and 0.02 MMTCO<sub>2</sub>e, respectively. This category includes the 21 major refineries and minor refineries located throughout California. Major refineries (50,000+ barrels per day of crude capacity) typically receive and process petroleum crude into its component parts for sale as fuel or for use as other petroleum-based products (e.g., waxes, lubricants, etc). Minor refineries may also refine crude or work with residual oil and other heavy residuals from major refinery outputs to make asphalt or other petroleum-based products.

The primary sources of greenhouse gas emissions at refineries are emissions from cogeneration units, hydrogen production, combustion emissions associated with distillation and other refining processes, catalyst regeneration in fluidized catalytic cracking units (FCCU), and fugitive emissions.

Methodology. Staff calculated fuel combustion emissions by multiplying the heat content of fuel by its relevant emission factors and constants. Hydrogen production emissions were estimated using hydrogen generation rates. Fugitive CH<sub>4</sub> emission estimates from refineries were derived from data in ARB's criteria pollutant database, the California Emissions Inventory Development and Reporting System (CEIDARS).

Updates from CEC Inventory. Western States Petroleum Association provided staff with improved hydrogen production data. Staff updated emission estimates from the combustion of catalyst coke and petroleum by dividing "coke" into catalyst coke and petroleum coke based on data from the CEC's Petroleum Industry Information Reporting Act (PIIRA) database. PIIRA contains data on fuel used by refineries in the State.

Data Sources. Publicly available datasets from the CEC and EIA provided improved data on fuel use. Fugitive emissions are from CEIDARS, which obtains



its data jointly from the local air districts and ARB calculations. The emission factors used in calculating emissions estimates are from U.S. EPA, EIA, and IPCC guidance.

Future Improvements to Annual Inventories. Staff is working to obtain additional data regarding the fuel used for hydrogen production. Additionally, refineries may provide data currently missing on fuel (e.g., refinery gas, naphtha, etc.) that they may export to other facilities for hydrogen production. Staff is investigating emission factor updates for CO<sub>2</sub> from the regeneration of FCCU catalysts.

#### **4. Agriculture**

The Agriculture sector was one of the smaller greenhouse gas emitters in 1990, emitting 23.4 MMTCO<sub>2</sub>e. It includes agricultural energy use, agricultural soil management, agricultural residue burning, enteric fermentation, manure management, and rice cultivation. The sector emits a relatively small amount of CO<sub>2</sub> emissions compared to other sectors. The largest CO<sub>2</sub> emission source is fuel combustion in agricultural equipment (4.5 MMTCO<sub>2</sub>e). This sector, however, includes the largest emitter of CH<sub>4</sub>, enteric fermentation (animal digestion) which emits 6.7 MMTCO<sub>2</sub>e of CH<sub>4</sub> in 1990. Agricultural energy use, agricultural residue burning, manure management, and rice cultivation emitted an additional 4.9 MMTCO<sub>2</sub>e of CH<sub>4</sub>. Agriculture was also the largest source of N<sub>2</sub>O in California in 1990. Agricultural soil management (processes that increase soil nitrogen availability) was responsible for 88 percent of N<sub>2</sub>O emissions within the agriculture sector and 40 percent of all N<sub>2</sub>O emissions statewide. Discussion of methodologies, data sources, and future improvements for this sector will focus on agricultural soil management, enteric fermentation, and manure management since they are the highest emitting categories in this sector.

##### ***Agricultural Soil Management***

Emissions Estimate. Agricultural soil management was the highest emitter of N<sub>2</sub>O in 1990, emitting 6.6 MMTCO<sub>2</sub>e of N<sub>2</sub>O and 0.1MMTCO<sub>2</sub>e of CO<sub>2</sub>. This category consists of agricultural activities that increase soil nitrogen availability including: applying fertilizers and manure; growing nitrogen fixing crops; retaining crop residuals; liming of soils; depositing waste by domestic and grazing animals; and, cultivating histosols (soils with high organic matter content). Emissions of N<sub>2</sub>O from managed soils occur as a result of nitrification and denitrification in soil.

Methodology. Staff calculated N<sub>2</sub>O emissions using an emission factor model, which is based on the 2006 IPCC guidelines and the guidance from the U.S. EPA's Emissions Inventory Improvement Program for greenhouse gases. Staff adapted the parameter values used by CEC staff to make them California-specific. For example, the residue-to-crop mass ratio and the fraction of residue applied were adjusted down for some crops to match the estimated residue

tonnages for agricultural burning in California. Staff multiplied applied tons of limestone and dolomite by the dolomite and limestone emission factors to estimate CO<sub>2</sub> emissions since CO<sub>2</sub> is emitted to the atmosphere when the limestone and dolomite applied to agricultural soils degrades.

