CALIFORNIA
AIR RESOURCES BOARD

California Greenhouse Gas Emissions for 2000 to 2018

Trends of Emissions and Other Indicators

Executive Summary

The annual statewide greenhouse gas (GHG) emission inventory is an important tool in tracking progress towards meeting statewide GHG goals. This document summarizes the trends in emissions and indicators in the California GHG Emission Inventory ("the GHG Inventory). The 2020 edition of the inventory includes GHG emissions released during 2000-2018 calendar years. In 2018, emissions from GHG emitting activities statewide were 425 million metric tons of carbon dioxide equivalent (MMTCO_2e), 0.8 MMTCO_2e higher than 2017 levels and 6 MMTCO_2e below the 2020 GHG Limit of 431 MMTCO_2e. The most notable highlights in the 2020 edition inventory include:

- California statewide GHG emissions dropped below the 2020 GHG Limit in 2016 and have remained below the 2020 GHG Limit since then.
- Transportation emissions decreased in 2018 compared to the previous year, which is the first year over year decrease since 2013.
- Since 2008, California's electricity sector has followed an overall downward trend in emissions. In 2018, solar power generation has continued its rapid growth since 2013.
- Emissions from high-GWP gases increased 2.3 percent in 2018 (2000-2018 average year-over-year increase is 6.8 percent), continuing the increasing trend as they replace Ozone Depleting Substances (ODS) being phased out under the 1987 Montreal Protocol.

Figure 1 compares annual statewide GHG emissions to the 2020 GHG Limit.

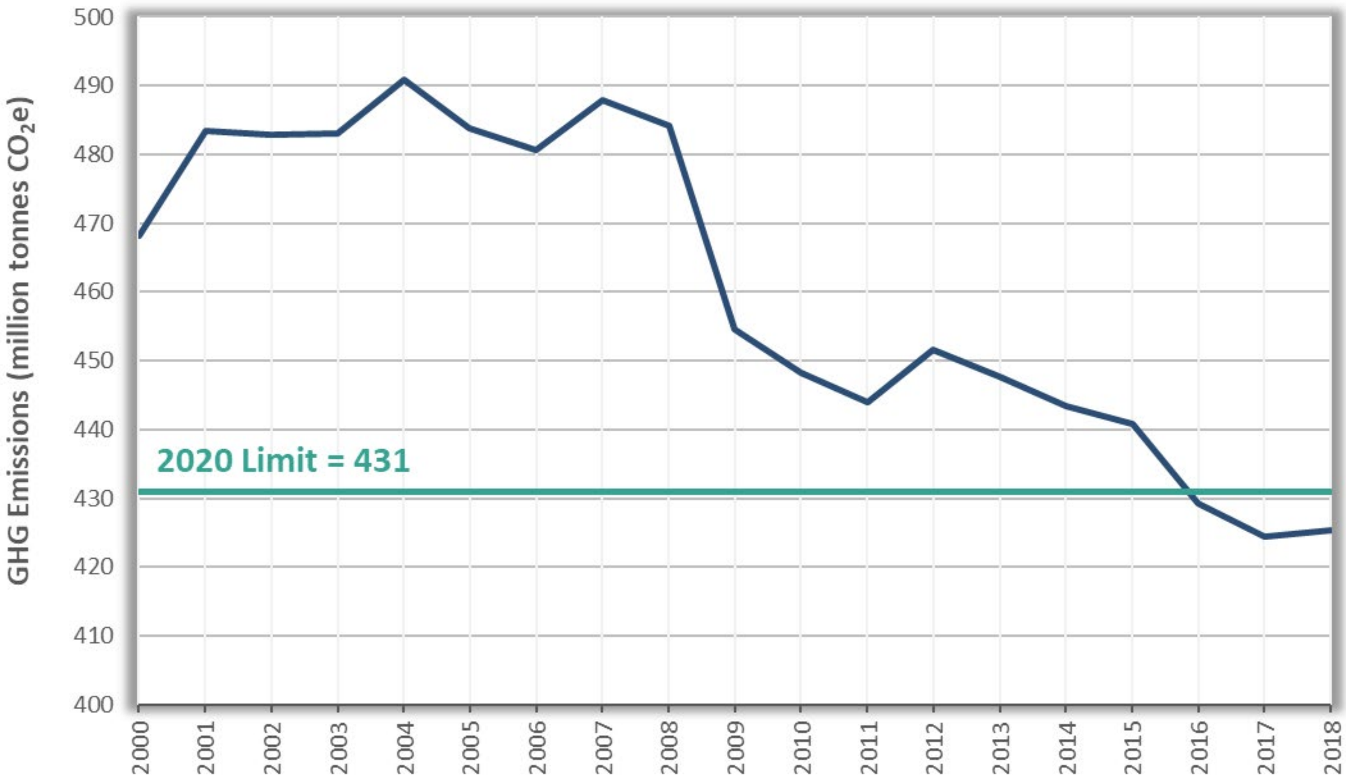


Figure 1. California's GHG emissions, 2000-2018. This graph shows California's annual GHG emissions from 2000 to 2018 in relation to the 2020 GHG Limit required by the California Global Warming Solutions Act (Assembly Bill 32). In 2016, California's GHG emissions dropped below the 2020 GHG Limit and have remained below the 2020 GHG Limit since that time.

Introduction

The GHG inventory is an important tool in demonstrating the State's progress towards achieving the statewide GHG goals established by Assembly Bill 32 (AB 32) (reduce emissions to 1990 levels by 2020) and Senate Bill 32 (SB 32) (reduce emissions to at least 40 percent below 1990 levels by 2030). The GHG Inventory includes the following type of sources: emissions from fossil fuel combustion, GHG generated as by-product of chemical reactions in industrial processes, use of GHG-containing consumer products and human-made chemicals, and emissions from agricultural and waste sector operations. The exchange of ecosystem carbon between the atmosphere and the plants and soils in land is separately quantified in the Natural and Working Lands Ecosystem Carbon Inventory [1], which also includes wildfire emissions. For the emission sources included in the GHG Inventory, the inventory framework is consistent with international and national GHG inventory practices [2].

The 2020 edition of the GHG Inventory includes the emissions of the seven GHGs identified in AB 32 [3] for the years 2000 to 2018. There are additional climate pollutants that are not included in AB 32 that are tracked separately outside of the GHG inventory. These climate pollutants include black carbon and sulfuryl fluoride (SO_2F_2), which are discussed in the Short-Lived Climate Pollutant (SLCP) Strategy [4] and ozone depleting substances (ODS), which are being phased out under a 1987 international treaty [5]. ODS are now being substituted with hydrofluorocarbons, which are pollutants specified in AB 32 [3].

