California Greenhouse Gas Emissions for 2000 to 2015 – Trends of Emissions and Other Indicators

Overview

California's annual statewide greenhouse gas (GHG) emission inventory is an important tool for establishing historical emission trends and tracking California's progress in reducing GHGs. Most importantly, 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 statewide GHG targets established by AB 32 (reduce emissions to the 1990 levels by 2020) and Senate Bill 32 (SB 32) (reduce emissions to 40% below the 1990 levels by 2030).* The 2017 edition of the GHG inventory includes the emissions of the seven GHGs identified in AB 32[1] for years 2000 to 2015 and uses an inventory scope and framework consistent with international and national GHG inventory practices.[2] Other programs within ARB address additional climate pollutants not included in AB 32 or the GHG inventory; for example, the Short-Lived Climate Pollutant (SLCP) Strategy[3] includes black carbon and sulfuryl fluoride (SO_2F_2).

California's GHG emissions have followed a declining trend since 2007. In 2015, emissions from routine emitting activities statewide were 1.5 million metric tons of CO_2 equivalent ($MMTCO_2e$) lower than 2014 levels**, representing an overall decrease of 10% since peak levels in 2004. During the 2000 to 2015*** period, per capita GHG emissions in California have continued to drop from a peak in 2001 of 14.0 tonnes per person to 11.3 tonnes per person in 2015, a 19% decrease.[4] Overall trends in the inventory also demonstrate that the carbon intensity of California's economy (the amount of carbon pollution per million dollars of gross domestic product (GDP)) is declining, representing a 33% decline since the 2001 peak, while the state's GDP has grown 37% during this period.[5]

* As part of the 2017 Climate Change Scoping Plan, 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.

** The exceptional Aliso Canyon natural gas leak event released 1.96 $MMTCO_2e$ of unanticipated emissions in calendar year 2015 and an additional 0.52 $MMTCO_2e$ in 2016. These emissions will be mitigated in the future according to legal settlement and are presented alongside but tracked separately from routine inventory emissions.

***Consistent with the United National inventory protocol, recalculations are made to incorporate new methods or reflect updated data for all years from 2000 to 2014, to maintain a consistent inventory time series. 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. For example, in the 2014 inventory (published in 2016), total 2014 emissions were estimated to be 441.5 $MMTCO_2e$. Recalculation for the 2015 inventory revised the 2014 emissions to 441.9 $MMTCO_2e$, reflecting updated methods and information gained since 2016. Analyses of emission trends, including the emissions drop of 1.5 MMTCO2e between 2014 and 2015, are based on the recalculated numbers in the 2015 inventory (published in 2017). A description of the method updates can be found here: https://www.arb.ca.gov/cc/inventory/pubs/reports/2000_2015/ghg_inventory_00-15_method_update_document.pdf.

Figure 1. California Total and Per Capita GHG Emissions

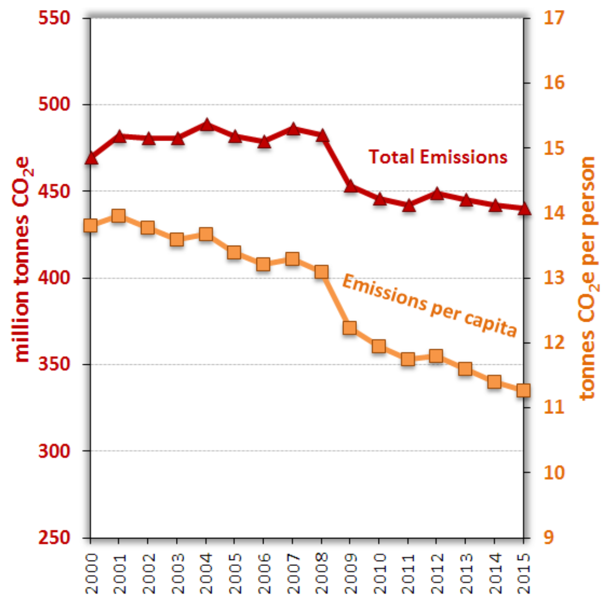


Figure 2. Carbon Intensity of California's Economy

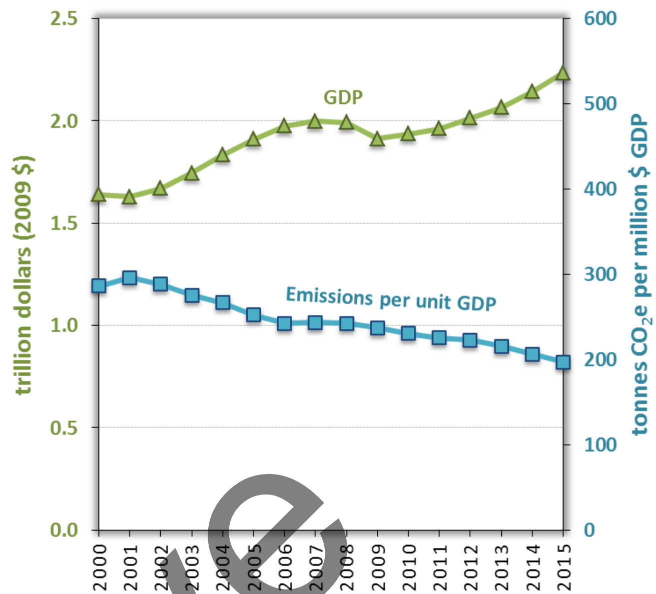


Figure 3 provides an overview of the emission trends by sector since 2000, while Figure 4 provides the relative breakdown of 2015 emissions by sector. Emissions in Figures 3 and 4 are organized by the categories in the Initial AB 32 Scoping Plan[6] and use the 100-year global warming potentials (GWPs) from the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report (AR4)[2] consistent with current international GHG inventory practices. However, other ARB programs may use different GWP values. For example, the SLCP strategy uses a 20-year GWP because the SLCP has greater climate impact in the near-term compared to the longer-lived GHGs, such as CO_2.