Updates from CEC Inventory. Improvements for estimating N<sub>2</sub>O emissions from agricultural soil management included computational improvements and updated emission factors.

Data Sources. Activity data are from CEC emission inventory spreadsheets, which are primarily from the California Department of Food and Agriculture (CDFA). Fertilizer usage data is from *Fertilizing Materials Tonnage Reports*, published by CDFA. Crop production data is from USDA National Agriculture Statistics Services. The animal population data used to estimate manure production were from the national greenhouse gas inventory spreadsheets (U.S. EPA 2007). Staff estimated histosols cultivation acreage based on the expert judgment of two California State soil scientists (CEC 2006). The amounts of limestone and dolomite applied to cropland soils are from the CDFA annual fertilizing materials tonnage reports and annual editions of the U.S. Geological Survey (USGS) *Minerals Yearbook*.

Future Improvements to Annual Inventories. Staff will evaluate the feasibility of using process-based models to quantify N<sub>2</sub>O emissions. Emission factor models cannot capture the emission variations from a wide range of agro-ecosystems, since N<sub>2</sub>O emissions from nitrification and denitrification processes are driven by many factors, such as climate, soil, and agricultural practices.

### ***Enteric Fermentation***

Emissions Estimate. Enteric fermentation is the microbial fermentation process in an animal's digestive system that produces CH<sub>4</sub>, which is in turn exhaled or burped by the animal. This process is the largest statewide emitter of CH<sub>4</sub> in 1990, emitting 6.7 MMTCO<sub>2</sub>e of CH<sub>4</sub>, most of which was released by domesticated ruminant animals.

Methodology. Staff used the U.S. EPA enteric fermentation emissions methodology to calculate California-specific emissions, consistent with 2006 IPCC guidance. The majority of enteric fermentation emissions are from dairy and beef cattle. Staff used a more detailed methodology to estimate emissions for domesticated cattle (except bulls) that employs several models and calculations. A less detailed methodology provided emissions estimates for other livestock, because overall these animals contribute a relatively small amount of the total enteric fermentation CH<sub>4</sub> emissions.

Updates from CEC Inventory. Updates from the CEC inventory estimates of enteric fermentation emissions centered on improved emission factors and data inputs obtained from U.S. EPA.

Data Sources. The original source of the animal population data, except for horses, is from the U.S. Department of Agricultural (USDA) National Agricultural Statistics Service (NASS). Horse population data is from the Food and Agriculture Organization (FAO). Output from the University of California, Davis AAMOLLEY model provides cattle digestible energy and CH<sub>4</sub> conversion rates by population category. Staff calculated the gross energy factor using IPCC recommended methods. For “other livestock” animal types, such as sheep and swine, staff obtained the emission factors from the 2006 IPCC guidance.

Future Improvements to Annual Inventories. Staff is investigating potential improvements to the enteric fermentation methodology. As research results emerge, and as the IPCC and U.S. EPA improve methodologies, the inventory will be updated to reflect those improvements.

### ***Manure Management***

Emissions Estimate. The manure management category emitted 5.0 MMTCO<sub>2e</sub> in 1990, the majority of which was CH<sub>4</sub> emissions. This sector includes the storage of livestock or poultry manure in liquid systems. The storage or treatment of manure waste in anaerobic conditions, such as liquid slurry in a pond or lagoon, promotes anaerobic decomposition of organic material, which produces CH<sub>4</sub> emissions. Small amounts of N<sub>2</sub>O are also produced through nitrification and denitrification.

When manure is handled as a solid, it tends to decompose aerobically, primarily producing N<sub>2</sub>O and little or no CH<sub>4</sub>. Nitrous oxide emissions from manure managed in pasture, range, and paddock or as daily spread is included in the agricultural soil management category.

Methodology. Staff used the U.S. EPA emissions calculation methodology for manure management to calculate California-specific emissions. The methodology considers animal population and location, amount of dry versus liquid manure, CH<sub>4</sub> and N<sub>2</sub>O emission factors, and other inputs. It is consistent with 2006 IPCC guidance and recommendations.

Updates from CEC Inventory. Updates from the earlier CEC inventory estimates emissions from manure management centered on improved emission factors and data inputs obtained from U.S. EPA.

