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California Environmental Protection Agency

Air Resources Board

California's 2000-2014 Greenhouse Gas Emissions Inventory

2016 Edition

Inventory Updates Since the 2015 Edition of the Inventory

Supplement to the Technical Support Document

State of California
Air Resources Board
Air Quality Planning and Science Division

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June 2016

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INTRODUCTION

Assembly Bill 1803 gave California Air Resources Board (ARB) the responsibility of preparing and updating California's greenhouse gas (GHG) inventory to track the State's progress in reducing GHG emissions. The GHG inventory is a critical piece, in addition to California Global Warming Solutions Act (AB 32) program data, in demonstrating the State's progress in achieving the 2020 statewide GHG target.[1] The 2016 edition of California's GHG inventory covers emissions for 2000 through 2014 and includes inventory improvements and accounting method updates.

The GHG inventory was developed according to the *Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories* (IPCC Guidelines)(IPCC, 2006), which are the internationally recognized standard for developing national GHG inventories. Since the 2015 edition of the inventory (2000-2013 emissions), staff has made several improvements to the inventory. These include updates to inventory categories, emissions estimation methods, and data sources, as well as emissions classification to align with international and national inventory practices. This document provides a description of the inventory updates since the previous edition of the inventory.

Each release of the California inventory incorporates the latest available data sources and current scientific understanding of GHG emissions. The IPCC guidance for GHG inventories states that it is good practice to recalculate historic emissions when methods are changed or refined, when new source categories are included in the inventory, or when errors in the estimates are identified and corrected. Consistent with the IPCC Guidelines, recalculations are made to incorporate new methods or to reflect changes in statistical data supplied by other agencies for all years from 2000 to 2014 to maintain a consistent time-series of estimates within the inventory. Therefore, emission estimates for a given calendar year may be different between editions as methods are updated or if the data source agencies revise their data series.

In the sections to follow, a background on each updated category is presented followed by a description of the update. The sections in this document are organized by the hierarchical structure of IPCC inventory categorization (as shown in the Table of Contents). For reader's convenience, a table summarizing inventory updates organized by AB 32 Scoping Plan sector category is provided on the next 2 pages.

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[1] As part of the 2030 Target Scoping Plan Update, to better track progress towards achieving our statewide GHG targets, ARB will be exploring how to structure a separate accounting framework that uses the GHG inventory, but incorporates GHG emissions related to land use conversion when biofuels are produced and supplied to California as a result of our Low Carbon Fuel Standard. ARB will also be exploring how flows of cap-and-trade program compliance instruments between California and Québec can be incorporated into such an accounting framework.

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SUMMARY LIST OF UPDATES

Scoping Plan Sector Category	Description of Update	IPCC Category	Section Number In This Documentation
Electricity	Add a new category for biomethane combustion to distinguish from generic biomass fuel combustion	Energy	A.1
Electricity	Track biogenic CO2 from imported electricity as part of the "biogenic CO2 emissions", consistent with the Mandatory GHG Reporting Regulation (MRR) data.	Energy	A.2
Transportation	Separate emissions from heavy duty trucks, buses, and motorhomes into three categories to allow independent tracking of each vehicle type	Energy	A.4
Transportation	Add new fuel categories for biodiesel, renewable diesel, and biomethane fuel combustion to distinguish from their generic fuel blends	Energy	A.5
Transportation	Reclassify carbon dioxide (CO2) from combustion of biofuels (ethanol, biodiesel, renewable diesel, and biomethane) as "biogenic CO2"	Energy	A.6
Transportation	Add new on-road unspecified diesel category	Energy	A.7
Transportation	Use interim emission estimation methodology for ocean going vessels due to unavailability of 2014 data	Energy	A.8
Industrial	Correct a typo in IPCC code assignment	Energy	A.3
Industrial	Reclassify natural petroleum seeps as "excluded" emissions	Energy	A.9
Industrial	Use interim emission estimation methodology for CO2 consumption due to unavailability of 2014 data	Industrial Processes and Product Use	B.2
High GWP	Update estimation of emissions from semiconductor operations to incorporate revised ARB survey data	Industrial Processes and Product Use	B.1
High GWP	Update estimation of emissions from ozone depleting substance (ODS) substitutes using new data reported by users of ODS substitutes under the Refrigerant Management Program	Industrial Processes and Product Use	B.3
Agriculture	Revise cattle population estimates used for manure and enteric fermentation emission estimates	Agriculture, Forestry and Other Land Use	C.1
Agriculture	Use interim emission estimation methodology for cattle emission factors due to unavailability of 2014 data	Agriculture, Forestry and Other Land Use	C.1

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Scoping Plan Sector Category	Description of Update	IPCC Category	Section Number In This Documentation
Agriculture	Disaggregate soil management N2O emissions from managed and unmanaged manure applied to soils into sub-categories by detailed animal type	Agriculture, Forestry and Other Land Use	C.2
Recycling & Waste	Incorporate new CalRecycle 2014 waste characterization into landfill model for years 2012 through 2014.	Waste	D.1
Recycling & Waste	Update emission estimation for domestic wastewater treatment with anaerobic digester using California-specific activity data	Waste	D.2
Recycling & Waste	Update emission estimation for domestic wastewater effluent using California-specific activity data	Waste	D.3
Recycling & Waste	Update industrial pulp & paper wastewater treatment emissions with California-specific activity data	Waste	D.4