Figure 3. Trends in California GHG Emissions*

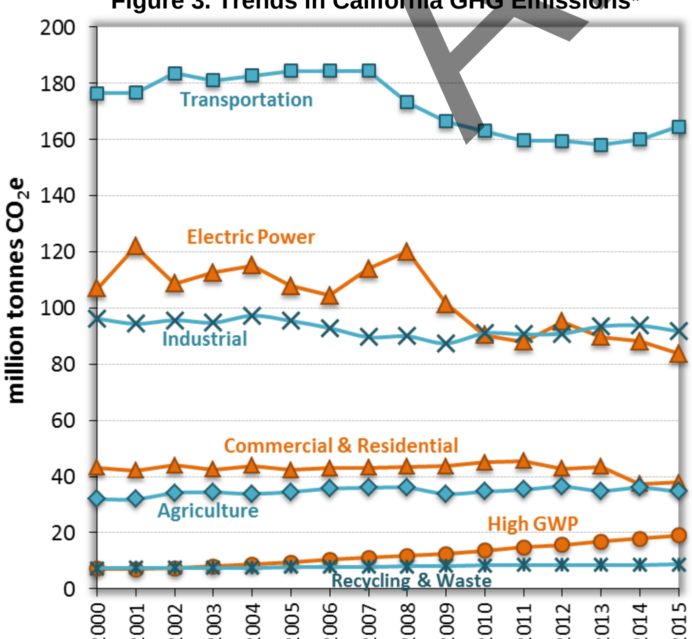
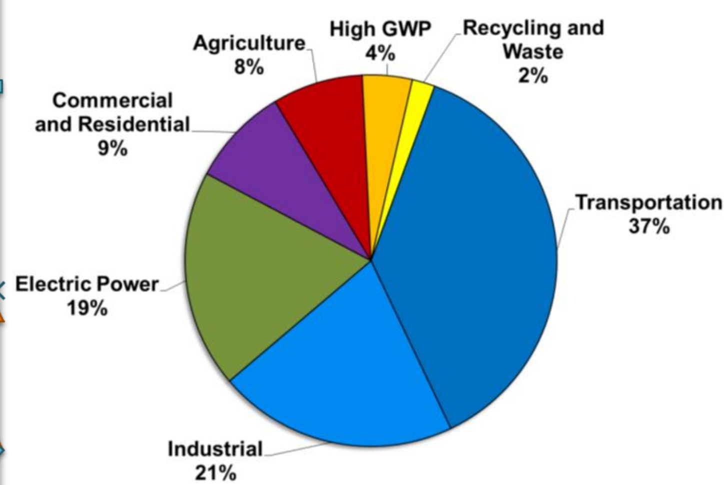


Figure 4. 2015 GHG Emissions by Sector*



The transportation sector remains the largest source of GHG emissions in the state, accounting for 37% of the inventory, and had an increase in emissions in 2015. Emissions from the electricity sector continue to decline due to growing zero-GHG energy generation sources. Emissions from the remaining sectors have remained relatively constant, although emissions from high-GWP gases have continued to climb as they replace ozone depleting substances (ODS) banned under the Montreal Protocol.[7] The following sections provide additional information on emission trends for each major sector of the statewide GHG inventory.

Transportation

The transportation sector remains the largest source of GHG emissions in 2015, accounting for 37% of California's GHG inventory. Contributions from the transportation sector include emissions from combustion of fuels sold in-state that are used by on-road and off-road vehicles, aviation, rail, and water-borne vehicles, as well as a few other smaller sources.*

Figures 6a and 6b show the trends in emissions and fuel sales for light-duty gasoline and heavy-duty diesel vehicles. Total fuel combustion emissions, inclusive of both fossil component (orange line) and bio-component (yellow shaded region) of the fuel blend, track trends in fuel sales.

