California's 2000-2016 Greenhouse Gas Emissions Inventory
2018 Edition

Inventory Updates Since the 2017 Edition of the Inventory

Supplement to the Technical Support Document

CALIFORNIA AIR RESOURCES BOARD

Air Quality Planning and Science Division

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Introduction

Assembly Bill 1803 gave California Air Resources Board (CARB) 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 data from various California Global Warming Solutions Act (AB 32) programs, in demonstrating the State's progress in achieving the statewide GHG targets established by AB 32 (reduce emissions to the 1990 levels by 2020) and Senate Bill 32 (SB 32) (reduce emissions to at least 40% below the 1990 levels by 2030). The 2018 edition of California's GHG inventory covers emissions for 2000 through 2016 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 2017 edition of the inventory (2000-2015 emissions), staff has made improvements to emissions estimation methods and incorporated new data sources. 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 emission quantification methodology. 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 2015, 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. In some cases, a model used for estimating emissions in the GHG inventory has been updated, but the way the model is utilized in the compilation of the GHG inventory has not changed. Though this type of update is not considered a change in methodology, for completeness, this document provides an overview of the model update and points readers to other technical documentations for more details.

The inventory category code associated with the hierarchical structure of IPCC inventory categorization is shown in the sub-heading title of each section. The sections are presented in the order of IPCC inventory category codes.

Description of Inventory Updates

1. In-State Electricity Generation (IPCC 1A1a): Incorporate Biomethane Data for 2011 and 2012

1.1 Background

CARB's Regulation for the Mandatory Reporting of Greenhouse Gas Emissions (MRR) program collects data on the amount of biomethane supply purchased by in-state power plant operators (CARB, 2017a). Biomethane purchases displace fossil natural gas combustion emissions. Biomethane quantities reported to the MRR program by power plant operators were first incorporated into the 2016 edition of the GHG inventory, starting with data for the 2013 and 2014 calendar years. Since then, each edition of the inventory incorporates an additional year of biomethane data (e.g., the 2017 edition included data for 2015, and the 2018 edition includes data for 2016). In the 2018 edition, staff went further back in time to incorporate biomethane data for 2011 and 2012. This inventory update does not affect emissions quantification for 2013-2016.

1.2 Data and Method

The biomethane quantities reported to the MRR program for calendar years 2011 and 2012 are used to displace the total natural gas combusted by in-state power plants in 2011 and 2012. All methodology, data sources, and emissions classification are the same as in previous inventory editions documented in the 2016 edition of the Technical Support Document (CARB, 2016).

2. Imported Electricity (IPCC 1A1ai): Add Energy Imbalance Market Outstanding Emissions

2.1 Background

Under AB 32, CARB must account for statewide GHG emissions, including all emissions resulting from the generation of electricity delivered to and consumed in California, whether that electricity is generated in-state or imported to California to serve California load. The Energy Imbalance Market (EIM) of the California Independent System Operator (CAISO) is a real-time market to manage transmission congestion and optimize procurement of energy to balance supply and demand for the combined CAISO and EIM footprint. EIM Outstanding Emissions are calculated by CARB staff to address emissions leakage and ensure full and accurate accounting of GHG emissions from imported electricity under EIM. EIM Outstanding Emissions were quantified in the latest version of the MRR regulation that became effective January 1, 2018, and therefore were not previously captured under MRR or the statewide GHG inventory.

2.2 Emissions Calculation Method and Data Source

EIM Outstanding Emissions are calculated using information reported to the MRR program and the default emissions factor pursuant to section 95111(h) of the MRR regulation (CARB, 2017a).

3. On-Road Transportation (IPCC 1A3b): Incorporate Updated EMFAC Model

3.1 Background

CARB's on-road mobile vehicles emission inventory model EMFAC was updated in December 2017 (EMFAC2017)(CARB, 2017b). The entire 2000-2016 time series for the on-road transportation category is calculated following the same methodology as in previous editions of the statewide GHG inventory, but the 2018 edition uses the latest model, EMFAC2017. Several major updates differentiate EMFAC2017 from its predecessor, EMFAC2014. The technical documentation of EMFAC2017 (CARB, 2017c) has more details. An overview of the model updates is presented in the next section.