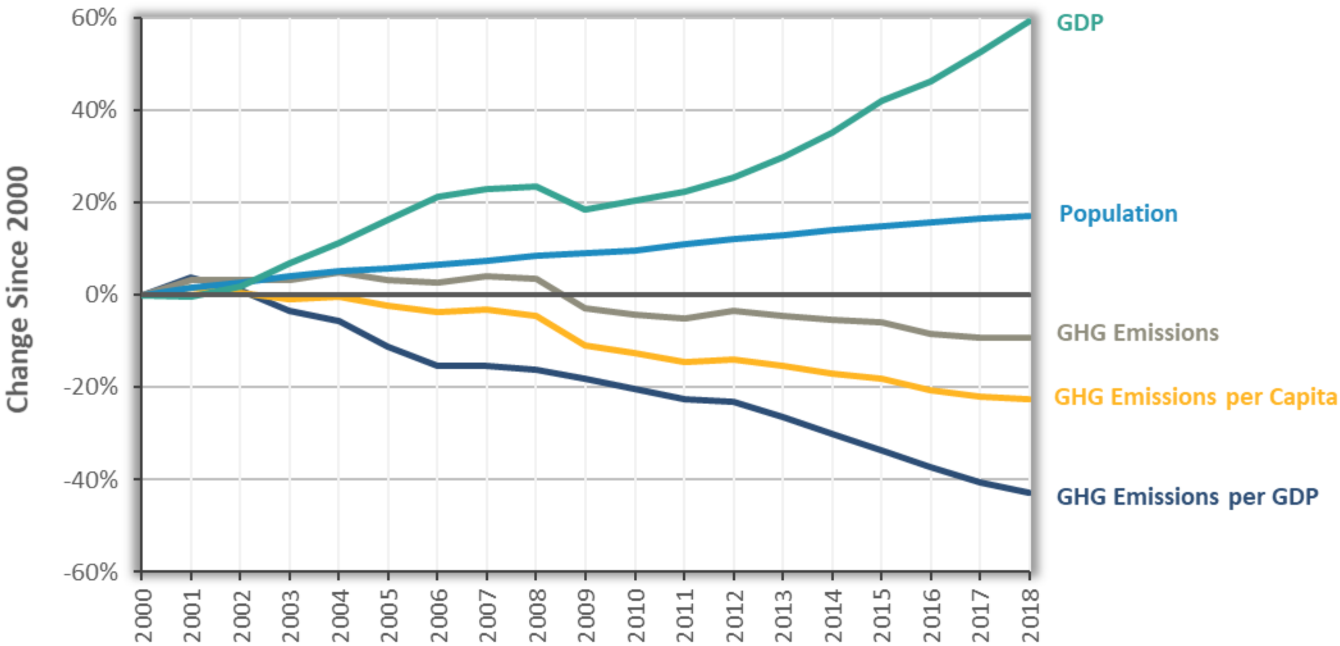
In this report, emission trends and indicators are presented in the categories outlined in the Initial AB 32 Scoping Plan [6]. There are alternative ways of organizing emission sources into categories, and the resulting percentages will be different depending on these categorization schemes. The *Additional Information* section at the end of this report provides further information on alternative categorization schemes. All emissions in this report are expressed in 100-year Global Warming Potential (GWP) from the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report (AR4) [7], consistent with current international GHG inventory practices.

Statewide Trends of Emissions and Indicators

In 2018, emissions from statewide emitting activities were 425 million metric tons of CO_2 equivalent (MMTCO_2e, or million tonnes CO_2e), 1.0 MMTCO_2e higher than 2017 levels and 6 MMTCO_2e below the 2020 GHG Limit of 431 MMTCO_2e. Since the peak level in 2004, California's GHG emissions have generally followed a decreasing trend. In 2016, statewide GHG emissions dropped below the 2020 GHG Limit and have remained below the Limit since that time.

Per capita GHG emissions in California have dropped from a 2001 peak of 14.0 tonnes per person to 10.7 tonnes per person in 2018, a 24 percent decrease [8] [9]. 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. From 2000 to 2018, the carbon intensity of California's economy decreased by 43 percent while the GDP increased by 59 percent. In 2018, GDP grew 4.3 percent while the emissions per GDP declined by 0.4 percent compared to 2017 [9] [10]. Figures 2(a)-(c) show California's growth alongside GHG emissions.

Figure 2a. Change in California GDP, Population, and GHG Emissions Since 2000



Metric	Associated 2018 Value
GDP	2.7 Trillion (2012 $)
Population	39.8 Million
GHG Emissions	425.3 Million Tonnes CO_2e
GHG Emissions per Capita	10.7 Tonnes CO_2e per Capita
GHG Emissions per GDP	156 Tonnes CO_2e per Million $

Figure 2b. California Total and Per Capita GHG Emissions

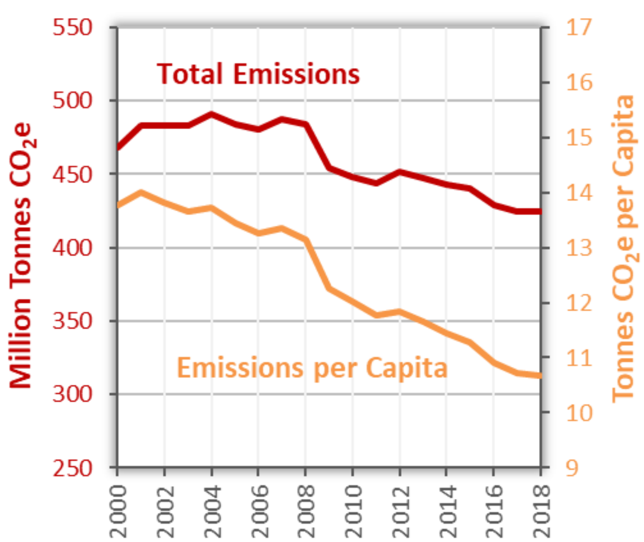
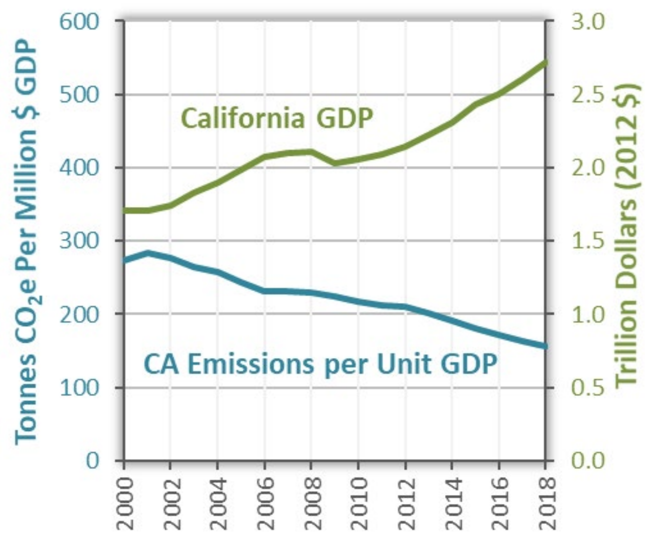


Figure 2c. Carbon Intensity of California's Economy



Figures 2(a)-(c). California's GHG emissions, population, GDP, GHG emissions per capita, and carbon intensity of the economy. Figure 2(a) shows percent change in GHG emissions relative to GDP and population since 2000. Figures 2(b) and 2(c) present these indicators in the original units. In the charts with 2 vertical axes, the color of a trend line matches the color of its corresponding vertical label.

Overview of Emission Trends by Sector

The transportation sector remains the largest source of GHG emissions in the State. Direct emissions from vehicle tailpipe, off-road transportation sources, intrastate aviation, etc., account for 40 percent[a] of statewide emissions in 2018. Transportation emissions decreased in 2018 compared to the previous year, which is the first year over year decrease since 2013. Emissions from the electricity sector account for 15 percent of the inventory and showed a slight increase in 2018 due to less hydropower. The industrial sector trend has been relatively flat in recent years and remains at 21 percent of the inventory. Emissions from high-GWP gases have continued to increase as they replace ODS that are being phased out under the 1987 Montreal Protocol [5]. Emissions from other sectors have remained relatively constant in recent years. Figure 3 shows an overview of the emission trends by Scoping Plan sector. Figure 4 breaks out 2018 emissions by sector into an additional level of sub-sector categories.