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Description of Inventory Updates

A. Energy

1. In-State Electricity Generation (IPCC 1A1a): Distinguish Biomethane Fuel from Generic Biomass Fuel

1.1 Background

After the Mandatory GHG Reporting Regulation (MRR) program started to collect data on the amount of biomethane supply purchased by in-state power plant operators in 2013, staff incorporated the facility-reported biomethane quantities (ARB, 2015a) into the GHG inventory. The CO_2 emissions from biomethane have been classified the same way as combustion of other biomass-derived fuels, as "biogenic CO_2" in the excluded inventory. However, in previous editions of the inventory, biomethane is rolled under the umbrella of generic biomass fuel category called "biomass" and was not a distinct fuel category of its own. To better support program data needs, a new fuel category "biomethane" has been added to the 2016 edition of the inventory to distinguish between biomethane purchases from other types of biomass fuel (such as wood waste combustion).

1.2 Fuel Category Update

A new fuel category named "biomethane" has been added to the inventory. This change involves disaggregating biomethane from the generic "biomass" fuel category and is an update to the emission activity category name. All methodology, data sources, and emissions classification are the same as in previous inventory editions.

2. Imported Electricity (IPCC 1A1ai): Informational Item Added for Biogenic CO_2 Emissions

2.1 Background

Imported electricity emissions are not under the usual domain of state inventories as defined by the state borders, but AB 32 specified that imported electricity must be included in California's GHG inventory. This accounting initially included only non-biogenic CO_2, CH_4, and N_2O emissions, but not biogenic CO_2 from combustion of biomass-derived fuels. To maintain

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consistency with MRR data, which collects information on biogenic CO_2 emissions from imported electricity, these emissions have been added to the "biogenic CO_2" portion of the excluded inventory. These emissions are not included in the GHG inventory but are separately tracked as informational items.

2.2 Update to Excluded Inventory

The same methodology used to calculate imported electricity emissions of other pollutants was used to calculate biogenic CO_2 emissions. Each specified import source is mapped to its corresponding U.S. Energy Information Administration (EIA) ID number, and the net generation (MWh) and fuel use by fuel type data from EIA for each power plant are used (EIA, 2015b). Emissions of non-biogenic CO_2, biogenic CO_2, CH_4 and N_2O are calculated from fuel use quantity using the default MRR emission factors (ARB, 2015a). These emissions are then divided by the net generation in MWh to obtain the plant-specific emission factor for each pollutant. This plant-specific emission factor is multiplied by the associated imported MWh to arrive at the biogenic CO_2 emissions.

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3. Industrial Fuel Combustion (IPCC 1A2m): IPCC Code Correction

3.1 Background

California's GHG inventory categorizes emissions using IPCC methodology to allow comparison with national and international inventories. The inventory catalogs emission sources and activities using the system of category codes defined in the IPCC Guidelines (IPCC, 2006). In the 2015 edition of the GHG inventory, two new categories were added to capture the coal and coke fuel use reported to the MRR program that were not already included in the petroleum refining, hydrogen production, cement production, and electricity generation sectors in the GHG inventory. However, typographical errors were made in assigning IPCC codes to these two new categories last year. The typographical errors are corrected in the 2016 edition of the inventory. This update does not affect emissions quantification or methodology.

3.2 Activity Code Update

Two new industrial fuel combustion categories added in the 2015 edition GHG inventory (sector activity codes 30-20-99-99-01-001 and 30-20-99-99-01-042) were assigned incorrect IPCC codes. The IPCC code was changed from 1A3 to 1A2m in this version of the GHG inventory.

4. On-Road Transportation (IPCC 1A3biii): Disaggregation of Heavy Duty Vehicle Category

4.1 Background

In previous editions of the GHG inventory, the on-road heavy duty vehicle category was a combination of trucks, buses, and motorhomes grouped into one inventory category. To better support program data needs, the 2016 edition of the GHG inventory disaggregates the previous heavy duty vehicle category into the three vehicle subcategories so that they can be tracked and analyzed separately.

4.2 Disaggregation of Inventory Category

Calculating emissions of the three heavy duty vehicle subcategories utilizes the same data sources and methodology as other on-road categories. For on-road categories, staff uses the relative proportion of fuel use amounts modeled by ARB's EMission FACtors model (EMFAC) to apportion the total fuel sales data (for gasoline and distillate) to the different categories of vehicles (ARB 2015b). EMFAC modeled outputs for the amount of fuel combusted are scaled to match fuel sales numbers obtained from the California BOE (BOE 2015). See the GHG inventory Technical Support Document (ARB, 2014b) for a detailed description of the methodology.