3.2 Model Updates

Latest vehicle registration data from the California Department of Motor Vehicle (DMV) and International Registration Plan (IRP) were used to update vehicle population and improve fleet characterization. Extensive on-road and chassis dynamometer emissions testing of both light and heavy duty vehicles better informs in-use emissions. Activity profiles include the latest California Household Travel Survey (2010-2012) for light duty vehicles as well as data from the most recent Heavy Duty Activity Data Collection (2016). Two new modules have been added, one for transit and another for calculating GHGs. The new GHG module uses fuel data from the California Board of Equalization, the California Energy Commission, and the MRR program. The GHG module uses emission factors and heat contents consistent with the MRR program for CO_2, and CARB's vehicle surveillance program (VSP) data for CH_4 for light duty vehicles. For N_2O, it uses data from VSP for gasoline vehicles and CARB's Cross California Portable Emission Measurement System (PEMS) for heavy duty vehicles. Additionally, Zero Emission Vehicle compliance assumptions for the Advanced Clean Cars program have been updated, and the Federal Phase 2 GHG Standards for Medium-Heavy and Heavy-Heavy Duty Vehicles was included.

3.3 Change in Emissions

There is no change in the way the EMFAC model is used in the compilation of the statewide GHG inventory. See the existing Technical Support Document (CARB, 2016) for a description of the on-road transportation methodology. However, as the entire 2000-2016 time series is calculated using the latest model EMFAC2017, there are notable differences in the emission estimates for 2000-2015, especially for nitrous oxide (N_2O). Using EMFAC2017, diesel combustion N_2O emissions in 2015 are now 3.8 times higher than if EMFAC2014 was used. The difference in gasoline combustion N_2O emissions in 2015 varies by vehicle type, and ranges from 31% to 83% higher using EMFAC2017. Comparing the total on-road N_2O emissions for same calendar year between the two versions of the model, EMFAC2017 outputs are 1.9 to 2.8 $MMTCO_2e$ higher than using EMFAC2014. Methane emissions also increased as a result of the model updates. For example, the 2015 emissions in the 2018 edition is approximately 0.08 $MMTCO_2e$ higher than the 2017 edition.

4. Ocean-Going Vessel Emissions (IPCC 1A3d): Model Update

4.1 Background

Ocean-going vessels (OGV) are a significant source of emissions around California ports and coastal shipping lanes. CARB's OGV model was used for analyzing the impacts of the CARB fuel rule amendments, providing updates for the State Implementation Plan, and providing activity data for calculating emissions in the CARB GHG inventory. CARB staff made updates to the OGV model in 2013 and 2016. More detail information about the OGV model updates can be found on CARB program webpage at: https://www.arb.ca.gov/msei/ordiesel.htm (CARB, 2014). An overview of the model updates are described in the next section.

The use of the OGV model in the CARB statewide GHG inventory is the same as The use of the OGV model in the CARB statewide GHG inventory is the same as documented in the previous edition of the Technical Support Document (CARB, 2016). By using the latest model in the 2018 edition of the GHG inventory, the updates made to the OGV model are now reflected in the inventory.

4.2 Model Updates

In 2013, CARB staff reviewed more recently available economic forecast data and updated the growth rates for the interim timeframe (2006-2012) and the long-term timeframe (2013 and beyond) in the OGV model. Updates to the long-term growth factors specific to each California port were made to container ships, auto ships, tankers, and cruise ships. For container ships, auto ships, and tankers, the growth factor updates are based on output from the Federal Highway Administration's (FHWA) Freight Analysis Framework (FAF) model. For cruise ships, the updates are based on the 2011 Cruise Market Update by the San Diego Unified Port District. The growth factors for year 2013 and onward are applied to 2006 base year activity and emissions.

For the interim timeframe covering years 2006-2012, updates to the growth factors were made using publicly available activity data from several data sources. For auto ships and tankers, data from the Maritime Transportation Administration were used. Growth factors were derived from trends in total tonnage delivered to specific ports in California by either auto ships or tanker ships from 2006 to 2011; and for 2012, growth factors were derived from the FAF model. For cruise ships, data from San Diego Unified Port District's Cruise Market Update were used. Growth factors were derived from trends in total passengers served from 2006 to 2012. For container ships, 20-feet equivalent units (TEU) throughput data from the Ports of Los Angeles/Long Beach and the Port of Oakland were used. Growth factors were derived from trends in TEU throughput as reported by each of the ports from 2006 to 2012. For the other vessel types (i.e. bulk, general cargo, reefer, and roll-on/roll-off ships), updated growth factors were derived from container ships growth rates from one of three container ship ports: Ports of Los Angeles/Long Beach, Port of Oakland, and Port of San Diego.