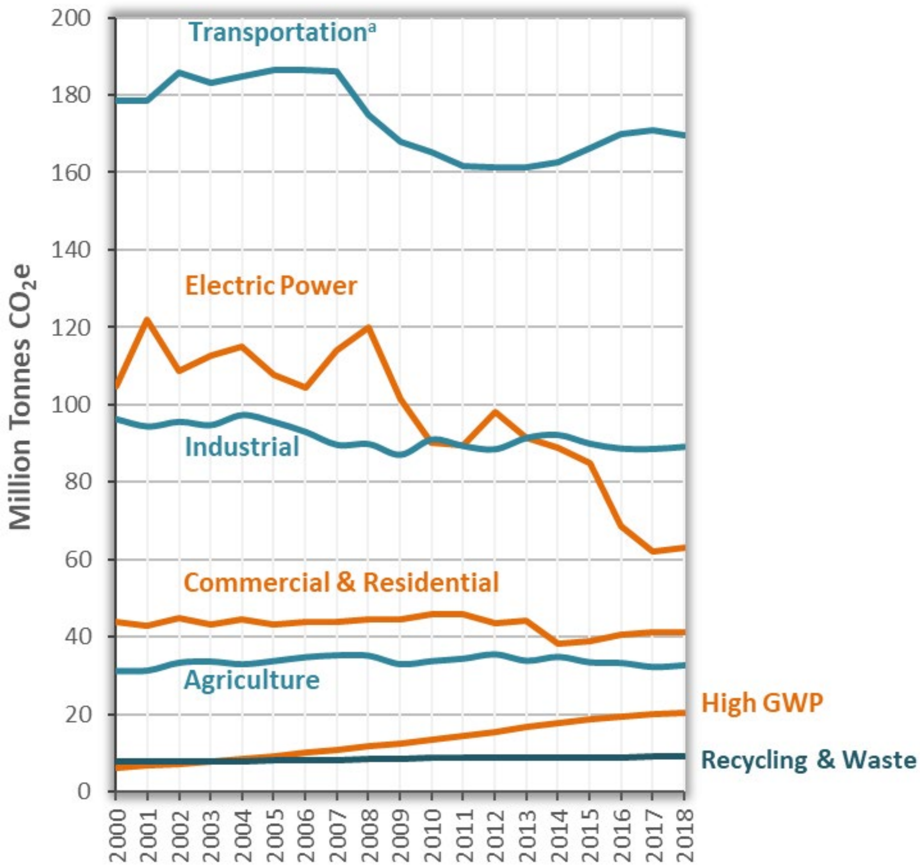


Figure 3. Trends in California GHG Emissions. This figure shows changes in emissions by Scoping Plan sector between 2000 and 2018. Emissions are organized by the categories in the AB 32 Scoping Plan.

[a] The transportation sector represents tailpipe emissions from on-road vehicles and direct emissions from other off-road mobile sources. It does not include emissions from petroleum refineries and oil extraction and production.

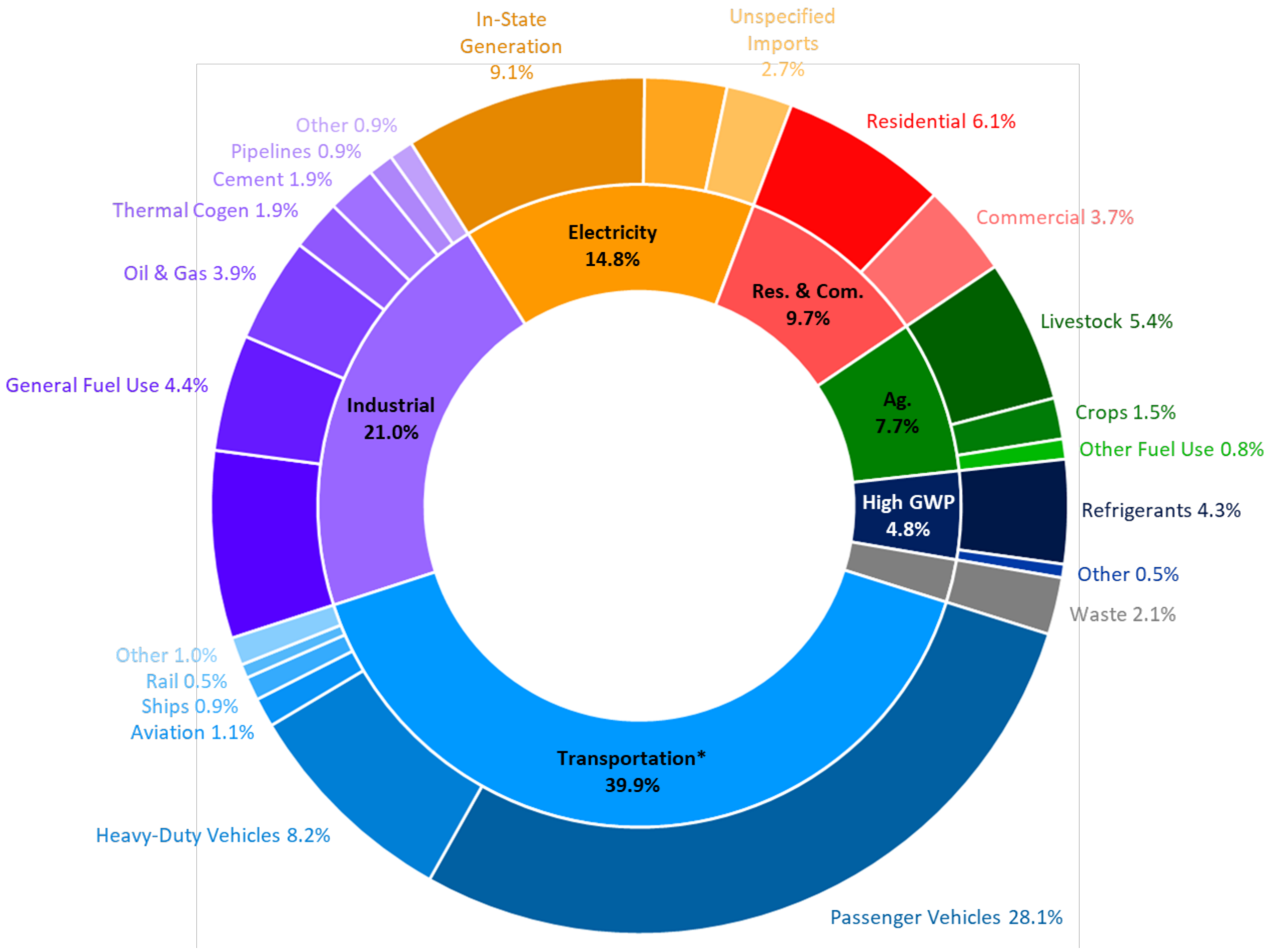


Figure 4. 2018 GHG Emissions by Scoping Plan Sector and Sub-Sector Category. This figure breaks out 2018 emissions by sector into an additional level of sub-sector categories. The inner ring shows the broad Scoping Plan sectors. The outer ring breaks out the broad sectors into sub-sectors or emission categories under each sector.

*The transportation sector represents tailpipe emissions from on-road vehicles and direct emissions from other off-road mobile sources. It does not include emissions from petroleum refineries and oil extraction and production, which are included in the industrial sector.

Transportation Sector

The transportation sector remains the largest source of GHG emissions in 2018, accounting for 40 percent[b] of California's GHG inventory. Contributions from the transportation sector[c] include emissions from combustion of fuels 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. (In this report, emissions from refrigerants used in vehicles, airplane, train, and ship and boat are shown in the High-GWP gases category.) Transportation emissions decreased in 2018 compared to the previous year, which is the first year over year decrease since 2013. Figure 5 shows emissions by transportation source categories and the sector total.