The fuel used by trucks, buses, and motorhomes is already segregated in the EMFAC model. In previous inventory editions, more detailed fuel use by heavy duty vehicle category was inventoried without specifying emissions for each heavy duty vehicle sub-type. In this inventory edition, fuel use quantities were disaggregated further so emissions could be calculated and inventoried more specifically to each of the three sub-categories. Emissions for each vehicle type are calculated using the same fuel-specific emission factors and heat content as in previous inventory editions. As with other on-road categories, the fuel amounts provided by EMFAC 2014 are normalized to total fuel sales reported by BOE.

4.3 Data sources

The relative proportion of gasoline and diesel consumed by each vehicle type is provided by EMFAC 2014 (ARB, 2015b). The total fuel sales are from the California BOE (Covert, 2013, BOE, 2015). Default fuel heat contents are consistent with those used by the mandatory GHG reporting programs of ARB and U.S. Environmental Protection Agency's (USEPA) (40 CFR 98, Subpart C) (ARB, 2015a). Default CH_4 and N_2O emission factors are from EMFAC 2014 (ARB, 2015b), and default CO_2 emission factors are consistent with those used in the mandatory GHG reporting programs of ARB and USEPA (USEPA, 2012,

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ARB, 2015a) but with an adjustment made to correct for denaturants (gasoline, water, and methanol) in ethanol. Gasoline and ethanol CO_2 emission factors are discussed in Section I.C.3 of the inventory Technical Support Document (ARB, 2014b).

5. On-Road Transportation (1A3): Disaggregate Biofuels from Generic Fuel Blends

5.1 Background

Most California transportation fuels consist of a blend of fossil-derived component and bio-derived or renewable component. Ethanol is the most commonly used biofuel, comprising approximately 10 percent of total gasoline fuel blend in California, and has already been separated from the fossil component of gasoline fuel in previous editions of the GHG inventory. Other biofuels, such as biodiesel, renewable diesel, and biomethane (also known as renewable natural gas) were not separated from the generic diesel or generic natural gas category in previous inventory editions. Biodiesel and renewable diesel components of diesel fuel are currently at 6% of diesel blend, while biomethane comprises a small fraction of current natural gas blends. They are projected to grow going forward in response to the federal Renewable Fuel Standard and California Low Carbon Fuel Standard. This edition of California's GHG inventory breaks out emissions from biodiesel, renewable diesel, and biomethane from generic fuel categories for the first time.

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5.2 Disaggregation of Fuel Categories

The California BOE provides data for total diesel blend, biodiesel and renewable diesel volumes used in California (Covert, 2013, BOE, 2015). The biodiesel and renewable diesel totals are subtracted from the total diesel blend volume, and the remainder is considered the fossil portion. Emissions from combustion of biodiesel and renewable diesel are calculated using the same methodology as for generic diesel fuel as described in the inventory Technical Support Document (ARB, 2014b).

The EIA reports total pipelined natural gas used for on-road transportation in California (EIA, 2015a). The total pipelined natural gas volume reported by EIA represents a mixture consisting of both biomethane and fossil natural gas, but the relative fraction of each is not reported. California's biomethane volume is reported to the Low Carbon Fuel Standard (LCFS) program (ARB, 2016) and can be segregated into two categories: pipelined and non-pipelined biomethane. Non-pipelined biomethane includes the portion delivered directly from the gas producer to refueling stations, thus not entering the natural gas pipeline. The

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pipelined biomethane for transportation use is subtracted from the total pipelined natural gas reported by EIA, and the remaining pipelined natural gas is attributed to fossil natural gas combustion for on-road transportation. Biomethane combustion emissions are calculated using the same methodology as for other on-road sources, using emission factors and heat contents consistent with the mandatory GHG reporting programs of ARB and USEPA (USEPA, 2012, ARB, 2015a), except that CH_4 and N_2O emission factors are from EMFAC 2014 (ARB, 2015b).

6. On-Road Transportation(1A3): Reclassification of Transportation Biofuel CO_2

6.1 Background

In previous editions of the GHG inventory, the biofuel components of diesel and natural gas (use by natural gas vehicles) were not explicitly broken out from the generic diesel and natural gas fuel categories; and the ethanol component of gasoline blend was broken out in the inventory but not classified as a biogenic source of emissions. Therefore, the biofuel components of fuel combustion CO_2 emissions were accounted for and summed together with the fossil fuel emissions. Reclassification of transportation biofuels as a biogenic source of emissions aligns with the existing treatment of stationary biofuel combustion in the inventory, as well as IPCC Guidelines (IPCC, 2006) for GHG inventory development, the USEPA national GHG inventory, and other nations' inventories submitted to the United Nations Framework Convention on Climate Change (UNFCCC). Following the IPCC Guidelines ensures consistency and comparability with other subnational and national inventories.

6.2 Reclassification of Emissions

The inventory update for transportation biofuels is already described in Section A.6. These biofuel CO_2 emissions are now reclassified under the "biogenic CO_2" part of the excluded inventory and will continue to be tracked as separate informational line items. Users can access excluded emission categories in the published inventory summary tables as well as the detailed inventory spreadsheets available on the GHG emission inventory program webpage (ARB, 2016b).