Figure 5. GHG Emissions from the Transportation Sector

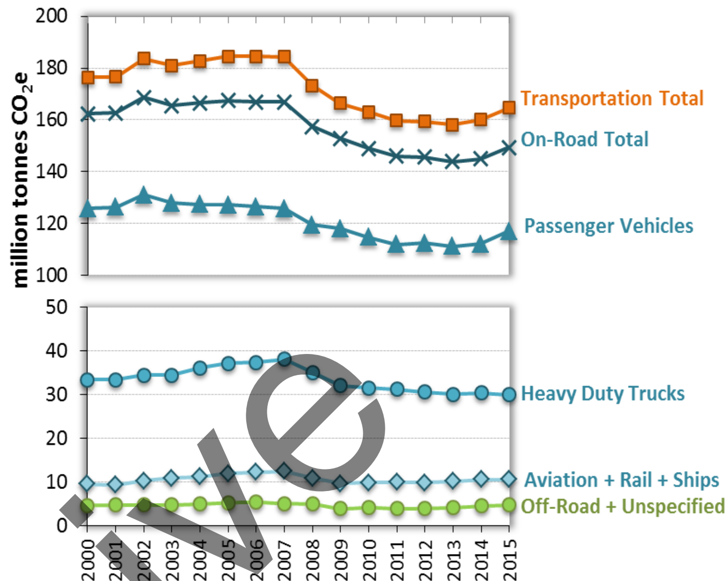


Figure 6a. Trends in On-Road Light Duty Gasoline Emissions

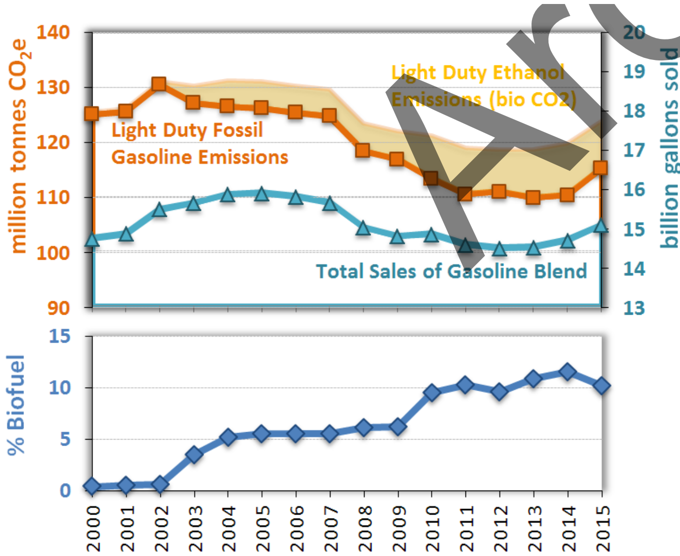
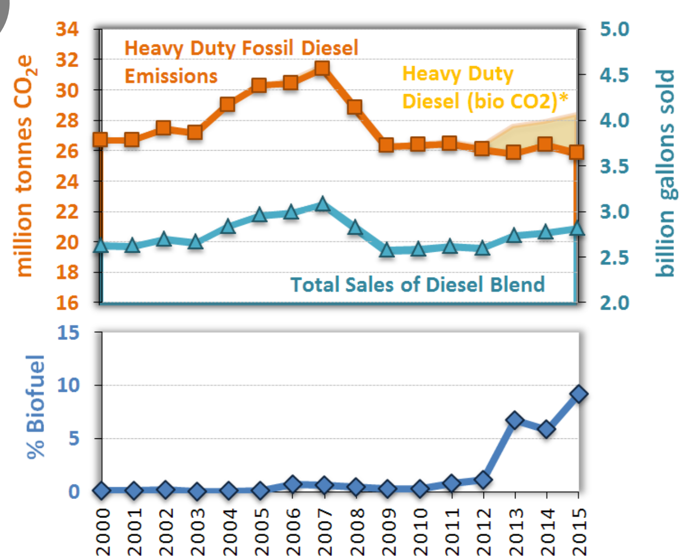


Figure 6b. Trends in On-Road Heavy Duty Diesel Vehicle Emissions



* Emissions from interstate and international aviation diesel, jet fuel use at military bases, and a portion of bunker fuel purchased in California that is combusted by ships beyond 24 nautical miles from California's shores are not included in the GHG emission inventory, but are tracked separately as informational items. Fuels purchased outside of California that are used in-state by passenger vehicles and trains crossing into California, and upstream emissions tracked by the Low Carbon Fuel Standard (LCFS) program are not included or tracked in this version of the GHG emission inventory.

Emissions from transportation sources were relatively constant through 2007, declined through 2013, then increased by 4.6 $MMTCO_2e$ (or 3%) from 2014 to 2015. On-road GHGs account for 99% of that increase. A combination of factors influences on-road transportation emissions. Regulations and improved fuel efficiency of the state's vehicle fleet drive down emissions over time, but population growth, lower fuel prices, and improved economic conditions and higher employment rate are potential factors that may increase fuel use.

Consistent with the *IPCC Guidelines for National GHG Inventories*[8] and the annual GHG inventories submitted by the U.S. and other nations to the United Nations Framework Convention on Climate Change (UNFCCC), the biofuel components of fuel combustion CO_2 emissions are classified as "biogenic CO_2" and are tracked separately as informational items from the rest of the emissions in the inventory (that are classified as "included" emissions). The continuously increasing market penetration of biodiesel and renewable diesel was able to offset the increase in on-road heavy-duty diesel use. As a result, the on-road heavy-duty diesel category showed an overall decrease in "included" emissions (Figure 6b). However, the percent of ethanol in gasoline blend dropped slightly in 2015 and did not offset the relative larger increase in gasoline fuel consumption (Figure 6a).

Electric Power

Emissions from the electric power sector comprise 19% of 2015 statewide GHG emissions. GHG emissions from this sector declined by 5.2% in 2015 compared to 2014. The GHG emission inventory divides the electric power sector into two broad categories: emissions from in-state power generation (including the portion of cogeneration emissions attributed to electricity generation) and emissions from imported electricity (gross imports are used in the inventory, not net imports which reduce gross imports by the amount of electricity exported). The overall decrease in this sector is driven by incrementally higher energy efficiency standards, the Renewable Portfolio Standard (RPS), which requires a greater share of power to come from renewable sources and carbon pricing in the cap-and-trade program. The GHG intensity of imported electricity has been declining steadily over time, while the GHG intensity of in-state electricity has been relatively constant.