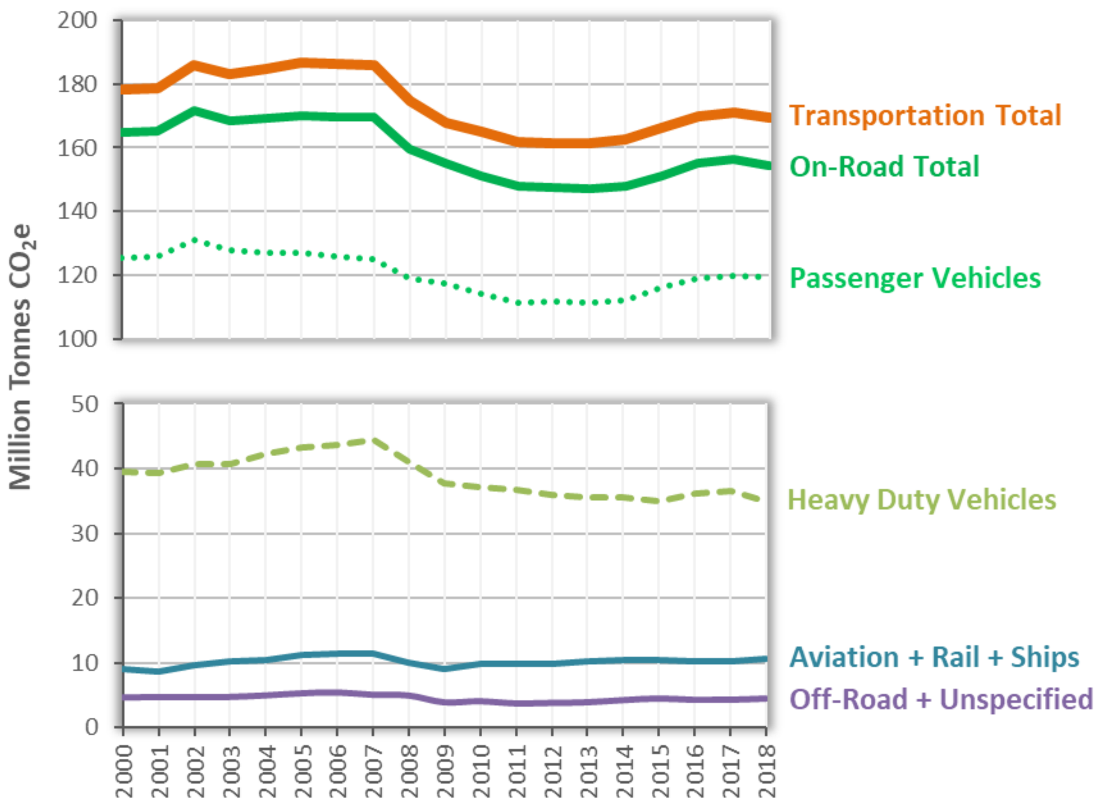


Figure 5. Overview of GHG Emissions from the Transportation Sector. "Transportation Total" is the sum of "On-Road Total," "Aviation + Rail + Ships," and "Off-Road + Unspecified." "On-Road Total" is the sum of "Passenger Vehicles" and "Heavy Duty Vehicles."

[b] The 40 percent figure represents tailpipe emissions from on-road vehicles and direct emissions from other non-road transportation sources. It does not include emissions from petroleum refineries and oil extraction and production, which are included in the industrial sector.

[c] Emissions from the following sources are not included in the GHG inventory for the purpose of comparing to the GHG Limit, but are tracked separately as informational items and are published with the GHG inventory: interstate and international aviation, diesel and 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. The following emissions are not included or tracked in the GHG inventory: emissions from the combustion of fuels purchased outside of California that are used in-state by passenger vehicles and trains crossing into California, and out-of-state upstream emissions tracked by the Low Carbon Fuel Standard (LCFS) program.

Figures 6 and 7 show the trends in emissions and fuel used in 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. Consistent with the IPCC Guidelines [2] and the annual GHG inventories submitted by the U.S. and other nations to the United Nations Framework Convention on Climate Change (UNFCCC), carbon dioxide (CO_2) emissions from biofuels (the biofuel components of fuel blends) are classified as "biogenic CO_2." They are tracked separately from the rest of the emissions in the inventory and are not included in the total emissions when comparing to California's 2020 and 2030 GHG Limits. Biogenic CO_2 emissions data are available on the CARB webpage [9]. Emissions of methane (CH_4) and nitrous oxide (N_2O) from biofuel combustion are included in the inventory along with CO_2 from fossil fuel combustion.

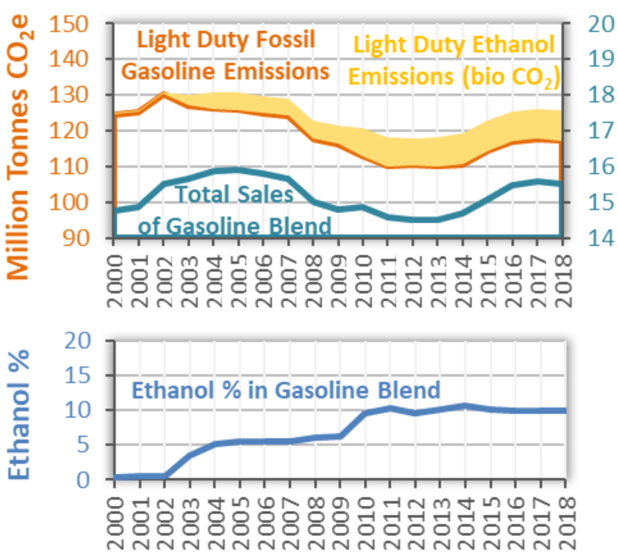


Figure 6. Trends in On-Road Light Duty Gasoline Emissions. In the top panel, the yellow shaded region represents CO_2 emissions from the ethanol-component of the gasoline fuel blend. The orange line includes all GHG emissions from the fossil gasoline component of the fuel blend, as well as the CH_4 and N_2O emissions from the ethanol-component of the fuel blend. "Total Sales of Gasoline Blend" includes gasoline used in any types of vehicles, 93% of which are used in light duty vehicles. The color of a trend line matches the color of its corresponding vertical axes label. The bottom panel shows the percent of gasoline blend that is ethanol.

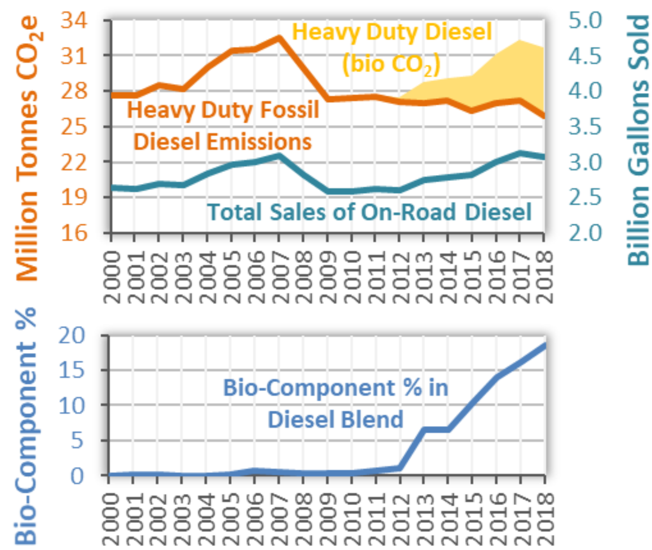


Figure 7. Trends in On-Road Diesel Vehicle Emissions. In the top panel, the yellow shaded region represents CO_2 emissions from the bio-component (biodiesel and renewable diesel) of the diesel fuel blend. The orange line includes all GHG emissions from the fossil diesel component of the fuel blend, as well as the CH_4 and N_2O emissions from the bio-component of the fuel blend. "Total Sales of On-Road Diesel " includes diesel blends used in any types of vehicles, 97% of which are used in heavy duty vehicles. The color of a trend line matches the color of its corresponding vertical axes label. The bottom panel shows the percent of diesel blend that are biodiesel or renewable diesel.