7. On-Road Transportation (IPCC 1A3): Addition of Unspecified Distillate Category

7.1 Background

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The California BOE tracks distillate fuel used by on-road transportation sources in California. Other agencies (such as the EIA) track distillate fuel used in non-road applications. A portion of distillate fuel purchased from on-road fuel suppliers is initially reported to BOE as on-road end use, but is then later excluded from BOE totals because the end user reports its use as non-road. This fuel is purchased in California, but has been excluded from the on-road totals published by BOE and is not included in the non-road totals published by other agencies. BOE tracks this fuel volume but does not typically publish the data annually. For the 2016 edition of the inventory, ARB obtained the unpublished data from BOE and added the volumes back into the GHG inventory, but placed in a new unspecified diesel category.

7.2 Inventory Update

For the 2016 edition of the GHG inventory, ARB staff obtained additional data from BOE that show further details beyond those that BOE typically publishes annually (BOE, 2016). The more detailed BOE dataset has four categories of exempt fuel that would not be captured by other agencies and need to be added back into the inventory: *Government Entity*, *Highway Vehicle Operator*, *Miscellaneous*, and *User Refunds*. In addition, the *User Refunds* category has the following subcategories: *Used in Construction Equipment*, *Used to Operate Power Take-Off Equipment*, and *Used for Other Non-Taxable Uses*. The *Used in Construction Equipment* and *Used to Operate Power Take-Off Equipment* portions are already accounted for by ARB models (Off-Road In Use Fuels Model and EMFAC respectively) and are already incorporated into the inventory; therefore, staff does not double count these volumes in the inventory. The *Used for Other Non-Taxable Uses* category is the difference between the *User Refunds* total and the sum of the *Used in Construction Equipment* and *Used to Operate Power Take-Off Equipment* amounts, but no additional information is known about the actual end use application of this fuel.

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However, the BOE data are incomplete for 2011-2014 for the construction and power take-off categories due to a change in reporting. BOE is in the process of doing data correction, but in the meantime, ARB staff has used data up to 2010 to generate a power extrapolation for estimating the 2011-2014 amounts for these categories. The *Used for Other Non-Taxable Uses* category is also adjusted by this extrapolation since it is derived from the difference between *User Refunds* and the two subcategories of *Used in Construction Equipment* and *Used in Power Take-Off Equipment*.

The sum of the four categories, *Government Entity*, *Highway Vehicle Operator*, *Miscellaneous*, and *User Refunds*, is used for the data available from BOE which spans 2007-2014 as the basis for the amount to be added back into the inventory. To estimate the amounts for 2000-2006, the average of 2007-2010 was used as a simplistic and transparent estimation approach in the absence of better data. Years 2011-2014 were not included in this average as it contained values derived from the power extrapolation, so the range of 2007-2010 was chosen as the range on which to base this average.

The emissions are calculated using the same method as for other distillate fuel categories in the inventory. The default heat content and emission factors from the mandatory GHG reporting programs of ARB and USEPA are used to convert the gallons of fuel from BOE into emissions (USEPA, 2012, ARB, 2015a).

8. Off-Road Transportation: Ocean Going Vessels (IPCC 1A3d): Interim Emission Estimation

8.1 Background

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The GHG inventory's water-borne navigation sector includes emissions from shipping activities in California or within 24 nautical miles of the coast. Ocean going vessels (OGV) are a subcategory of water-borne navigation. In previous inventory editions, staff utilizes ARB's OGV model based on geographically specific shipping activity data (ARB, 2010b; ARB, 2011b). Staff apportioned distillate and residual fuel oil used by the model outputs for marine vessels for port activities, harbor craft, transit (within 24 nautical miles from California's coast) and travel outside of California waters among intrastate, interstate and international activities. Emissions are then calculated from the estimated fuel use quantities. At the time of GHG inventory compilation, the OGV model was in the process of being updated and the 2014 activity data were not yet available; therefore, staff used an interim emission quantification methodology to estimate 2014 emissions. For bunker fuel volume purchased in California in excess of the volume modeled by the OGV model, emission calculation methodology and emission classification are the same as in previous inventory editions.

8.2 Interim Emission Estimation Methodology

Methodology for 2000 through 2013 emissions from ocean going vessels remains the same as the previous inventory, but 2014 activity data were not yet available at the time of inventory development. To estimate 2014 emissions, a growth factor surrogate was calculated from the twenty-foot equivalent unit (TEU) container activities at the three largest ports in California. TEU activities for the ports of Oakland (PO, 2016), Los Angeles (PLA, 2015), and Long Beach (PLB, 2015) were compiled for 2013 and 2014. The relative change in activity for 2013 to 2014 was used as a growth surrogate for 2014 emissions, calculated based on 2013 emissions.

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9. Oil and Gas— Petroleum Seeps (IPCC 1B2): Reclassification of Emissions

9.1 Background

Petroleum seeps were previously included in the inventory as part of oil and gas fugitives. Petroleum seeps are a natural emission source. The IPCC Guidelines do not identify petroleum seeps as an emission source to be quantified, nor are they included in USEPA's national GHG inventory. Reclassification of petroleum seeps as "excluded" emissions is therefore consistent with the IPCC framework and the inventories of USEPA and other nations.