Figure 7. GHG Emissions from the Electric Power Sector

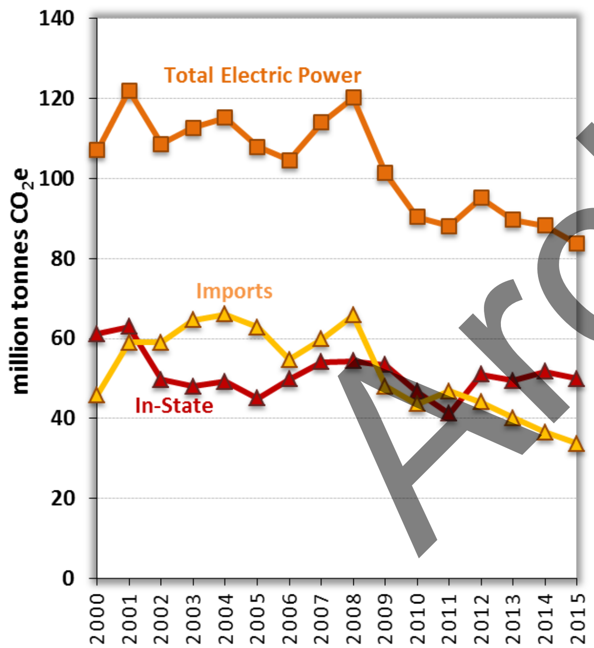
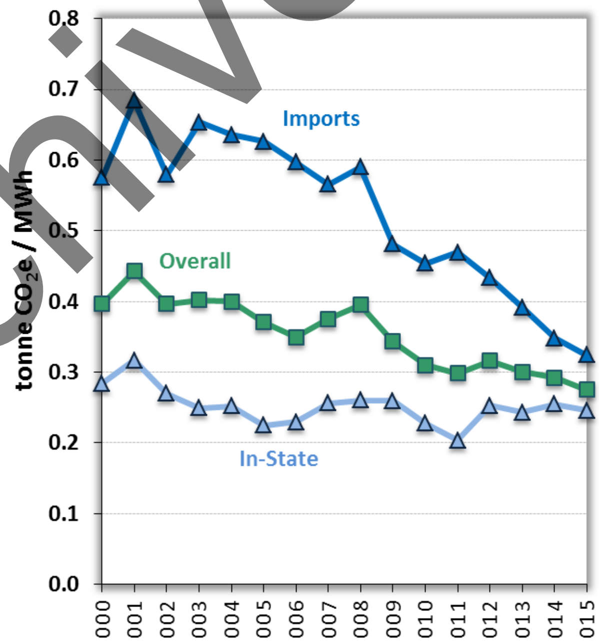


Figure 8. GHG Intensity of Electricity*



* All three GHG intensities account for renewables and exclude biogenic CO_2 emissions. For calculating in-state and overall intensities, in-state electricity emissions and MWh generation include on-site generation for on-site use, cogeneration emissions attributed to electricity generation, in-state generated electricity exported out of state, and rooftop solar. The denominator of overall intensity is the total MWh consumed in and exported from California, and excludes MWh lost during transmission and distribution.

Since 2012, the loss in electricity generation due to the shutdown of the San Onofre Nuclear Generating Station (SONGS) and the continuing decline in hydropower have been replaced by a combination of new solar and wind resources and increased natural gas generation. In 2015, 35% of total electricity generation (in-state generation plus imported electricity) came from zero-GHG generation sources, which include solar, wind, hydropower, and nuclear.* Between 2011 and 2015, rooftop photovoltaic solar generation increased by 250%[10], total solar generation has increased seven-fold,[9,10] while in-state wind energy generation has increased by 58%.[9] Solar and wind power now make up 16% of the total in-state generation in 2015. Hydropower continues its decline due to the prolonged drought (at its fourth year in 2015), and about half the gains in new renewable generation were offset by a decline in hydropower.

Figure 9. In-State Zero-GHG Generation*

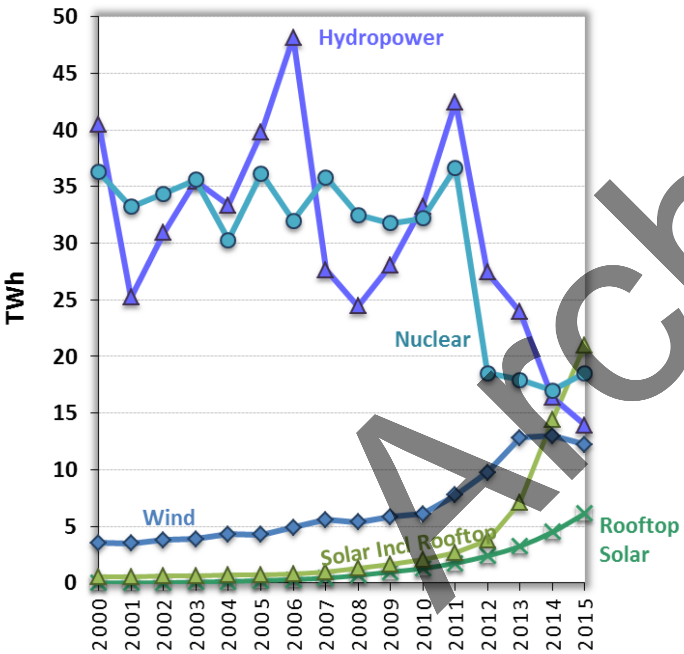
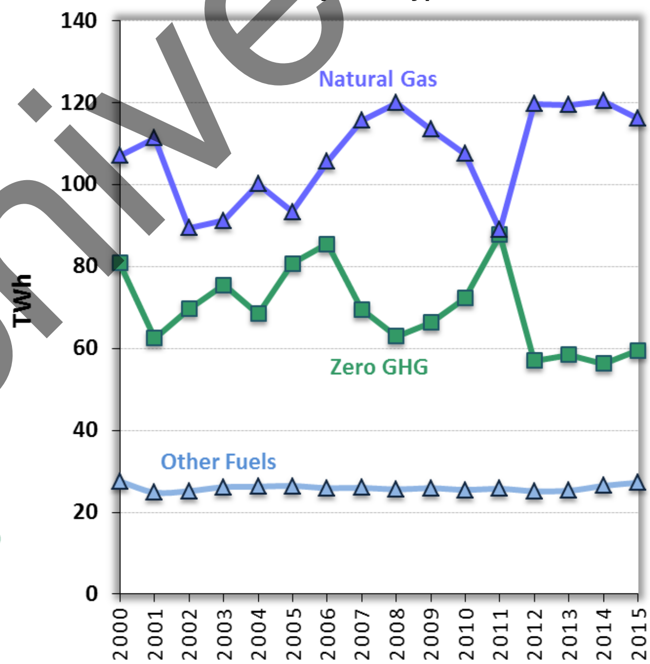