Emissions from transportation sources declined from 2007 to 2013, followed by four consecutive years of annual increases through 2017. Transportation emissions dropped by 1.5 $MMTCO_2e$ in 2018. Sales of gasoline fuel blend decreased more than 60 million gallons, while ethanol blending increased by 15 million gallons. Diesel fuel blend sales decreased 50 million gallons, while sale and blending of biodiesel and renewable diesel increased by more than 60 million gallons. Emissions from gasoline used in on-road passenger cars, trucks, and SUVs are 74 percent of the transportation inventory and had been the main driver of the increases between 2013 and 2017.

A combination of factors influences on-road transportation emissions. Regulations, improved fuel efficiency of the state's vehicle fleet, and higher market penetration of zero-emission vehicles can drive down consumption and emissions over time; but population growth, lower fuel prices, more consumer activity, and higher overall employment are factors that may increase fuel use. Biofuels such as ethanol, biodiesel, and renewable diesel displace fossil fuels and reduce the amount of fossil-based CO_2 emissions released into the atmosphere. The percentages of biodiesel and renewable diesel in the total diesel blend have shown significant growth in recent years, growing from 0.5 percent in 2011 to 18.5 percent in 2018, due mostly to the implementation of the Low Carbon Fuel Standard.

Electric Power

Emissions from the electric power sector comprise 15 percent of 2018 statewide GHG emissions. The GHG emission inventory divides the electric power sector into two broad categories: emissions from in-state power generation (including the portion of industrial and commercial cogeneration emissions attributed to electricity generation) and emissions from imported electricity.

Since the early 2000's, the development of renewable and less carbon-intensive resources have facilitated the continuing decline in fossil fuel electricity generation. The Renewable Portfolio Standard (RPS) Program and the Cap-and-Trade Program continue to incentivize the dispatch of renewables over fossil generation to serve California load. Higher energy efficiency standards also reduce growth in electricity consumption driven by a growing population and economy. However, year-to-year fluctuations in hydropower availability may result in small increases in carbon intensity in some years. Figures 8 and 9 show California's electricity emissions and GHG intensities of electricity generation over time.

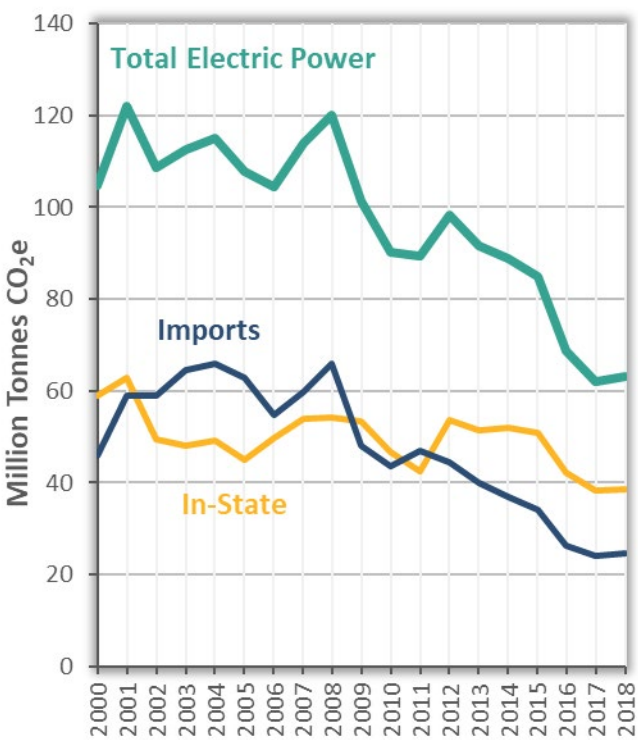


Figure 8. GHG Emissions from the Electric Power Sector. This figure shows trends in emissions of in-state electricity generation, emissions associated with electricity imported from outside of California, and the total electric power sector emissions, which is the sum of in-state generation and imports.

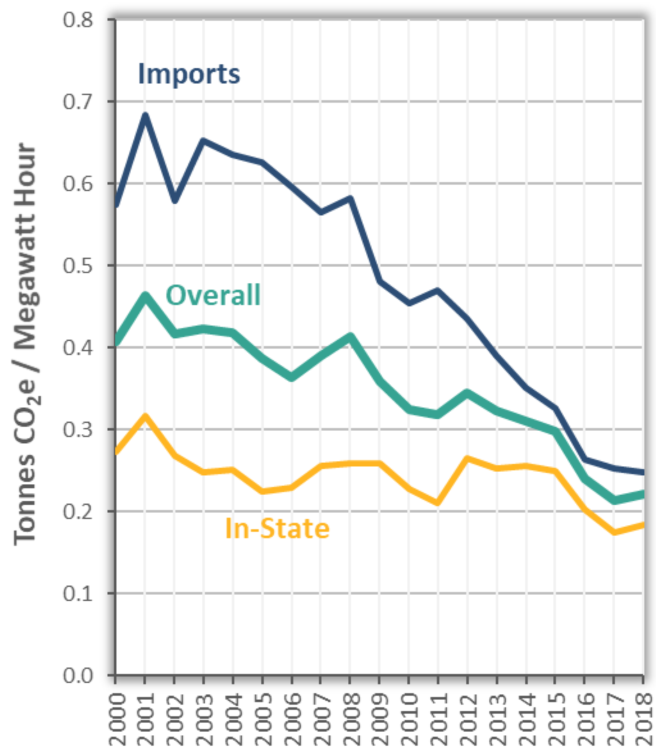


Figure 9. GHG Intensity of Electricity Generation.[d] This figure shows trends in GHG intensities of electricity generated by in-state power plants, electricity imported from outside of California, and the overall GHG intensities aggregating both in-state generation and electricity imports.

[d] 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 generation (MWh) 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 electricity (MWh) consumed in and exported from California, and excludes electricity (MWh) lost during transmission and distribution.

From 2017 to 2018, electric power emissions increased by 1 $MMTCO_2e$, primarily due to a 39 percent decrease in in-state hydropower generation (a result of lower precipitation levels in the 2017-2018 winter season) that was partially compensated by increases in solar generation and other lower GHG intensity resources. In 2018, 44 percent of total electricity generation (in-state generation plus imported electricity) came from solar, wind, hydropower, and nuclear power; and another five percent came from Asset Controlling Suppliers[e], which imported low GHG intensity electricity consisting primarily hydropower.

In-state solar generation grew 14 percent in 2018 compared to 2017. Between 2011 and 2018, in-state solar generation saw significant growth as rooftop photovoltaic solar generation increased eight-fold [11] and total solar generation (commercial-scale plus rooftop solar) increased by a factor of 15 during that period [11] [12]. In-state wind energy generation ramped up through 2013, but its trend has remained relatively constant since 2013 [12]. Figure 10 shows trends in in-state hydro, solar, and wind electricity generation.