9.2 Reclassification of Emissions

There is no change to emission calculation methodology and data source. Petroleum seeps emissions are now reclassified as excluded emissions in the inventory and will continue to be tracked as separate informational line items. Users can access excluded emission categories in the published inventory summary tables as well as the detailed inventory spreadsheets, available on the GHG emission inventory program webpage (ARB, 2016b).

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B. Industrial Processes and Product Use

1. Electronics Industry - Semiconductor Operations (IPCC 2E)

1.1 Background

Semiconductor operations use fluorinated greenhouse gases in the etching or chemical vapor deposition (CVD) chamber cleaning processes. Semiconductor operations consist of the processing of semiconductor devices or related solid state devices. It may include, but is not limited to, the processing of diodes, zeners, stacks, rectifiers, integrated microcircuits, transistors, solar cells, light-sensing devices, and light-emitting devices.

1.2 Emissions Estimation

For regulatory purposes, ARB staff conducted a survey in 2007 to collect 2006 data from semiconductor operations in California that used fluorinated gases or fluorinated heat transfer fluids in the etching or CVD chamber cleaning processes (ARB, 2007; ARB, 2015c). ARB staff used the survey data

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to determine the 2006 emissions. The kilograms (kg) of emissions were determined using the Tier 2b methodology in the 2006 IPCC Guidelines (IPCC, 2006). Kilograms of emissions were converted to million metric tons of carbon dioxide equivalent (MMT CO_2e) using the IPCC 1996 Second Assessment Report GWP values for all fluorinated gases with the exception of NF_3 which was based on the GWP value from the IPCC Fourth Assessment Report.

For inventory purposes and to be consistent with the IPCC, the carbon dioxide equivalent emissions are calculated using IPCC Fourth Assessment Report GWP values. To determine California (CA) emissions in other years, the ratio between 2006 CA emissions and United States (US) emissions was used to apportion US emissions to CA. In the absence of more accurate data, this emissions estimation method uses the emissions from the USEPA's annual national GHG inventory in Table 4-91 (USEPA, 2015a) as surrogates, and assumes that the CA/US ratio in 2006 also provides an approximate apportionment for other years. Equation 1 is used to calculate emissions for each GHG.

Equation 1: Emissions from semiconductor operations[2]

$$\boxed{E_{CA,\,GHG} = E_{US,\,GHG} \bullet \left(\frac{S_{CA,2006}}{E_{US,2006}} \right)}$$

Where,

$E_{CA,\,GHG}$	= Emissions of a particular fluorinated gas from semiconductor operations in California (g)
$E_{US,\,GHG}$	= Emissions of the particular fluorinated gas from semiconductor manufactures in the entire US (g)
$S_{CA,2006}$	= 2006 survey of emissions of a particular fluorinated gas from semiconductor operations in California (g)
$E_{US,2006}$	= 2006 emissions of the particular fluorinated gas from semiconductor manufactures in the entire US (g)
GHG	= [CF_4, C_2F_6, C_3F_8, C_4F_8, HFC-23 (CHF_3), SF_6, NF_3]

For the 2016 edition of the inventory, ARB staff revised the 2006 emission data to reflect a clarification in the IPCC Tier 2b methodology in calculating emissions and by-product emissions (ARB, 2015c). Although this change revised the emissions estimate, it did not impact the 2006 survey conclusion used to develop the regulation.

[2] Air Resources Board uses term "semiconductor operations" whereas United States Environmental Protection Agency uses "semiconductor manufactures."

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The ratio of CA/US emissions for the 2006 year in Equation 1 is updated to the revised 2006 emissions derived from the survey data.

2. Carbon Dioxide Consumption (IPCC 2G4a): Interim Emission Estimation

2.1 Background

Carbon dioxide (CO_2) is used in a variety of processes including food processing, carbonated beverages, and refrigeration. The CO_2 used in these applications is eventually released to the atmosphere, thus is a source of GHGs. CO_2 consumption data is acquired from the USEPA GHG inventory (USEPA, 2015a) and scaled to California using population. USEPA is in the process of updating the national CO_2 consumption emission estimates, but had not finalized the inventory by the time California's inventory was compiled. Therefore, staff used an interim emission quantification methodology to estimate CO_2 consumption emissions for the 2016 edition of the inventory.

2.2 Interim Emission Estimation Methodology

Draft CO_2 consumption data from USEPA (USEPA, 2016) indicate a growth of 7.1 percent between 2013 and 2014; therefore, this growth surrogate was used to estimate California's 2014 CO_2 consumption emissions. Emissions for all other years are the same as in the previous inventory editions. Emissions from this category will be revisited next year to incorporate the latest updates from USEPA.

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3. Use of ODS Substitutes (IPCC 2F): Incorporation of Latest Data

3.1 Background

Ozone-depleting substances (ODS) are being phased out under the terms of the Montreal Protocol and the Clean Air Act Amendments of 1990. Many of the substances approved to replace ODS are themselves GHGs including hydrofluorocarbons (HFC) and perfluorocarbons (PFC). As ODS use declines, the emissions of their replacements show an increasing emission trend.