Figure 10. In-State Electricity Generation by Fuel Type*



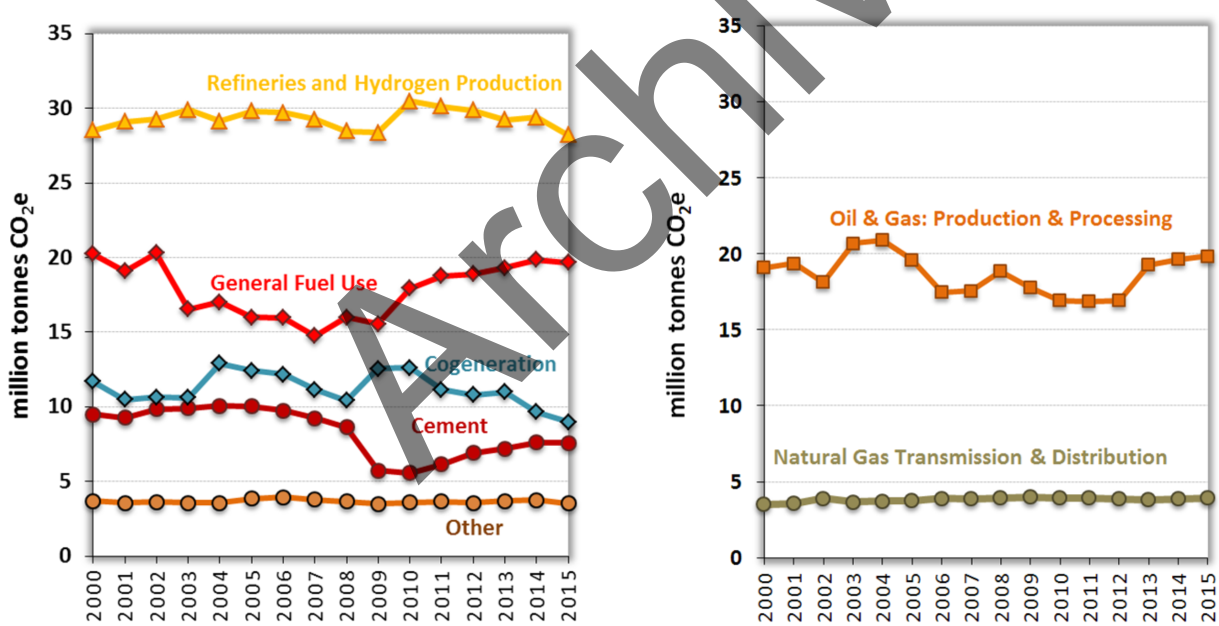
* "Zero GHG" includes solar, wind, hydro, and nuclear. This is distinguished from the definition of renewables under RPS, which includes generation sources that may be considered renewable energy but still release GHG emissions, such as biomass, biogas, geothermal, and municipal solid waste (MSW). Nuclear is not considered renewable but is a zero-GHG source.
"Other Fuels" include energy generations from associated gas, biomass, coal, crude oil, digester gas, distillate, geothermal, jet fuel, kerosene, landfill gas, lignite coal, MSW, petroleum coke, propane, purchased Steam, refinery gas, residual fuel oil, sub-bituminous coal, synthetic coal, tires, waste coal, waste heat, and waste oil.

Industrial

Emissions from the industrial sector contributed 21% of the total GHG emissions in 2015. Emissions in this sector are driven by fuel combustion from sources that include refineries, oil & gas extraction, cement plants, and other stationary sources, as well as the portion of cogeneration emissions attributed to thermal energy output. Emissions from this sector declined through 2009, then remain relatively consistent over the past few years.

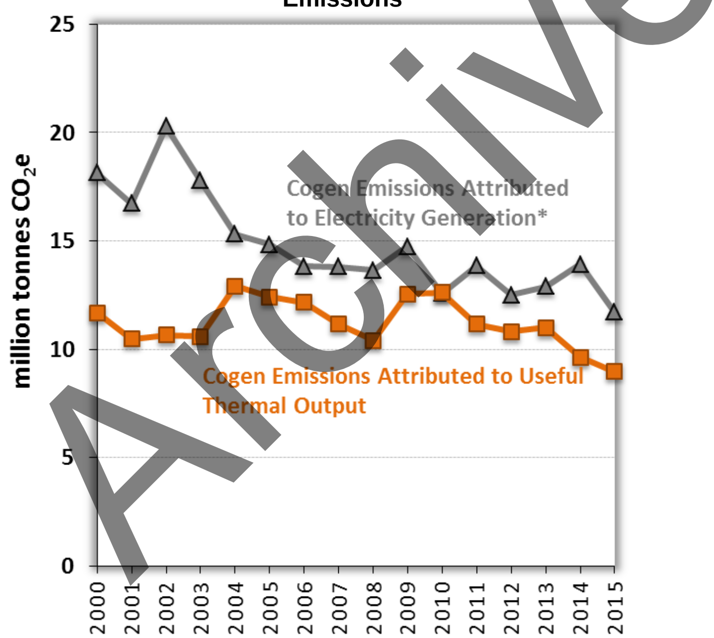
Emissions from oil and gas extraction represent 22% of 2015 industrial sector emissions. Although these emissions increased 14% between 2012 and 2013, emissions in the recent three years have not grown significantly. Routine emissions from the natural gas transmission and distribution sector have remained relatively constant over time. The Aliso Canyon natural gas leak event released 1.96 $MMTCO_2e$ of unanticipated emissions in 2015 and 0.52 $MMTCO_2e$ in 2016. These leak emissions will be fully mitigated according to legal settlement and are tracked separately from routine inventory emissions. The portion of emissions released during calendar year 2016 will be tracked in the 2018 edition of the inventory (covering 2000-2016 emissions).