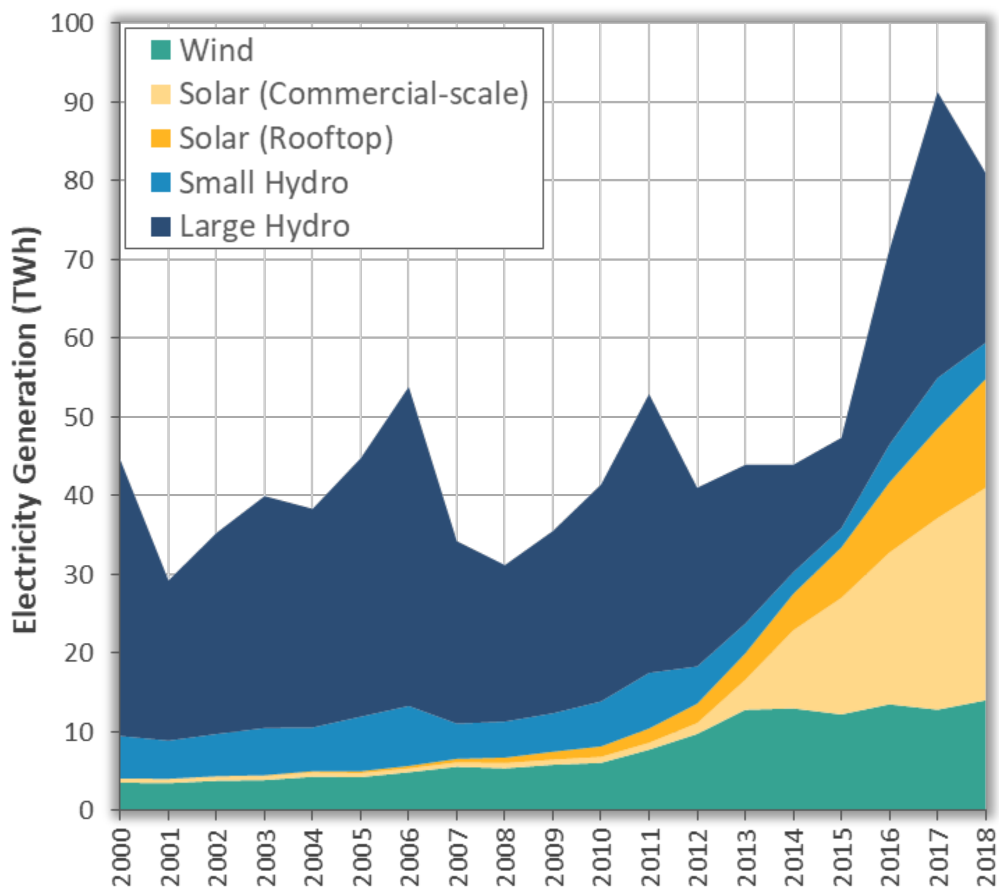


Figure 10. In-State Hydro, Solar, and Wind Electricity Generation. This figure shows the amounts of electricity generated by California's in-state wind power projects, large commercial-scale solar power projects, rooftop solar panels, and hydropower generation stations. The units are in terawatt-hour (1 TWh = 10^9 kWh).

[e] "Asset Controlling Suppliers" are as defined by the Mandatory GHG Reporting Regulation (MRR). The term refers to an electric power entity that owns or operates inter-connected electricity generating facilities or serves as an exclusive marketer for these facilities even though it does not own them. Imports from ACS are primarily hydropower, but include some non-zero GHG power sources such as natural gas.

Trends in the types of in-state generation are presented in Figure 11. In-state natural gas generation complements the year-to-year fluctuations in hydro, solar, wind, and nuclear power, while generation from other fuel types gradually decline over time.

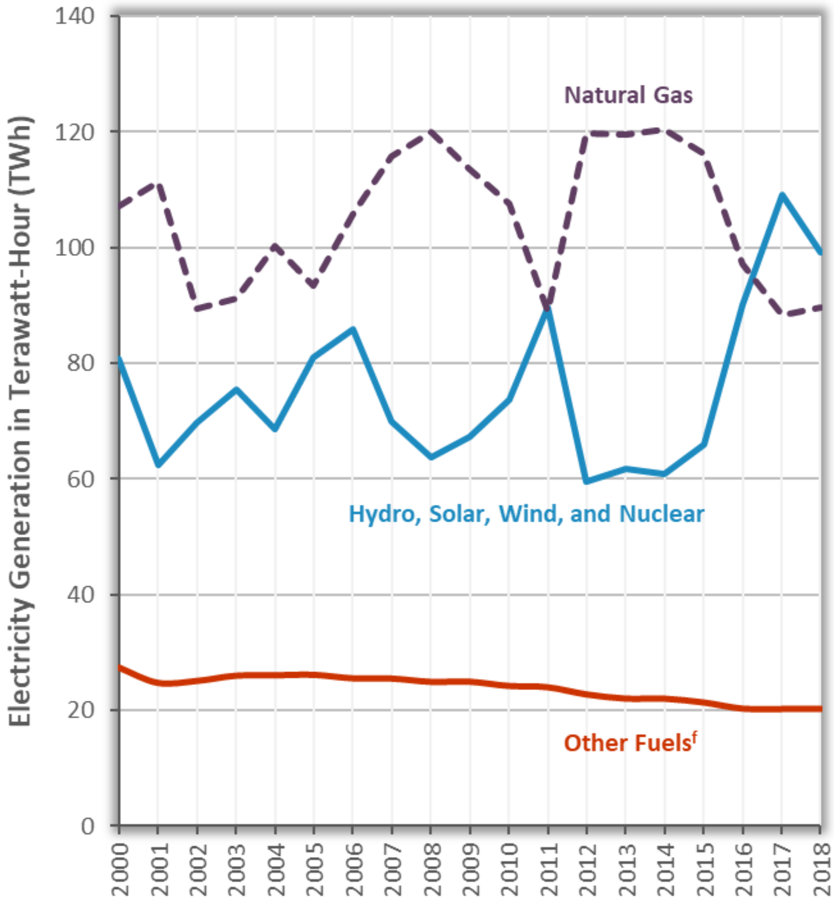


Figure 11. In-State Electricity Generation by Fuel Type. This figure shows the amounts of electricity generated by in-state natural gas power plants, hydro/solar/wind/nuclear resources, and other generation sources. The units are in terawatt-hour (1 TWh = 10^9 kWh).

[f] "Other Fuels" include energy generation from associated gas, biomass, coal, crude oil, digester gas, distillate, geothermal, jet fuel, kerosene, landfill gas, lignite coal, municipal solid waste (MSW), petroleum coke, propane, purchased steam, refinery gas, residual fuel oil, sub-bituminous coal, synthetic coal, tires, waste coal, waste heat, and waste oil. CO_2 and CH_4 emissions from geothermal power and CH_4 and N_2O emissions from biomass power are included in the statewide total for comparing to the 2020 GHG Limit. Except for geothermal power, most of these fuels are combusted in industrial cogeneration facility.

Trends in the types of imported electricity are presented in Figure 12 [13]. In 2018, imports of hydro, solar, wind, and nuclear energy grew nine percent while imports of coal energy dropped 21 percent. Comparing to 2011 levels, imports of hydro, solar, wind, and nuclear energy nearly tripled, while imports of coal energy dropped by 67 percent.[g]