Data Sources. Animal population data, except for horses, is from the USDA NASS. Horse population data is from the FAO. Staff obtained all factors used to

estimate CH<sub>4</sub> and N<sub>2</sub>O emissions from U.S EPA's inventory spreadsheets and reports.

Future Improvements to Annual Inventories. As research results emerge, and as the IPCC and U.S. EPA improve methodologies, staff will update future time series inventories.

## 5. Landfills

Emissions Estimate. Landfills are the second highest emitter of CH<sub>4</sub> statewide, releasing 6.3 MMTCO<sub>2</sub>e as a result of the degradation of organic waste. Anaerobic decomposition of landfilled waste forms roughly an even mix of CO<sub>2</sub> and CH<sub>4</sub> as a byproduct of degradation. Methane emissions from landfills are the chief pollutant of concern for this category. The CO<sub>2</sub> generated from landfills, whether through oxidation in cover material or through landfill gas combustion, is considered biogenic and accounted for in the atmospheric CO<sub>2</sub> flux (see Appendix B).

The landfills included in the inventory are only those landfills in California that receive or have received organic waste. Landfills receiving only ash or inert construction debris are not considered since they do not emit CH<sub>4</sub>. A large fraction of landfill carbon, including organic waste, cannot degrade and may be permanently sequestered in the landfill.

Landfills may install or expand a gas collection system to capture landfill gases in an effort to comply with local, state or federal regulations. Captured gas may be flared, filtered, or combusted for electricity production. Some landfills do not generate enough gas for effective combustion and simply vent the gas. Gases that are not captured escape through the surface or migrate out through other means.

Methodology. Staff used the IPCC Mathematically Exact First-Order Decay Model, which calculates the amount of carbon that degrades over time in a landfill. The amount of landfill carbon before degradation is based on national and California waste characterization studies and 2006 IPCC factors that convert each waste type into carbon mass. Staff received the total amount of waste deposited into landfills (waste-in-place data) from CIWMB for 1990 and prior years. All of these data served as inputs into the IPCC model.

Staff surveyed landfills in the State to improve the model output results, augmenting model estimates with actual measured landfill gas collection levels. Collection efficiencies and oxidation factors for gas migration through the cover soils used defaults of 75 percent and 10 percent, respectively. Staff combined these defaults with the model output to determine total amount of CH<sub>4</sub> that was released.

Updates from CEC Inventory. CEC relied on CEIDARS data for landfill CH<sub>4</sub>, which is based on local air district-specific methods. Staff updated emissions estimates by using waste data obtained from CIWMB in conjunction with IPCC models to obtain a consistent, statewide estimate that incorporates all the latest data available.

Data Sources. Waste-in-place data is from the CIWMB. Rainfall for each landfill, which influenced landfill decay rates, is based on data from CIWMB and the Natural Resources Conservation Service. The decay model itself is from the 2006 IPCC Guidelines (Mathematically Exact First-Order Decay Model). Waste characterization comes from U.S. EPA (national data) and CIWMB (California-specific data) studies, while carbon content and sequestration factors come from U.S. EPA, CEC, and 2006 IPCC Guidelines. The default collection efficiency of 75 percent is from U.S. EPA. The default oxidation factor of 10 percent for gas migration through the surface cap is from 2006 IPCC Guidance.

Future Improvements to Annual Inventories. Staff is currently working to obtain more landfill-specific survey data to better improve estimates. Staff hopes to improve the default collection and oxidation values through studies focused on these areas.

## **6. Cement**

Emissions Estimate. The cement category includes all cement manufacturers in California. Emissions result from the processing of raw materials into clinker, as well as the combustion of fuel to heat kilns. Clinker is one of the key ingredients used to produce cement, releasing CO<sub>2</sub> in the process. The production of clinker produced 4.6 MMTCO<sub>2</sub>e in 1990. Carbon dioxide was also emitted, along with small quantities of CH<sub>4</sub> and N<sub>2</sub>O, when fossil fuel was combusted to heat kilns, emitting 3.5 MMTCO<sub>2</sub>e. Carbon dioxide emissions from clinker production accounted for unrecycled cement kiln dust (CKD).

Methodology. Staff calculated CO<sub>2</sub> emissions from clinker production by first multiplying clinker production data with a clinker CO<sub>2</sub> emission factor, and then by a CKD correction factor. The CKD correction factor is calculated based on the known amounts of CKD leaving the kiln, the bypass dust leaving the kiln, and a CKD factor (IPCC/UNEP/WMO 2006). Staff calculated fuel combustion emissions by multiplying the heat content of fuel by its relevant emission factors and constants.