Figure 11. Industrial Emissions



Refineries and hydrogen production represent the largest individual industrial source, contributing 31% of the sector's total emissions. Refinery and hydrogen production emissions have been declining since 2010 and had a steeper drop in 2015 due to the Exxon Mobil Torrance refinery's temporary shutdown between February 2015 and May 2016. Since 2007, general fuel use by industries has followed a gradually increasing trend, signally a growing industrial sector as the state's economy continues to expand. With the onset of the economic downturn around 2009, cogeneration (cogen) facilities used more of their capacity to generate useful thermal energy (such as steam for industrial processes); however, useful thermal energy production has been on a downward trajectory since that time. Several cogeneration facilities, most of them associated with oil and gas operations, have either shutdown or become non-operational in recent years and further contributed to the downward trend in cogeneration emissions.

Figure 12. Industrial Cogeneration Emissions



* Cogeneration emissions attributed to electricity generation are categorized under the Electric Power Sector pursuant to the IPCC Guidelines. The electricity emissions are shown in this figure for the purpose of putting cogeneration emissions into context.

Commercial and Residential Fuel Combustion

Emissions from the commercial and residential sectors are driven by the combustion of natural gas and other fuels for household use and for commercial businesses, such as space heating, cooking, and hot water or steam generation. Emissions from electricity used for cooling (air-conditioning) and appliance operation are already accounted for in the Electric Power sector. Changes in annual fuel combustion emissions are primarily driven by variability in weather conditions and the need for heating in buildings, as well as increased energy efficiency standards for buildings and appliances. In 2015, emissions had a slight increase compared to 2014, due to a rise in residential natural gas use. The heating degree day index,[11] an estimate of the heating energy need in a given year, had been declining since 2011, but had a 10% increase between 2014 and 2015. The heating degree day index, natural gas use, and residential emissions are all closely tied with each other.

While the number of residential housing units grew steadily from 12.2 million units in 2000 to 13.9 million units in 2015,[12] emissions and fuel consumption per housing unit have generally followed a declining trend during this period.[13] Emissions from commercial fuel use have grown by 11% since 2000; however, during the same period, commercial floor space grew by 22%. As a result, the commercial sector also exhibits a slight decline in fuel use per unit space.

Figure 13. Emissions from Residential and Commercial Sectors

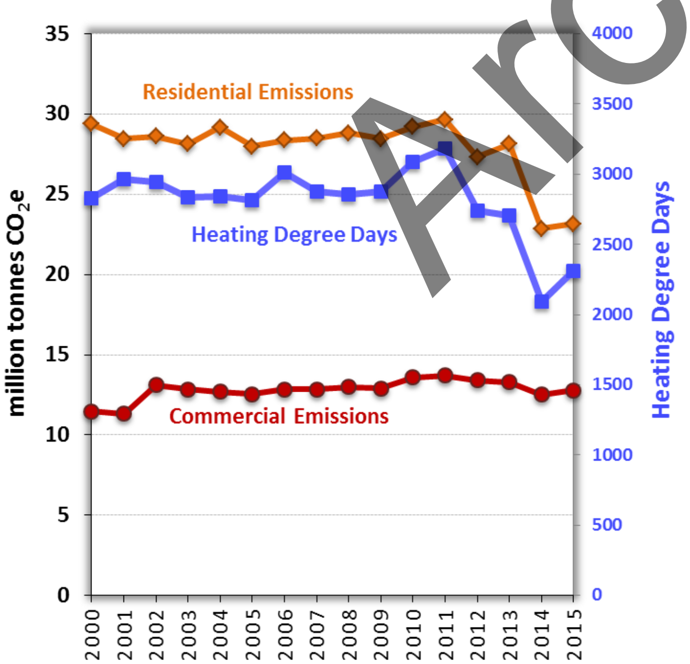
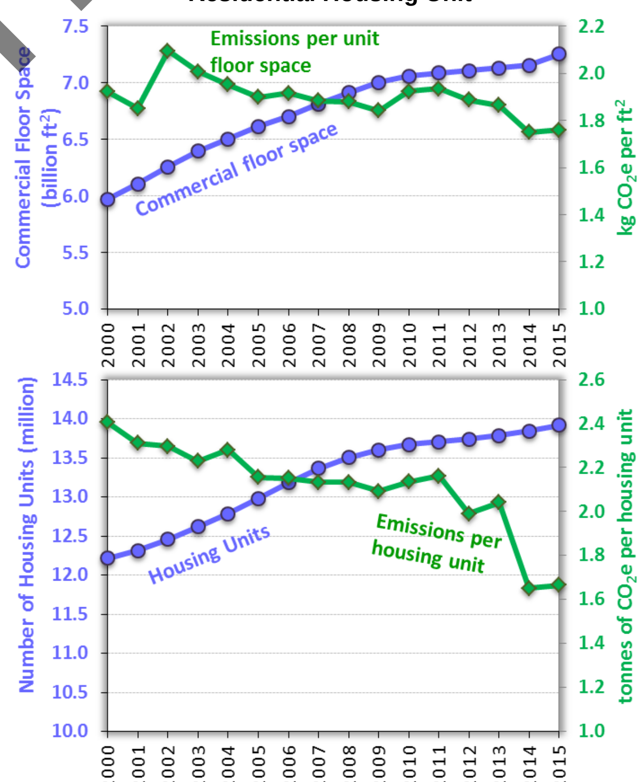