In 2016, minor technical improvements were made to the OGV model to align the timeframe of input data with the model structure for 2016 and earlier years. Other changes that do not impact the years covered by the 2018 edition of statewide GHG inventory (2000-2016) include incorporation of more recent data to inform future projections beyond 2016.

5. Rice Cultivations (3C7): Update to Tier 3 Methodology Using DNDC

5.1 Background

There were over 220,000 hectares (ha) of rice paddy in California in 2016, comprised of approximately 3% of the State's harvested cropland (USDA, 2017). Because of the unique requirement of flooding for rice growth, rice paddy is a significant source of methane (CH_4) emissions in the State. Methane is produced from rice paddy through methanogenesis, a process that breaks down soil organic matter (SOM) into CH_4 under anaerobic conditions where oxygen is restricted. The CH_4 emission rate from rice soil is therefore driven by two principal variables: the amount of SOM available and the redox potential (or Eh value), a parameter that measures the degree of oxygen deficiency in soil. Any factors that influence either of these variables would change CH_4 fluxes. The redox potential in rice paddy fluctuates normally between -300 and +600 mV, depending on the water regime. Methane emissions, however, occur only within the narrow range of soil redox potential between -150 mV and -300 mV (Wang et al., 1993; Yu, 2011).

Water regime (or flooding pattern) and crop residue management are the two most important management factors that affect CH_4 fluxes. Other management practices, such as fertilizer application, tillage, and rice cultivar, can also play a role. The most common practices for rice management in California involve wet seeding, continuous flooding during rice growing season and incorporation of rice straw into the soil followed by winter flooding. Besides rice management practices, other environmental factors such as soil type and weather, especially temperature, can affect CH_4 emissions as well.

In the previous edition of CARB's GHG inventory, methane emissions from rice paddy were estimated using default emission factors derived from California-specific studies. In this edition, staff upgraded the methodology to a process-based modeling approach using the geochemical model DeNitrification-DeComposition (DNDC)(Li et al., 1992; Li, 2000). With this updated methodology, effects of all environmental and management factors were captured in estimating CH_4 emissions from California rice cultivation. DNDC is already used for estimating N_2O emissions from agricultural soil management in cropland receiving no manure applications in California.

5.2. Methodology

DNDC Model

The DNDC model (Li et al., 1992; Li, 2000) is a process-based computer simulation model of carbon (C) and nitrogen (N) biogeochemistry and was developed for quantifying carbon sequestration and GHG emissions in agroecosystems. The core of DNDC modeling consists of microbe-mediated biochemical processes dominating carbon- and nitrogen-cycling in agroecosystems. DNDC has been evaluated against CH_4 emissions data in California rice systems with an R^2=0.85 between measured and predicted values (Simmonds, et al., 2015). A full description of the DNDC scientific basis and processes, including all equations involved, is available at the model host site (UNH, 2016).

Methane Emission Calculations

Methane emissions from rice cultivation were calculated by linking the DNDC model with a California-specific database containing spatial and temporal information on weather, crop, soil, and rice management practices in California. Model parameters calibrated for the rice cultivar M206 in Simmonds et al. (2015) were used for the simulation because of the broad adaptation of M206 in the entire rice growing region in California (California Rice Research Board, 2016). For each given year, DNDC was run for three consecutive years, allowing the distribution of carbon and nitrogen speciation in soil to match closely to field conditions. The CH_4 emissions of the third year were then used as the emission estimate for that year. To alleviate year-to-year variability in emissions due to weather conditions, 3-year rolling average of emission estimates was used as the final inventory estimate for a given inventory year.

Rice straw burning is a practice that has been used as a method to control pests in certain rice fields. Rice straw burning reduces SOM available for decomposition and thus reduces methane emissions from the rice fields. To account for effects of rice straw burning on methane emissions, DNDC simulations were performed separately for fields with and without straw burning and a weighted mean of emission estimates was taken based on the percentage of rice acreages subject to burning. For detailed information on the acreage of rice fields burned over time, please refer to Section III.D of the full Technical Support Document (CARB, 2016c).

5.3 Data Sources

The DNDC database contained California-specific information on (1) daily meteorological records, (2) land area of rice cultivation, (3) soil properties, and (4) farming management practices. The data were organized at the county level.