Updates from CEC Inventory. Staff used known amounts of clinker production, cement kiln and bypass dust data, and fuel use data, which are all based on facility-specific surveys aggregated to a statewide total. CEC used a default correction factor for CKD, because data on the amounts of CKD were not available. CEC also used clinker production data from the USGS, whereas ARB

staff used plant-specific aggregated clinker production data provided by the Portland Cement Association (PCA).

Data Sources. PCA provided California-specific data on clinker production, cement kiln dust, bypass dust leaving the kiln system, and fuel use from a cement plant survey for 1990, 1995, 2000, and 2005. ARB staff interpolated missing data for the intervening years, upon PCA's recommendation. The clinker emission factor and the factor for cement kiln dust are IPCC factors (IPCC/UNEP/WMO 2006).

Future Improvements to Annual Inventories. ARB staff would like to obtain cement plant-specific data on the mass of individual inputs (i.e., carbonates) consumed in the kiln to produce clinker. These data would be used to improve the CO<sub>2</sub> emissions resulting from clinker production in future time series inventories.

## **7. Forestry and Rangelands**

Emissions Estimate. The Forestry sector is unique, because it not only includes CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O emissions from disturbances on forests and rangelands, such as harvest, fire, and land use conversion, but also includes removals of atmospheric CO<sub>2</sub> by photosynthesis, which is then bound (sequestered) in plant tissues. The inventory balances the CO<sub>2</sub> emissions and atmospheric removals of CO<sub>2</sub> by vegetation through an atmospheric CO<sub>2</sub> flux approach (Appendix B). The sector's emissions are therefore the sum total of greenhouse gas emissions to the atmosphere and CO<sub>2</sub> removals by photosynthesis.

In 1990, this sector removed more CO<sub>2</sub> from the atmosphere than it emitted. As a result, it was a net sink, removing 6.7 MMTCO<sub>2</sub>e from the atmosphere in 1990. Emissions from the Forestry sector due to management of forests and rangelands accounted for less than one percent of all CH<sub>4</sub> and N<sub>2</sub>O emissions statewide in 1990.

Methodology. For forests and rangelands, staff estimated CO<sub>2</sub> removals and emissions from changes in forest and rangeland biomass with products developed by Winrock for CEC (CEC 2004). The products used satellite imagery and empirical relationships between tree canopy cover and biomass to estimate changes in biomass over time. Increases in biomass are associated with removals of CO<sub>2</sub> from the atmosphere, while decreases indicate wood harvesting and emissions from fires (CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O) and harvest events (CO<sub>2</sub> and CH<sub>4</sub>). Winrock provided data for 1994-2000. Staff used scaling factors based on forest land area trends from CalFIRE and USDA-FS to extrapolate data for the remaining years (1990-1993 and 2001-2004). Emissions associated with soil disturbance and residue oxidation resulting from harvest activities are accounted for in the inventory. When wood is harvested, a portion of the tree biomass is converted to wood products. The wood products serve as

reserves of carbon, some of which degrade slowly over long periods of time to CO<sub>2</sub> and CH<sub>4</sub> in landfills and composts. Staff estimated emissions from the statewide disposal of wood products as part of the landfill category.

Updates from CEC Inventory. Forest and rangeland greenhouse emissions are reported by individual gas (CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O) and emission source (e.g., fire, soil disturbances, etc.). CEC combined these gases and sources. The Forestry sector inventory now includes emissions from the decomposition of wood products disposed in landfills, and emissions from composting operations. Emissions from landfilled and composted urban greenwaste are now reported under the landfills category, pending further data on atmospheric CO<sub>2</sub> removals by urban forests. Woody and non-woody crop biomass annual stock changes have been removed from the inventory pending further study.

Data Sources. Staff used products developed by Winrock for the CEC PIER program to estimate CO<sub>2</sub> removals and greenhouse gas emissions for forests and rangelands. Data on wood product use in the State is from WOODCARB model output provided by the USDA-FS Forest Products Laboratory. CIWMB provided data on wood product disposal in landfills. The decay rates used to model CO<sub>2</sub> and CH<sub>4</sub> generation from landfilled wood product decomposition are from the U.S. EPA.