Figure 14. Emissions per Unit Floor Space and Residential Housing Unit



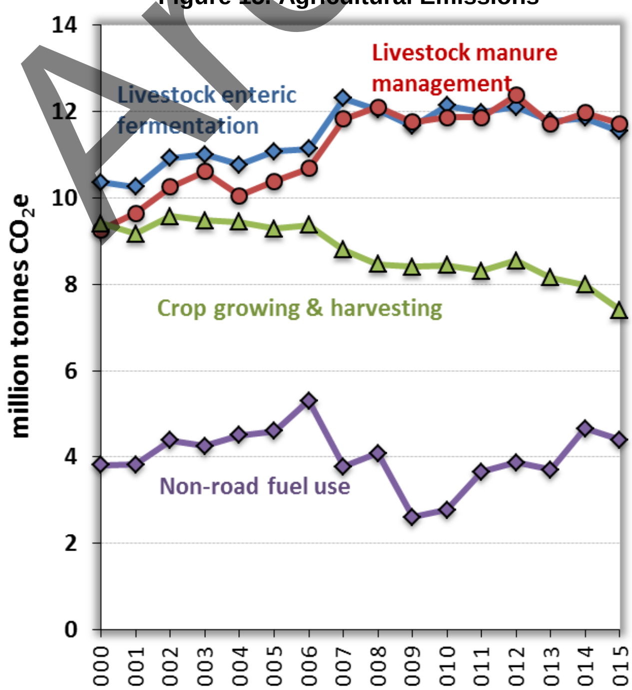
Agriculture

The agricultural sector contributed approximately 8% of statewide GHG emissions in 2015, mainly from methane (CH_4) and nitrous oxide (N_2O) sources. Sources include enteric fermentation and manure management from livestock, crop production (fertilizer use, soil preparation and disturbances, and crop residue burning), and fuel combustion associated with agricultural activities (water pumping, cooling or heating buildings and commodities). Livestock accounted for approximately two thirds of the agricultural emissions, primarily CH_4 from enteric fermentation and manure management. Dairies are a major source, accounting for roughly 60% of agricultural emissions. Comparing 2015 to 2000, California dairies' total milk production grew 27%[14], while GHG emissions from dairy manure management and enteric fermentation increased by 23%.

Emissions from the growing and harvesting of crops have been declining since 2012, with 2015 emissions showing the largest decrease in the time series. This corresponds to a reduction in crop acreage and associated synthetic fertilizer use likely due to drought[14] and large-scale changes in irrigation management practices that moved from flood irrigation towards sprinkler and drip irrigation. About three quarters of crop emissions are from fertilizer and manure use.

Eighty-three percent of agricultural fuel combustion emissions are due to diesel fuel combustion. Emissions from agricultural fuel use are historically variable, and have followed an increasing trend since 2009. However, 2015 emissions decreased compared to 2014, with a 5.8% decrease in total emissions.

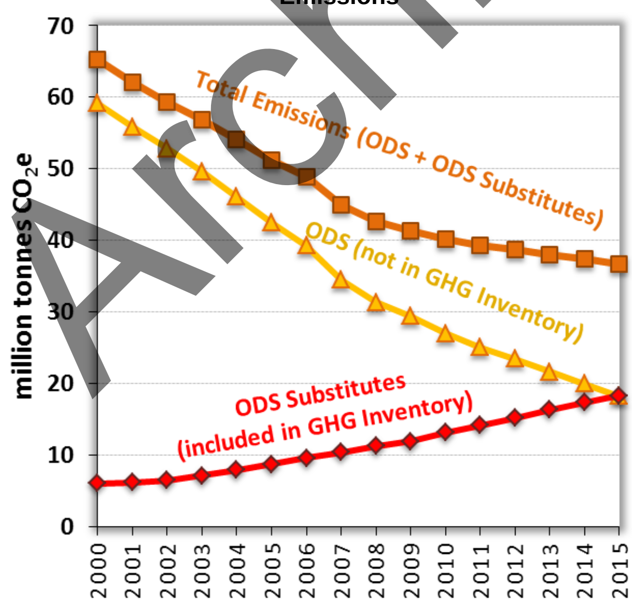
Figure 15. Agricultural Emissions



High Global Warming Potential Gases

In 2015, High Global Warming Potential (high-GWP) gases comprise 4.3% of California's emissions. The GHG inventory tracks High-GWP gas emissions from substitutes for ozone depleting substances (ODS), losses from the electricity transmission and distribution system, and gases that are emitted in the semiconductor manufacturing process. Out of these, 96% of high-GWP gases are attributed to ODS substitutes, which are primarily hydrofluorocarbons (HFCs). ODS substitutes are used in refrigeration and air conditioning equipment, solvent cleaning, foam production, fire retardants, and aerosols. In 2015, refrigeration and air conditioning equipment across all sectors contributed 92% of ODS substitutes emissions. Emissions of ODS substitutes are expected to continue to grow as they replace ODSs banned under the Montreal Protocol.[7] Note that ODSs are also GHGs, but they are not within the inventory scope defined by the IPCC or AB 32; and therefore, are not included in the GHG inventory. Emissions of ODS have decreased significantly since the 1990s, when they began to be phased out, and have dropped below ODS substitutes emissions for the first time in 2015. The combined emissions of ODS and ODS substitutes have also been steadily decreasing over time.

