California Environmental Protection Agency

Air Resources Board

2015 Edition

California's 2000-2013
Greenhouse Gas Emissions Inventory

Method Updates Since
2014 Edition of the Inventory

Supplement to the Technical Support Document

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

June 2015

INTRODUCTION

The Global Warming Solutions Act of 2006 (AB 32) requires California to reduce greenhouse gas (GHG) emissions to 1990 levels by 2020. Assembly Bill 1803 gave California Air Resources Board (ARB) the responsibility of preparing and updating California's GHG emission inventory, an important tool for establishing historical emission trends and tracking California's progress toward the emission reduction goal.

Since the 2014 edition of the inventory (2000-2012 emissions), staff has made several improvements to emissions estimation methods or data sources. This document provides a description of the update to methods since the previous edition of the inventory. As such, this document serves as a supplement to the methods descriptions found in the 2000-2012 Inventory Technical Support Document (ARB 2013a). The GHG inventory was developed according to the *IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2006), which are the internationally recognized standard for developing national GHG inventories. 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 2013 in order to maintain a consistent time-series of estimates within the inventory.

In the sections to follow, a background of each category is presented followed by a discussion of the updated method used to estimate emissions, including calculation equations and data sources. There is no method update for the Electric Power Sector and the Recycling and Waste Sector. This documentation describes the method updates for the Transportation, Industrial, Commercial and Residential, and Agriculture sectors, as well as High GWP Gases. A summary list of updated methods is provided on page 3.

LIST OF UPDATED METHODS

I. Transportation

- Methane (CH_4) and nitrous oxide (N_2O) emissions from combusting gasoline and diesel fuels in on-road transportation sources are now based on the output of the 2014 version of the EMFAC model.

II. Industrial

- Emissions estimation method for oil and gas production is changed to capture additional fugitive CH_4 emissions that were not captured by the Mandatory GHG Reporting Regulation.
- Emissions estimation method for natural gas pipelines is changed to capture additional fugitive CH_4 emissions that were not captured by the Mandatory GHG Reporting Regulation.
- Process emissions from lead production, a new sector added to the Mandatory GHG Reporting Regulation program, have been added to the GHG emission inventory.
- Methane emissions from wastewater of non-citrus fruit processing plants now exclude apples and wine grapes, which are accounted in a separate category.

III. Commercial and Residential

- The use of nitrogen fertilizer on commercial and residential turf grass has been added as a new inventory category.

IV. Agriculture

- Method for estimating nitrous oxide (N_2O) emissions from fertilizer applied to crops is updated based on crop acreage and recommended fertilizer application rate.

V. High-GWP

- The "Other Ozone Depleting Substances (ODS) substitutes" category in previous editions of the inventory has been disaggregated into individual compounds to provide details on the emissions.

UPDATED METHODS AND SUPPORTING DATA SOURCES

I. Transportation

A. On-Road Transportation Sources: Gasoline and Diesel Fuel Use (IPCC 1A3b)

1. Background

   This category estimates the GHG emissions from combustion of on-road gasoline and diesel fuels. To quantify the CH_4 and N_2O emissions, staff has been using outputs from successive versions of ARB's EMission FACtors (EMFAC) model (2007, 2011, and 2014). The EMFAC model was created by ARB to output California's on-road vehicle emissions for air quality analysis within various geographic regions which can be aggregated statewide. With each new version of the model, pollutant emissions such as CH_4 and NO_x (and consequently N_2O, which is a portion of NO_x) are updated based on the results from ARB's latest tailpipe emissions testing. EMFAC is used because it allows for apportioning of fuel sales data (for gasoline and distillate) among different categories of vehicles, and thus allows for calculating emissions for each class of vehicles. Staff uses EMFAC modeled outputs for the amount of fuel combusted as well as CH_4 and NO_x emissions to form the basis for the GHG emission inventory, which are then scaled so that EMFAC fuel combustion numbers would match fuel sales numbers obtained from the Board of Equalization (BOE).

   The EMFAC model was updated in 2014. The 2014 update embedded previously-external CH_4 speciation emission factors inside the model, as well as updated vehicle population inputs based on the make/model/year-specific vehicle population data from the California Department of Motor Vehicles.