Future Improvements to Annual Inventories. ARB is partnering with land management agencies and the research community to investigate the feasibility of using products from the USDA-FS Forest Inventory and Analysis (FIA) program to better estimate biomass and carbon stocks and stock changes on forested lands. The FIA represents a robust standard for forest inventories, and serves as the basis for the U.S. EPA forest lands greenhouse gas inventory.

Trees in urban areas account for a small but increasing fraction of forest cover in the State. Future inventories may include an inventory of urban forest stocks and stock changes. Future editions of the inventory could also include soil organic carbon, which makes up a large carbon reservoir on forested lands, rangelands and croplands, as data and models become available.

Improvements to forecasting for this sector beyond land area trends will involve assessments of climate forcing and future human activities affecting biomass stocks, such as forest management. These assessments will also be needed to develop forecasts for other categories of managed land, such as croplands and urban areas.

## **B. Emissions estimates for other sectors**

The remaining statewide greenhouse gas emissions in 1990 were from sectors and categories not discussed above, but included in Table 5. Staff reviewed the CEC estimates for these emissions sources and, as appropriate, updated the

input data, emission factors, and methodologies to reflect the best available data and estimation methods. Commercial and Residential sectors are discussed briefly below since they are not part of the four sectors examined above. The Industrial sector is also mentioned since it is much broader than the three industrial categories (landfills, cement, and petroleum refining) discussed previously.

The Commercial sector emitted 14.4 MMTCO<sub>2</sub>e, while the Residential sector emitted 29.7 MMTCO<sub>2</sub>e in 1990. The Commercial sector includes emissions from all commercial activities statewide, as listed in Table 5. The Residential sector contains emissions from households. Staff combined fuel use data and improved emission factors from the IPCC to calculate emissions in both sectors. This approach is the same as that used by the CEC.

Greenhouse gas emissions for both sectors were due to fuel combustion. Fuel was burned to prepare food, heat buildings, provide hot water and steam, and supply energy for natural gas transmission through pipelines. As a result, the Commercial sector emitted 14.4 MMTCO<sub>2</sub>e of CO<sub>2</sub> and 0.06 MMTCO<sub>2</sub>e of CH<sub>4</sub> in 1990. The Residential sector produced 29.1 MMTCO<sub>2</sub>e of CO<sub>2</sub> and 0.5 MMTCO<sub>2</sub>e of CH<sub>4</sub>. Both sectors emitted very little N<sub>2</sub>O as a by-product of fuel combustion.

The Industrial sector, which includes cement production, landfills and petroleum refining, emitted a substantial amount of greenhouse gases in 1990, 103.0 MMTCO<sub>2</sub>e. More than 70 percent of these emissions are due to fuel combustion.

## **V. PRELIMINARY 2020 GREENHOUSE GAS PROJECTIONS**

As ARB develops the Scoping Plan, which identifies actions for reducing greenhouse gases to the 1990 level, it will be necessary to estimate a projected 2020 business-as-usual statewide emissions estimate of total greenhouse gases. Business-as-usual emissions estimates are the levels anticipated to occur in the absence of additional policies and measures aimed at reducing future emissions. Projections are based on forecasted demographic and economic growth.

A 2020 business-as-usual forecast will be included in the 2008 Scoping Plan. For Scoping Plan development, staff has calculated a preliminary net business-as-usual emissions estimate for 2020, which is approximately 600 MMTCO<sub>2</sub>e. The difference between the proposed 1990 emissions level and ARB's preliminary estimate of 2020 emissions is therefore 173 MMTCO<sub>2</sub>e. This number will be refined in the final Scoping Plan.



## **VI. CONCLUSIONS**

Staff estimates that the 1990 statewide emissions level was 427 MMTCO<sub>2</sub>e. Staff proposes that the Board approve 427 MMTCO<sub>2</sub>e as California's greenhouse gas emissions limit for 2020.

The total reductions needed to achieve a level of 427 MMTCO<sub>2</sub>e by 2020 are determined from the difference between the projected 2020 business-as-usual emissions level and the proposed 2020 limit of 427 MMTCO<sub>2</sub>e. Staff developed a preliminary estimate of approximately 600 MMTCO<sub>2</sub>e for the 2020 business-as-usual projection. This 2020 business-as-usual estimate will continue to be assessed during development of the Scoping Plan in 2008.

Staff will continue to work to improve our greenhouse gas inventory methods and data as we develop annual greenhouse gas inventories. If additional information becomes available that would significantly alter the total emissions for 1990, staff will bring a revised 1990 emissions level back to the Board for consideration.

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