3.2 Inventory Update

The underlying activity as well as assumptions about the mix of ODS substitutes used in a given technology were updated to use the most currently available California-specific data. Assumptions about refrigerant type and usage for estimating commercial refrigeration emissions have been updated using data reported to ARB through the Refrigerant Management Program (RMP)(ARB, 2014a). In addition, assumptions to estimate emissions from residential refrigerator-freezers, consumer aerosol propellants, and medical dose inhaler (MDI) propellants were revised to reflect lower actual usage based on data from the Department of Energy (USDOE, 1997), the ARB 2006 Consumer Products Survey (ARB, 2006), and data reported by the United Nations Environment Programme (UNEP) for MDI propellants (UNEP, 2010, UNEP, 2011, UNEP, 2013).

C. Agriculture, Forestry and Other Land Use

1. Enteric Fermentation (IPCC 3A1) and Manure Management (IPCC 3A2): Update Dairy Population Estimation and Interim Emission Estimation

1.1 Background

The microbial fermentation that occurs in the digestive system of some animals is called enteric fermentation. It is a normal digestive process during which microbes break down indigestible carbohydrates (e.g., cellulose, hemi-cellulose) and reprocess them into nutrients that can be absorbed by the animal. This microbial fermentation process produces CH_4 as a by-product, which is then exhaled, eructated or passed out as gas by the animal. The amount of CH_4 produced and emitted by an animal depends on its anatomy and the amount and type of feed it consumes.

1.2 Interim Emission Estimation Methodology

The 2016 edition of the GHG inventory uses the USEPA Cattle Enteric Fermentation Model (CEFM) (Wirth, 2015) and manure management assumptions as in previous inventories. However, certain constant parameters within the models showed unusual trends in the most recent version of the model provided by USEPA. The data could not be verified before publication of California's GHG inventory; therefore, staff elected to keep the parameters consistent with previous inventory versions. These data will be revisited in future GHG inventories.

1.3 Update Dairy Population Estimate

The data source for dairy livestock populations was updated to better incorporate the current knowledge of California's diary population. Dairy cattle population is from the U.S. Department of Agriculture (USDA) census (USDA, 2015), which is compiled every 5 years. For the intermediate years that the USDA census does not cover, staff used the trends in CDFA annual population

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estimates (CDFA, 2015) to map to USDA 5-year census data to complete the time series.

2. Nitrous Oxide from Soil Management – Manure (IPCC 3C4 & 3C5): Disaggregation of Category

2.1 Background

The large scale input of nitrogen into soils has greatly increased the nitrogen availability for microbial processes such as nitrification and denitrification. N_2O is an intermediate gaseous product of denitrification and a by-product of nitrification that leaks from microbial cells into the soil and ultimately into the atmosphere. There are many sources of nitrogen input into soils aside from synthetic fertilizers, including managed and unmanaged manures from livestock. Past versions of the inventory included all animal types in managed manure emissions, and broke out unmanaged manure into two groups 1) cattle, swine, and poultry and 2) sheep, goats, and horses. This version of the inventory provides more detailed disaggregation to allow tracking and analysis by animal type. There are now six animal subcategories: beef cattle; dairy cows; dairy heifers; poultry; sheep, goat, horse; and swine.

2.2 Disaggregation of Inventory Category

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Emission calculation methodology is the same as in previous inventory editions, but includes information for more detailed animal subtypes. As described in more detail in the Technical Support Document (ARB, 2014b), the nitrogen applied to soils from managed manure is calculated as the total nitrogen excreted by animal groups in manure management systems minus the amount of nitrogen lost to volatilization, runoff and direct N_2O emissions during the manure management phase. The nitrogen in un-managed manure is equal to the total nitrogen excreted by animal groups depositing their urine and dung directly on the land (i.e. pasture, rangeland and paddocks) and animal groups whose manure is spread daily. Input data for these calculations are provided by USEPA (USEPA, 2015b) by detailed animal subtype, and is already disaggregated according to the new groupings. Therefore, this update is not a methodological update, but a disaggregation of an existing category into further details.

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D. Waste

1. Landfills (IPCC 4A1): Incorporate Latest Waste Characterization Profiles

1.1 Background

Landfills are sites for solid waste disposal in which refuse is buried between layers of dirt. Ninety-five percent of the waste-in-place contained in these landfills is in landfills with a gas collection system that reduces methane emissions by combusting collected landfill gas. Landfilled carbon-bearing waste degrades mainly through anaerobic biodegradation. In an anaerobic environment (i.e., without oxygen from the air), water is the source of oxygen for oxidation and becomes the limiting reactant for biodegradation. The water content of a landfill determines how fast the waste degrades. If water is not available, the waste does not degrade and does not continue to generate methane.

1.2 Inventory Update

The waste deposited each year is provided by The Department of Resources Recycling and Recovery (CalRecycle) Solid Waste Information System (SWIS) database. The annual waste quantity is converted into amount of degradable carbon using waste characterization profiles also provided by CalRecycle (CalRecycle, 2014).