2. Methodology

   For the 2000-2013 edition of the GHG emission inventory, the emission estimation method for on-road transportation sources continues to use the same data sources and method as in previous inventory editions, except that the new 2014 version of the EMFAC model (ARB 2015) is used (EMFAC 2014). In EMFAC 2014, CH_4 outputs are now embedded in the model instead of being derived from an external calculation based on the total organic gas (TOG) emissions from heavy duty diesel vehicles. There is no change to organic gas speciation, and the overall difference resulting from updates to CH_4 and N_2O data are negligible between the 2000-2012 and 2000-2013 editions of the inventory. (For example, the small CH_4 increase for heavy duty vehicles represents approximately 0.02-0.08% of the heavy duty GHG inventory total in

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2012.) The CH_4 outputs are still scaled according to fuel sales the same way as in previous GHG inventories.

3. Data Sources

For more information on Board of Equalization fuel sales, the use of the EMFAC model in the GHG emission inventory, and other data pertinent to calculating this inventory, see the Technical Support Document for the GHG emission inventory (ARB 2013a). For information on EMFAC 2014 update specifically, see the mobile source emission inventory webpage (ARB 2015).

II. Industrial Sector

A. Oil & Gas Production (IPCC 1A1cii and 1B2)

1. Background

Previous editions of the inventory used data from the Mandatory GHG Reporting Regulation (MRR) for years 2011 and 2012 (ARB 2014a). Because MRR does not capture all the emitting activities and facilities in the oil and gas production sector, due to the reporting threshold specified in the regulation, staff scaled up the emissions captured by MRR using the ratio of oil production data reported to MRR and those reported to the Division of Oil, Gas and Geothermal Resources (DOGGR) (DOGGR 2015). The emissions were extended back to 2000-2010 using the emissions trends in ARB's California Emission Inventory Development and Reporting System (CEIDARS) data (ARB 2013b).

The previous method had two primary sources of uncertainty. In CEIDARS, TOG is speciated to obtain CH_4, but part of these data is based on outdated speciation profiles and activity data that have not been updated by the local air districts. In addition, total emissions from this sector are not necessarily proportional with production itself, as fugitive emissions occur continuously, even from non-producing wells and fields. Therefore, using oil and gas production data as the scaling surrogate can introduce additional uncertainty for fugitive emissions estimate.

2. Methodology

The 2015 edition of the inventory uses the Survey conducted in 2009 on 2007 emissions by ARB's Stationary Source Division (SSD) (ARB 2007a), which captured additional fugitive emissions from the oil & gas production sector that were not captured by either CEIDARS or MRR. The 2007 SSD Survey is considered the most comprehensive data source for this sector and is used as the basis for year 2007 emissions. This single year of data is then scaled forward and backward to span all other inventory years using the emissions for the *Production Field Operations (Potential)* category in the U.S. Environmental Protection Agency's (U.S. EPA) National GHG Inventory (USEPA 2014a).

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Because using emissions data from CEIDARS can introduce additional uncertainties, the National GHG Inventory trend will be used as the scaling surrogate until a better surrogate becomes available.

Emissions for the time series are estimated as follows:

Equation 1: CH$_4$ emissions from oil & gas production, 2000-2013

$$E_{20xx} = E_{2007} * EPA_{20xx} / EPA_{2007}$$

where,

E_{20xx} = Emissions from oil and gas production in year 20xx (g)

E_{2007} = Emissions from oil and gas production in year 2007, based on the 2007 SSD Survey (g)

EPA_{20xx} = EPA National Inventory methane emissions estimate for *Production Field Operations (Potential)* in year 20xx (g)

EPA_{2007} = EPA National Inventory methane emissions estimate for *Production Field Operations (Potential)* in year 2007 (g)

3. Data Sources

The 2007 SSD Oil & Gas Production Survey (ARB 2007a) and the USEPA National GHG Inventory (USEPA 2014a) were used as the data sources.

B. Natural Gas Pipelines Fugitive Emissions (IPCC 1B2b)

1. Background

Methane emissions occur due to leaks arising from the pumping and pressurization of pipelines. Previous editions of the inventory used data from MRR for years 2011 and 2012. Because MRR does not capture all the emitting activities in the natural gas pipelines category, staff scaled up the emissions captured by MRR using the ratio of natural gas production reported to MRR and to DOGGR. The emissions were extended back to 2000-2010 using the emissions trends in the CEIDARS data set.