Figure 16. Trend in ODS and ODS Substitutes Emissions



Recycling and Waste

Emissions from the recycling and waste sector consist of CH_4 and N_2O emissions from landfills and from commercial-scale composting. Emissions from recycling and waste, which comprise 2% of California's GHG inventory, have grown by 19% since 2000. Landfill emissions account for 96% of the emissions in this sector,* while compost production facilities make up a small fraction of emissions. The annual amount of solid waste deposited in California's landfills grew from 39 million tons in 2000 to its peak of 46 million tons in 2005, followed by a declining trend until 2012, then increased again in the past 3 years.[16] Landfill emissions are driven by the total waste-in-place, an accumulation of degradable carbon in the solid waste stream, rather than year-to-year fluctuation in annual deposition of solid waste[17]. The amount of methane emitted to the atmosphere as a portion of the total amount of methane generated from the decomposition of accumulated waste has gradually declined over time due to improvements in landfill gas control.

Figure 17. Landfill Methane Generation and Emissions

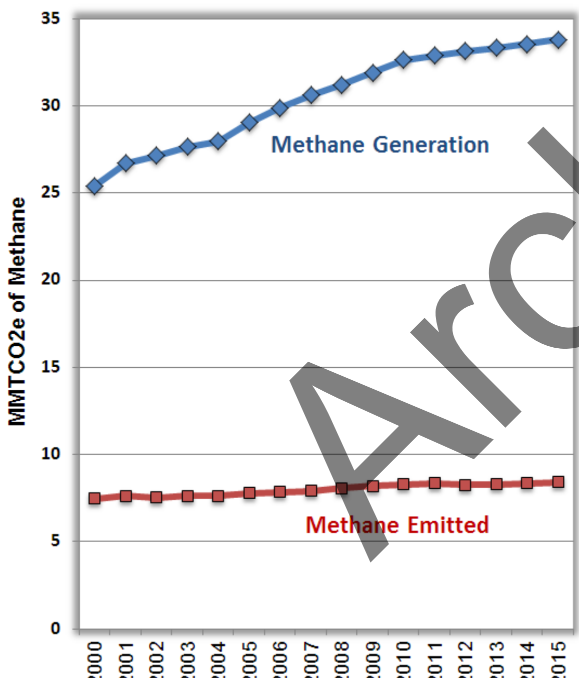
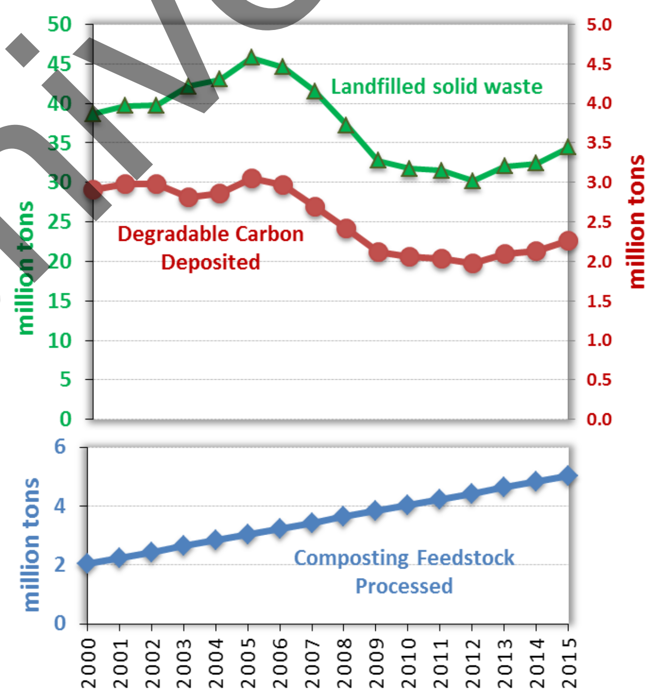


Figure 18. Landfill Waste



* ARB's GHG inventory methodology has been using an assumption of 75 percent methane capture efficiency, consistent with common practice nationally. ARB is currently in the process of evaluating the effects of the Landfill Methane Control Measure. Previous estimates for the measure indicated that it may potentially increase the collection efficiency at regulated landfills to 80-85 percent. However, current landfill collection efficiency estimates vary widely and are highly dependent on a variety of site-specific factors, including landfill size, age, waste composition, local climate, soil type, landfill cover, and gas collection system. Additional California-specific data is necessary to assess the overall collection efficiency at landfills. In recognition of this, ARB and CalRecycle are planning additional research to evaluate gas collection efficiencies at California's landfills. Future inventories will incorporate the results of new research in landfill collection efficiency estimates.

Sources of Data Used in the GHG Emission Inventory

Statewide GHG emissions are calculated using many data sources. The primary data source is from reports submitted to the California Air Resources Board (ARB) through the Regulation for the Mandatory Reporting of GHG Emissions (MRR). MRR requires facilities and entities with more than 10,000 metric tons CO_2e of combustion and process emissions, all facilities belonging to certain industries, and all electric power entities to submit an annual GHG emissions data report directly to ARB. Reports from facilities and entities that emit more than 25,000 metric tons of CO_2e are verified by an ARB-accredited third-party verification body. Emissions data from MRR are aggregated and reallocated to match existing GHG inventory classifications developed to align with IPCC guidelines. More information on MRR emissions reports can be found at: http://www.arb.ca.gov/cc/reporting/ghg-rep/reported-data/ghg-reports.htm

Since MRR data represent a subset of total GHG emissions in the State, ARB also relies on data from other California State and federal agencies to develop an economy-wide GHG inventory for the State of California. These additional sources include, but are not limited to, data from the California Energy Commission, Board of Equalization, Department of Conservation/ Division of Oil, Gas, and Geothermal Resources, Department of Food and Agriculture, and CalRecycle, U.S. Energy Information Administration, and U.S. Environmental Protection Agency. All data sources used to develop the GHG Inventory are listed in the GHG Emission Inventory supporting documentation at: http://www.arb.ca.gov/cc/inventory/data/data.htm

The main GHG inventory page is located at: http://www.arb.ca.gov/cc/inventory/inventory.htm

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