The daily meteorological data were obtained from the DAYMET model (Thornton et al., 2015). Rice cultivation areas were obtained from the U.S. Department of Agriculture's (USDA's) National Agricultural Statistics Service (NASS), Quick Stats (USDA, 2017) prior to 2012 or the California Department of Food and Agriculture's (CDFA) California Agricultural Statistics reports after 2012 (CDFA, 2013-2017). Soil data, including bulk density, clay content, soil organic carbon content and pH, were compiled from the USDA's Soil Survey Geographic Database (SSURGO) database (USDA, 2016). The SSURGO map units were overlaid with the regions of agricultural land use developed by the Land Use Surveys of the California Department of Water Resources (CDWR, 2014) on ArcMap, and the area-weighted means of the four soil properties were calculated for each county and were used as "representative" soil values in DNDC modeling. Farming management data, including planting and harvest dates, tillage, fertilization, irrigation, and crop residue management, were developed from open literature sources such as the Cost and Return Studies of UC Davis (UCD, 2015) and Rosenstock et al. (2013).

5.4 Change in Emissions

Overall, the new methodology using DNDC modeling reduced CH_4 emission estimates from rice cultivation by 8.5% compared to the estimates using default emission factors. Changes in the emission estimates are attributable to two sources: the acreage increase due to inclusion of wild rice and the methodology change. Emissions from wild rice, which comprised about 3% (2.1-3.8% over 2000-2016) of the total rice acreage in the state, were not use in the previous edition, but were included in the current inventory edition.

Interim Method During Data Transition

The CARB utilizes data from several data sources in calculating California GHG emissions. Occasionally, a data source agency may experience delays in data compilation due to various reasons; and as a result, the data needed for CARB to calculate GHG emissions may not be available at the time of inventory compilation. In other instances, a data source agency may begin revising statistical data using an improved method but could not complete the entire time series in one year, resulting in an artificial change in emissions numbers without an actual change in emissions. In these situations, CARB staff temporarily fills in the data gaps by either using the previous year value as a placeholder or employing data extrapolation techniques until revised data become available in future inventory cycles. This section describes the interim methods used in this inventory edition that are not permanent changes to inventory methodology, but that are expected to be revised once the data become available.

1. Miscellaneous Fuel Combustion (Multiple Categories, IPCC 1A1-4)

1.1 Background

The CARB GHG inventory uses fuel use data from the U.S. Energy Information Administration (EIA) for certain fuel combustion categories. The EIA completes fuel use estimates for 50 states each year, but some of the data are not updated until 18 months after the end of a calendar year; and therefore, are not available in time for CARB's annual inventory compilation. These fuel use categories include: liquefied petroleum gas (LPG), coal, and wood fuel use not reported to the MRR program; certain diesel fuel use activities in non-road categories that are not captured by CARB's off-road mobile source model; and natural gas use in pipeline pressurization and on-road uses. CARB staff temporarily filled in data gap with placeholder values until these data are updated in the following year.

1.2 Interim Emission Estimation Methodology

For 2015 EIA fuel use data that were not available in time for the compilation of CARB's 2017 edition of the GHG inventory, staff had temporarily filled in 2014 values as placeholders. EIA has made these 2015 fuel data available since that time. In the 2018 edition of the GHG inventory, staff updated the 2015 emissions using the 2015 fuel data that are now available from EIA. Because EIA did not released 2016 data in time for the compilation of the 2018 edition of the inventory (covering 2000-2016 emissions), staff temporarily filled 2016 values with 2015 values as placeholders in the 2018 edition.

2. Lubricant Use (IPCC 2D1)

2.1 Background

The CARB GHG inventory uses data from the EIA for lubricant uses in the industrial and transportation sectors. The EIA completes fuel use estimates for 50 states each year, but some of the data are not updated until 18 months after the end of a calendar year, and therefore, are not available in time for CARB's annual inventory compilation. CARB staff temporarily filled in data gap with placeholder values until these data are updated in the following year.

2.2 Interim Emission Estimation Methodology

For 2015 EIA lubricant data that were not available in time for the compilation of CARB's 2017 edition of the GHG inventory, staff had temporarily filled in 2014 values as placeholders. EIA has made 2015 data available since that time. In the 2018 edition of the GHG inventory, staff updated the 2015 emissions using the 2015 data that are now available from EIA. Because EIA did not released 2016 data in time for the compilation of the 2018 edition of the inventory (covering 2000-2016 emissions), staff temporarily filled 2016 values with 2015 values as placeholders in the 2018 edition.

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