2. Methodology

The 2015 edition of the inventory uses the survey conducted in 2009 on 2007 emissions by ARB's Stationary Source Division (SSD) (ARB 2007a). The 2007 Survey captured additional fugitive emissions from natural gas distribution system that were not captured by either CEIDARS or MRR (for 2011-2013), which were the primary data sources for these emissions in the GHG inventory. Emissions for 2000-2013 are estimated by scaling the emissions captured by the 2007 SSD Survey with the pipeline mileage data from Pipeline and Hazardous Materials Safety Administration (PHMSA) in combination with annual counts of residential building units (DOF 2013). PHMSA pipeline mileage data captures the impact of pipeline leakage, while the number of

residential housing units captures the impact of customer meter leaks. Both surrogates are given equal weight in the scaling. Emissions for the time series are estimated as follows:

Equation 2: CH_4 emissions from pipeline leaks, 2000-2013

$$P_{20xx} = \sum Mi_{20xx} * EFi$$

where,

P_{20xx} = Estimate of emissions derived from PHMSA pipeline mileage for year 20xx (g)

Mi_{20xx} = Pipeline mileage of material type i (e.g. steel, plastic, iron) in year 20xx (miles)

EF_i = Default MRR emission factor for material type i in year 20xx (g/mile)

$$E_{20xx} = E_{2007} * (P_{20xx}/P_{2007} + R_{20xx}/R_{2007})/2$$

where,

E_{20xx} = Emissions from Pipeline leaks in year 20xx (g)

E_{2007} = Emissions from Pipeline leaks in year 2007 (g)

P_{20xx} = PHMSA pipeline mileage emissions estimate in year 20xx (g)

P_{2007} = PHMSA pipeline mileage emissions estimate in year 2007 (g)

R_{20xx} = Residential Housing units in year 20xx (g)

R_{2007} = Residential Housing units in year 2007 (g)

3. Data Sources

The 2007 SSD Pipeline Survey (ARB 2007b), PHMSA Pipeline Data (PHMSA 2010) and Residential Units Data (DOF 2013) were used as the data sources. The default emission factor for pipeline material type came from MRR.

C. Lead Production: Process Emissions (IPCC 2C5)

1. Background

Lead Production, a new category captured by MRR, has been added under industrial manufacturing in the GHG emission inventory. In the process of lead production, the lead ore or the secondary materials such as lead batteries and scrap lead are heated in blast furnace, generating carbon dioxide (CO_2) emissions. The treatment of recycled batteries utilized in secondary lead production also generates CO_2 emissions. Although fuel combustion emissions

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from lead production were already included in the GHG emission inventory, the 2015 edition of the inventory is the first time CO_2 emissions from lead smelting are included.

2. Methodology

ARB's MRR program included the process CO_2 emissions from lead production for the first time in 2014, for data year 2013. The process emissions from all the lead production facilities were reported under Subpart R. U.S.EPA's GHG Reporting program included CO_2 emissions from lead production from all facilities in U.S. for years 2011 and 2012. The CO_2 emissions data for facilities in California were downloaded from U.S.EPA's online data publication tool. For years 2000-2010, the following equation was applied to estimate the CO_2 emissions using a simplistic scaling method.

Equation 3: CO_2 emissions from lead production 2000-2010

$$E_{CA} = E_{US} * R_{POP}$$

where,

E_{CA} = California emissions from lead production (g)

E_{US} = U.S. emissions from lead smelting (g)

R_{POP} = Ratio of population of California to the population of U.S.

3. Data sources

For year 2013, emissions were reported by each lead production facility in California under ARB's MRR program (ARB 2014a). For years 2011 and 2012, the CO_2 emissions from lead production facilities in California were reported under U.S.EPA's GHG Reporting program and were downloaded from their online GHG data publication tool (USEPA 2014b). National CO_2 Emissions from lead production from years 2000-2010 were obtained from U.S.EPA's draft emission inventory (USEPA 2014a). Population data were obtained from California Department of Finance (CADOF 2013).