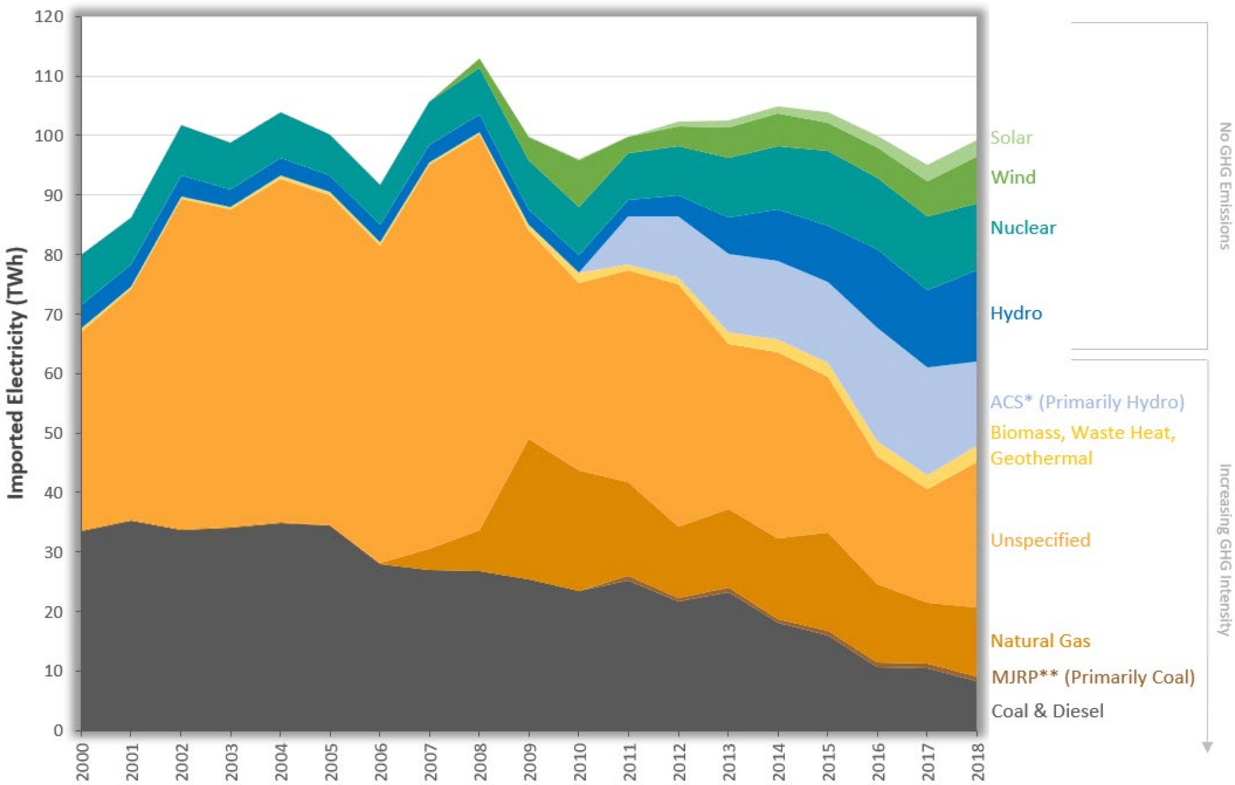


Figure 12. Imported Electricity by Generation Type. This figure shows the amounts of imported electricity by generation type. Non-emitting resources are on the top and include hydro, nuclear, wind, and solar. Asset Controlling Suppliers (ACS) and Multi-Jurisdictional Retail Provider (MJRP) are as defined by the Mandatory GHG Reporting Regulation (MRR) [13]. *Imports from ACS are primarily hydropower, but include some GHG-emitting power sources such as natural gas. **Imports from MJRP are primarily coal, but include other types of generation resources. The units are in terawatt-hour (1 TWh = 10^9 kWh).

[g] All claims of non-GHG-emitting imports are subject to third party verification to ensure against resource shuffling.

Industrial

Emissions from the industrial sector contributed 21 percent of California's total GHG emissions in 2018. Emissions in this sector are primarily driven by fuel combustion from sources that include refineries, oil & gas extraction, cement plants, and the portion of cogeneration emissions attributed to thermal energy output. Process emissions, such as from clinker production in cement plants and hydrogen production for refinery use, also contribute significantly to the total emissions. Refineries and hydrogen production represent the largest individual source in the industrial sector, contributing 34 percent of the sector's total emissions. Refining and hydrogen production sector emissions have remained relatively constant in the past few years. Figure 13 shows emissions trends of the industrial sector over time.

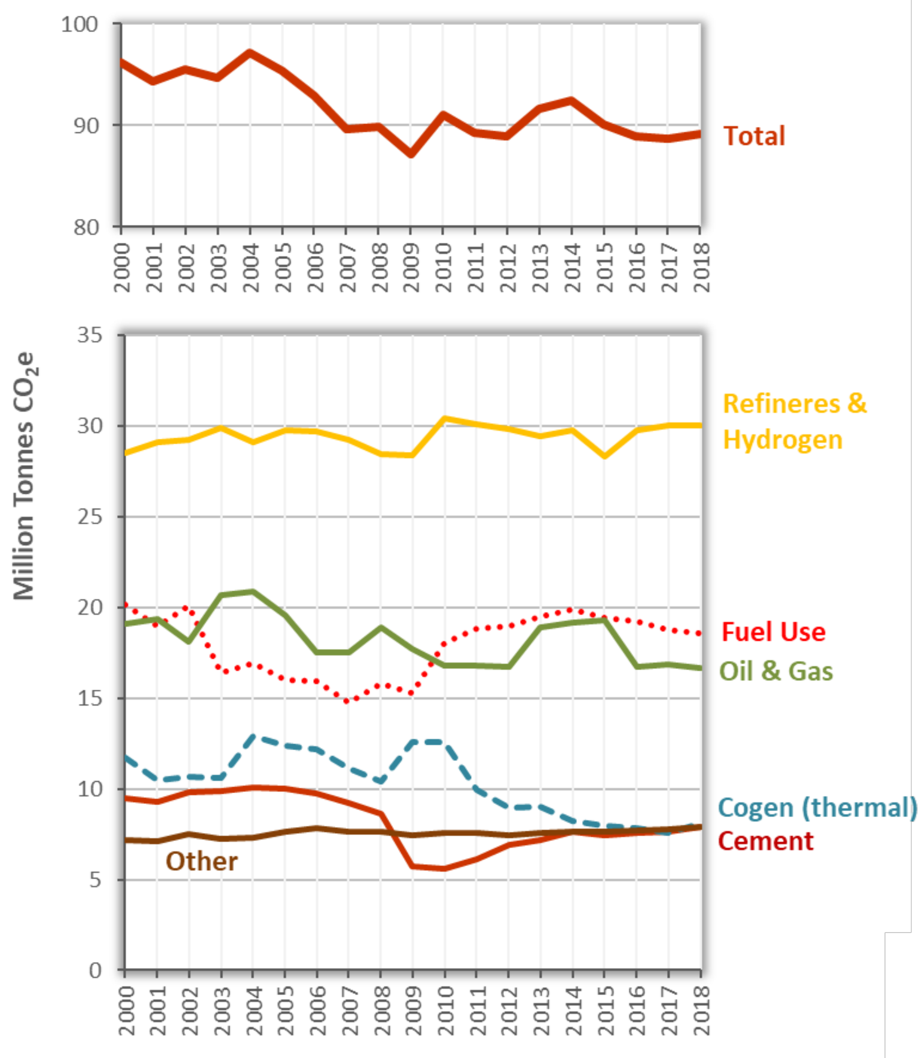


Figure 13. Industrial Sector Emissions. The top panel of this figure shows the overall emissions trend of the total industrial sector. The bottom panel shows emissions trends by sub-sector. Summing the bottom panel will equal the top panel. The "General Fuel Use" category includes emissions from combustion of fuels used by sectors not specifically broken out elsewhere in this figure. The "Other" category includes fugitive and process emissions (e.g., GHG released from chemical reaction during manufacturing process) from industrial sectors. In accordance with the IPCC Guidelines, the "Cogen (thermal)" category under the industrial sector includes only the portion of cogeneration emissions attributed to the total thermal output of cogeneration. The portion of cogeneration emissions attributed to electricity generation is assigned to the electric power sector and not shown in this graph.