CalRecycle's 2014 waste characterization was made available in 2015, and is used for years 2012+ in this edition of the GHG inventory. A summary of all waste characterization profiles, and the associated inventory years can be found in Table 1.

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Table 1: Waste Characterization Profiles

Waste Component	Up to 1964	1965 -1974	1975 -1984	1985 -1992	1993 -1995	1996 -2002	2003 -2006	2007-2011	2012 +
Newspaper	6.4%	6.4%	5.9%	4.8%	3.9%	4.3%	2.2%	1.2%	1.5%
Office Paper	10.7%	11.3%	12.0%	13.1%	15.0%	4.4%	2.0%	0.7%	0.7%
Corrugated Boxes	10.8%	13.5%	11.5%	10.5%	10.3%	4.6%	5.7%	3.7%	3.1%
Coated Paper	2.2%	2.0%	2.4%	2.1%	1.8%	16.9%	11.1%	11.2%	12.0%
Food	14.8%	11.3%	9.5%	12.1%	13.4%	15.7%	14.6%	16.5%	18.1%
Grass	12.1%	10.3%	10.1%	9.0%	6.6%	5.3%	2.8%	3.4%	3.8%
Leaves	6.1%	5.1%	5.0%	4.5%	3.3%	2.6%	1.4%	2.8%	3.1%
Branches	6.1%	5.1%	5.0%	4.5%	3.3%	2.4%	2.6%	1.8%	1.7%
Lumber	3.7%	3.3%	5.1%	7.0%	7.3%	4.9%	9.6%	13.7%	11.9%
Textiles	2.1%	1.8%	1.7%	3.3%	4.5%	2.1%	4.4%	5.6%	5.8%
Diapers	0.1%	0.3%	1.4%	1.6%	1.9%	6.9%	4.4%	3.7%	4.3%
Construction/Demolition	2.6%	2.5%	3.5%	3.9%	4.5%	6.7%	12.1%	9.8%	8.0%
Medical Waste	-	-	-	-	-	0.0%	0.0%	0.1%	0.1%
Sludge/Manure	-	-	-	-	-	0.1%	0.1%	0.7%	0.6%

* Dash indicates no data available; percentage assumed to be zero.

The detailed methodology for calculating the degradable carbon in the waste can be found in the inventory Technical Support Document (ARB, 2014b). For comparison, the overall carbon balance calculated using each waste characterization profile is presented in Table 2. The previous 2008 profile yielded an overall percent degradable carbon of 7.23%, while the latest 2014 profile shows 7.33%, indicating a slight increase in methane generating potential of recent deposited waste. As a result, landfill emissions for 2012 and 2013 in the 2016 inventory edition are revised to slightly higher values as compared to the 2015 edition of the GHG inventory.

Table 2. Carbon Balance of Overall Waste in Place

Waste Type	Up to 1964	1965 - 1974	1975 - 1984	1985 - 1992	1993 - 1995	1996 - 2002	2003 - 2006	2007 - 2011+	2012 +
Biodegradable	23.16%	22.90%	22.86%	23.32%	22.95%	20.77%	18.87%	19.24%	19.14%
Decomposable	*10.45%*	*10.44%*	*10.34%*	*11.02%*	*11.62%*	*8.42%*	*7.45%*	*7.23%*	*7.33%*
Sequestered	*12.71%*	*12.46%*	*12.52%*	*12.30%*	*11.33%*	*12.35%*	*11.42%*	*12.01%*	*11.81%*
Other Materials	76.84%	77.10%	77.14%	76.68%	77.05%	79.23%	81.13%	80.76%	80.86%

2. Domestic Wastewater: Anaerobic Digesters (IPCC 4D1): Incorporate California-Specific Information

2.1 Background

Methane emissions from wastewater are estimated from the volume of wastewater generated, organic loading in wastewater (measured in biochemical oxygen demand (BOD) or chemical oxygen demand (COD)), and percentage of wastewater that is centrally treated (aerobic or anaerobic systems), anaerobically digested or treated in septic systems. Methane is emitted from

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wastewater when it is treated in anaerobic conditions. Nitrous oxide is emitted as the result of the nitrification and denitrification processes, which take place at wastewater treatment plants, but also in the water bodies where effluent is discharged.

2.2 Emission Estimation

Anaerobic digestion occurs naturally in the absence of oxygen as bacteria break down organic materials and produce biogas, which can be used as an energy source. Methane emissions from the treatment of anaerobic digesters are estimated using the following equations. In this edition of the inventory, the following equations were not updated, but updates were made to the data sources.