D. Wastewater Treatment (IPCC 4D) – Industrial Wastewater

1. Background

Methane emissions from the wastewater of citrus and non-citrus fruit processing plants are included in the industrial sector of the inventory. Non-citrus fruits include apricots, avocados, sweet cherries, dates, figs, raisin grapes, table grapes, kiwifruits, nectarines, olives, peaches pears, plums and other miscellaneous fruits. In addition to citrus and non-citrus fruit, emissions from apples and wine grapes processing facilities are also included in the inventory.

2. Methodology

In the previous inventories, the method for estimating emissions from non-citrus fruit included emissions from apples and wine grapes along with all other non-citrus fruits. However, the emissions from apples and wine grapes are calculated as a separate category; and hence were being double counted. In the updated method, the following equation is used to separate the amounts of apples and wine grapes from non-citrus fruit:

Equation 4: Updated amount of non-citrus fruit = Total amount non-citrus fruit – (amount of apples + amount of wine grapes)

3. Data sources

The data source for the amount of fruit production remained the same as U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) Quick Stats Survey (USDA 2013). The entire time series of 2000-2013 emissions was revised. The revised method now excludes apples and wine grapes emissions from "non-citrus fruit" so there are no double counting of emissions.

III. Commercial and Residential

A. Use of Nitrogen Fertilizer (IPCC 3C4)

1. Background

Use of nitrogen fertilizer on soil results in both direct and indirect N_2O emissions. Residential and commercial turf comprises a significant fraction of all acreage under irrigated cultivation in California, and much of this acreage receives nitrogen fertilization.

2. Methodology

Direct and indirect N_2O emissions from residential and commercial nitrogen use are calculated using the IPCC guidelines for agricultural synthetic fertilizer use (ARB 2013a)(see section III.F of the Technical Support Document for the GHG emission inventory).

Nitrogen fertilizer applied to residential and commercial soils.

The amount of nitrogen fertilizer applied to residential and commercial soils was calculated using Equations 5 and 6 respectively. Fertilizer use was not differentiated into synthetic versus organic due to lack of activity data; therefor, all nitrogen was assumed to be synthetic.

Equation 5: Residential Nitrogen Use

$$N_{Res} = F_{Res} * A_{Turf} * R_{Fert, Res} / 907.185$$

Where

N_{Res} = Amount of N from fertilizer applied to residential turf (short tons)

F_{Res} = Fraction of turf acreage that is residential

A_{Turf} = Total area of turf grass in California (ha)

$R_{Fert, Res}$ = Average N fertilizer application rate for residential turf (kg N/ ha)

1/907.185 = conversion factor from kg to short tons

Equation 6: Commercial Nitrogen Use

$$N_{Com} = F_{Com} * A_{Turf} * R_{Fert, Com} / 907.185$$

Where

N_{Com} = Amount of N from fertilizer applied to commercial turf (short tons)

F_{Com} = Fraction of turf acreage that is commercial

A_{Turf} = Total area of turf grass in California (ha)

$R_{Fert, Com}$ = Average N fertilizer application rate for commercial turf (kg N/ ha)

1/907.185 = conversion factor from kg to short tons

N_2O emission calculation.

Both direct and indirect N_2O emissions were calculated using the IPCC methodology for synthetic fertilizer application to agricultural soils (ARB 2013a, see section III.F).

3. Data Sources

Total area of urban turf grass.

The total area of turf grass in California was 1,115,900 ha in 2005 for both residential and commercial uses (Milesi et al. 2005). 66% of total acreage was assumed to be residential and 33% commercial based on the median of 10 surveys conducted in the United States (Milesi et al. 2009).

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Nitrogen application rates to residential and commercial turf grass.

The rate of nitrogen application for residential use ($R_{Fert, Res}$) was 170.8 kg N/ha/year from the average of recommended fertilization rates (UCD 2014). The rate of nitrogen application for commercial use ($R_{Fert, Com}$) was 225 kg N/ha/year and is the average of multiple sources (Sartain 2002, PSU 2003, Rosen et al. 2008, VCE 2009, UCD 2014).

IV. Agriculture

A. Synthetic Fertilizer Use (IPCC 3C5)

1. Background

Use of nitrogen fertilizer on soil results in both direct and indirect N_2O emissions. N_2O emissions are proportional to the amount of fertilizer applied to soil in the GHG emission inventory. Previous editions of the inventory used the California Department of Food and Agriculture (CDFA) fertilizer tonnage reports (CDFA Various Years) to estimate synthetic nitrogen fertilizer applied to agricultural croplands. This method has been updated as part of the effort to distribute nitrogen fertilizer use among commercial, residential and agricultural end uses.