Equation 2: CH_4 emissions from Anaerobic Digesters

$$E_{Digester,CH4} = V_{biogas} \bullet f_{CH4} \bullet 0.02831 \bullet 662 \bullet (1 - D_{CH4})$$

Equation 3: Volume of biogas produced in anaerobic digesters

$$V_{biogas} = W_{Digester} \bullet \frac{R_{biogas}}{R_{wastewater}} \bullet 365.2425$$

$E_{Digester,\ CH4}$	= Emissions from Anaerobic Digesters (gram)
V_{biogas}	= Volume of biogas produced (ft^3)
f_{CH4}	= Fraction of methane in biogas (unitless)
0.02831	= Factor used to convert between m^3 and ft^3 (m^3/ft^3)
662	= Density of methane (g/m^3)
D_{CH4}	= Methane destruction efficiency from flaring or burning in engine (unitless)
$W_{Digester}$	= Total wastewater flow to treatment plants that have anaerobic digesters (gal)
R_{biogas}	= Rate of per capita digester gas production (ft^3/person/day)
$R_{wastewater}$	= Rate of per capita wastewater production (gal/person/day)
365.2425	= Average number of days produced per year

In previous editions of the inventory, the total wastewater flow to treatment plants that have anaerobic digesters ($W_{Digester}$) was obtained using national wastewater flow data from USEPA. The national wastewater flow (gallons per day) was scaled to state-level wastewater flow using CA/US population ratio. However, for this edition of the inventory, staff obtained 2014 California-specific wastewater flow data (gallons per day) for all the wastewater treatment facilities in California that have anaerobic digesters. The data were obtained from USEPA staff by email communication (USEPA, 2015).

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3. Domestic Wastewater: Effluent Emissions (4D1): Incorporate California-Specific Information

3.1 Background

Emissions of nitrous oxide occur from wastewater within treatment plants and from nitrogen in effluent discharged to surface waters. Nitrogen in effluent is estimated based on protein excretion by humans, less the sewage sludge removed from the treatment plant, which is used for land application, composted, or landfilled. The nitrogen in that sludge does not enter the waterbodies. Emissions of N_2O and CH_4 associated with the various pathways of sludge use are calculated as part of other relevant sectors: N_2O from soil management (IPCC 3C4 & 3C5), composting (IPCC 4b), and landfills (IPCC 4A1).

3.2 Methodology and Update to Emission Estimation

Effluent emissions ($E_{N2O,\ Effluent}$) are estimated using the following equation:

Equation 4: N_2O emissions from wastewater effluent

$$E_{N2O,Effluent} = \{[(P - (P_{NDN} \bullet 0.9)) \bullet R_{protein} \bullet f_N \bullet F_{NCN} \bullet F_{IC}] - N_{sludge}\} \bullet EF_{effluent} \bullet 1.5711$$

$E_{N2O,\ Effluent}$	= Effluent N_2O emissions (gram)
P	= California population (person)
P_{NDN}	= California population served by biological denitrification (person)
0.9	= Factor to scale the population served by biological denitrification to reflect the amount of N removed by denitrification (unitless)
$R_{protein}$	= Rate of per capita protein consumption (gram/person/year)
f_N	= fraction of N in protein (gram N/gram protein)
F_{NCN}	= Factor for non-consumed protein added to wastewater (unitless)
F_{IC}	= Factor for industrial and commercial codischarged protein into the sewer system (unitless)
N_{sludge}	= Sewage sludge N not entering aquatic environment (gram N/year)
$EF_{Effluent}$	= Emission factor for effluent water (g N_2O-N/ gram sewage N produced)
1.5711	= Molecular weight ratio of N_2O to N_2 (unitless)

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In previous editions of the inventory, nitrogen in sewage sludge not entering waterbodies (N_{sludge}) was obtained using national data from USEPA and was scaled to state-level nitrogen using CA/US population ratio. However, for this edition of the inventory, staff obtained the 2014 California-specific quantity of biosolids for all the wastewater treatment facilities in California that have anaerobic digesters, under section 503 of Clean Water Act. The IPCC Guidelines' default biosolids nitrogen content of 5 percent (IPCC, 2001) was used to establish the amount of nitrogen in biosolids. The data were obtained from USEPA staff by email communication (USEPA, 2015).

4. Industrial Wastewater: Pulp and Paper (IPCC 4D2): Incorporate California-Specific Information

4.1 Background

Methane emissions from the pulp and paper manufacturing industry are included in the industrial wastewater emissions sector. Emissions were calculated by multiplying paper processing activity, wastewater outflow factor (liter/tonne), COD, fraction of COD that is anaerobically degraded during wastewater treatment, maximum methane generation potential, and a methane correction factor. In previous editions of the inventory, pulp and paper processing activity was estimated by a simplistic approach of scaling activity level from USEPA national data (USEPA, 2016) to California using CA/US population ratio. Staff revisited this inventory category this year and identified a way to refine inventory estimation.

A closer examination of the USEPA data revealed that it had included both pulp and paper mills in the estimation of paper processing activity. There are several paper mills but no pulp mills in California. Pulp mill wastewater treatment emits significantly higher methane than paper mill wastewater treatment. As a result, the simplistic estimation approach used in previous inventory editions had overestimated methane emissions from the pulp and paper wastewater sector in California.

4.2 Inventory Update

For the 2016 edition of the GHG inventory, staff obtained California-specific paper production data from the Federal Reserve System via the Center of Paper Business and Industry Studies (CPBIS) at Georgia Institute of Technology (CPBIS, 2015). The California-specific data replace the simplistic estimate derived from CA/US ratio in the wastewater methane emission calculation. Other than this change in data, the method and equation are the same as in the previous inventory editions.

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