2. Methodology

N_2O emission calculation.

Direct and indirect N_2O emissions from agricultural soils still use IPCC recommended formulas and default emission factors. For more information on N_2O emissions from soils, see the 2000-2012 GHG inventory Technical Support Document (ARB 2013a).

Total nitrogen applied to agricultural soils.

Total (synthetic and organic) nitrogen applied to agricultural soils was calculated using the harvested crop acreage multiplied by the crop-specific recommended nitrogen application rate (equation 5). Organic nitrogen applied to soils was subtracted from the total nitrogen use in Equation 7 to obtain the synthetic fertilizer use.

Equation 7: Agricultural Nitrogen Use

$$N_{Ag,i,j} = A_{i,j} * R_{Fert,j} / 2,000$$

Where
i refers to the year
j refers to crop

$N_{Ag,i,j}$ = Amount of total (synthetic + organic) N fertilizer applied to agricultural soil (short tons)
$A_{i,j}$ = Area harvested (ac)
$R_{Fert, j}$ = Crop-specific N fertilizer application rate (lbs N/ ac)
1 / 2,000 = conversion from pounds to short tons

3. Data sources

Crop acreage for 2000-2013.

Crop acreage harvested for 2000-2013 was acquired from a combination of U.S. Department of Agriculture (USDA) national agricultural statistics services quick stats (USDA 2014a), USDA crop reports (USDA 2014b), and CDFA crop-specific reports (CDFA 2014a, CDFA 2014b, CDFA 2014c). When available, census data was used in place of survey data. Missing data were interpolated from reported acreage for other years (including pre 2000 data if necessary).

Crop-specific nitrogen application rates.

Crop-specific nitrogen application rates were compiled from University of California Davis Extension cost studies (Rosenstock et al. 2013, UCD Various), and, if missing from the previous references, from the California-specific DeNitrification-DeComposition (DNDC) database produced for ARB (Li et al. 2014).

Organic fertilizer use.

Organic fertilizer use was compiled from the CDFA fertilizer tonnage reports (CDFA Various Years) assuming all organic fertilizer reported was used for agriculture.

4. Changes in Estimates

Synthetic fertilizer use by agriculture decreased compared to past inventory versions, because some synthetic fertilizer was apportioned to commercial and residential use. Agricultural use of synthetic fertilizer and associated N_2O emissions decreased by an average of 26% for 2000-2013.

V. High GWP Gases

A. Other Ozone Depleting Substances (ODS) Substitutes (IPCC 2F)

1. Background

In the previous edition of the inventory, several Ozone Depleting Substances (ODS) Substitutes were aggregated into the "Other ODS Substitutes" category. The "Other ODS Substitutes" category includes various hydrofluorocarbons (HFCs) with global warming potentials (GWPs) ranging from 124 to 14,800.

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GWP values of some of the HFCs (HFC-43-10mee, HFC-152a, HFC-227ea, HFC-245fa, HFC-365mfc) and perfluorocarbon (PFC)/PFEs solvents were grouped together and assigned an average GWP. As these compounds were assigned a single GWP values, their emissions were also reported as a single value under "Other ODS substitutes". The current inventory splits the "Other ODS Substitutes" into individual compounds.

2. Methodology

   In previous editions of the inventory, the emissions of these individual gases in grams were aggregated together and multiplied by an average GWP value each year. In the current edition of the inventory, emissions of each gas in grams are calculated separately and multiplied by its own GWP value to obtain emissions in equivalents of CO_2 (CO_2e). The HFCs mentioned above are now listed as individual compounds in the inventory using the GWP values from the IPCC Fourth Assessment Report (AR4) (IPCC 2007). For estimating the individual amount of emissions in grams of each of the gas, refer to the Technical Support Document for the GHG emission inventory (ARB 2014b).

3. Data sources

   The data sources for the updated method remain the same as in the previous edition. For estimating the emissions of the individual gases, see the Technical Support Document for the GHG emission inventory (ARB 2014b).

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