Commercial and Residential Fuel Combustion

Greenhouse gas emissions from the commercial and residential sectors are dominated by the combustion of natural gas and other fuels for household and commercial business use, such as space heating, cooking, and hot water or steam generation. Emissions from electricity used for cooling (air-conditioning) and appliance operation are accounted for in the Electric Power sector. In this report, using the Scoping Plan categorization, emissions from refrigerants use in commercial and residential buildings are presented in the high-GWP gases category. Changes in annual fuel combustion emissions are primarily driven by variability in weather conditions and the need for heating in buildings, as well as population growth. In 2018, emissions increased slightly compared to 2017 due to a rise in commercial natural gas use. Figure 14 presents emissions from the commercial and residential sectors, along with heating degree days, an estimate of the heating energy need in a given year.

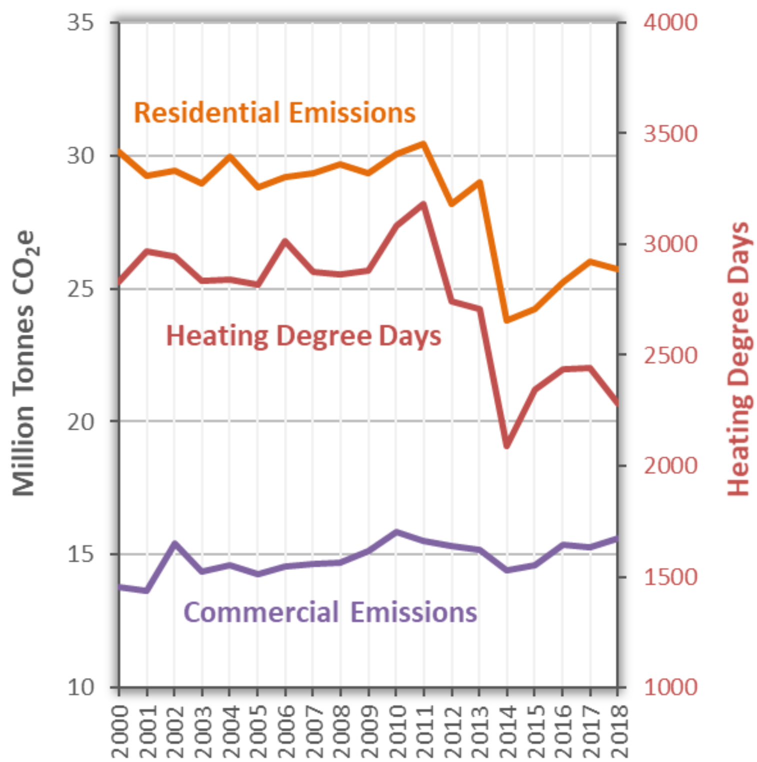


Figure 14. Emissions from Residential and Commercial Sectors. Emissions from the residential and commercial sectors are compared with heating degree days, an estimate of the heating energy need in a given year.

Emissions from fuel use by the commercial sector have grown by 13 percent since 2000; however, during the same period, commercial floor space grew by 27 percent. As a result, the commercial sector also exhibits a slight decline in fuel use per unit space. The number of occupied residential housing units grew steadily from 11.9 million units in 2000 to 13.1 million units in 2018 [14]. Emissions per housing unit generally fluctuate with the need for heating depending the winter temperatures of the given year, which is also illustrated by the heating degree day index in Figure 14 [15]. Figures 15a and 15b show emissions from these sectors and the related indicators.

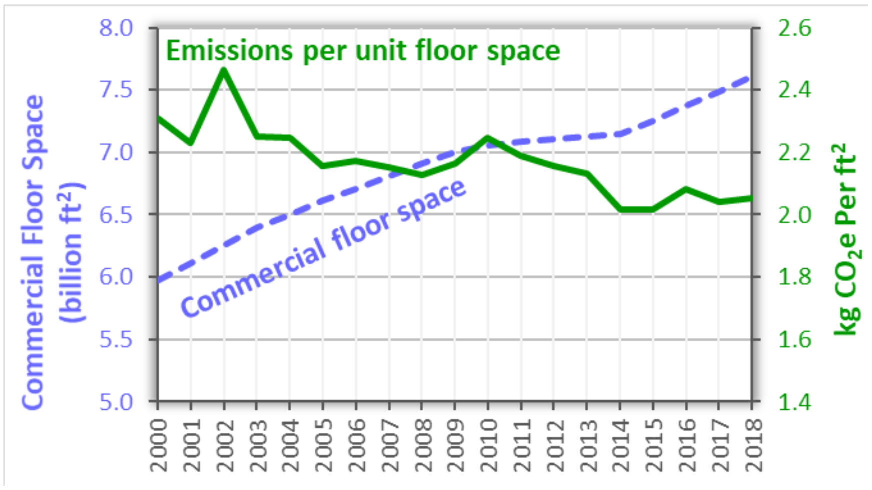


Figure 15a. Emissions per Unit Floor Space. The figure shows total square feet of commercial floor space and the emissions per square feet of commercial floor space.

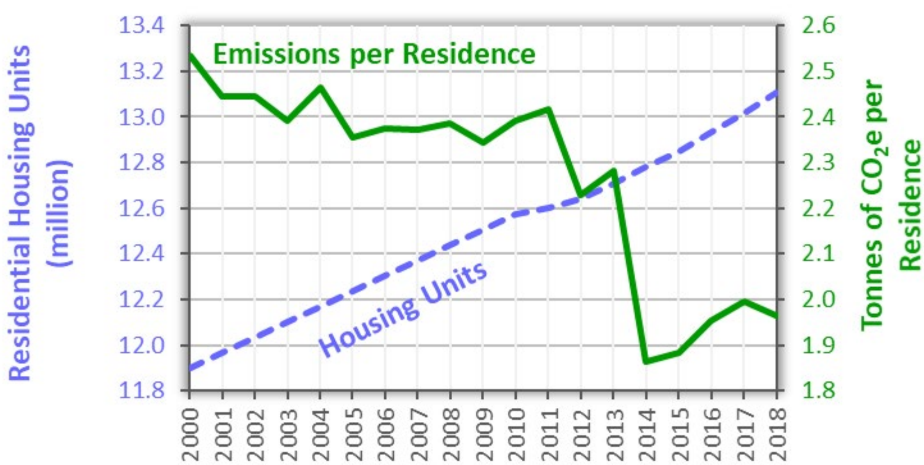


Figure 15b. Emissions per Residential Housing Unit. The figure shows number of occupied residential housing units and emissions per housing unit.

Agriculture

California's agricultural sector contributed approximately eight percent of statewide GHG emissions in 2018, mainly from CH_4 and N_2O sources. Sources include enteric fermentation and manure management from livestock, crop production (fertilizer use, soil preparation and disturbance, and crop residue burning), and fuel combustion associated with agricultural activities (water pumping, cooling or heating buildings, and processing commodities).

Approximately 70 percent of agricultural sector greenhouse gases are emitted from livestock. Livestock emissions in 2018 are 19 percent higher than 2000 levels. Livestock emissions are almost entirely CH_4 generated from enteric fermentation and manure management, and most of the livestock emissions are from dairy operations. GHG emissions from dairy manure management and enteric fermentation followed an increasing trend between 2000 and 2007, and year-to-year changes since 2007 have been relatively small.

Crop production accounted for 20 percent of agriculture emissions in 2018. Emissions from the growing and harvesting of crops have generally followed a declining trend since 2000. The long-term trend of emissions reduction from 2000 to 2018 corresponds to a reduction in crop acreage (which leads to an associated decrease in synthetic fertilizer use) [16] and large-scale changes in irrigation management practices. Specifically, California agriculture has been shifting from flood irrigation towards sprinkler and drip irrigation. The increase from 2017 to 2018 is due to climatic factors that affect the amount of N_2O produced from synthetic fertilizer (e.g. precipitation and min/max temperature). Figure 16 presents emissions from the livestock and crop production sectors.

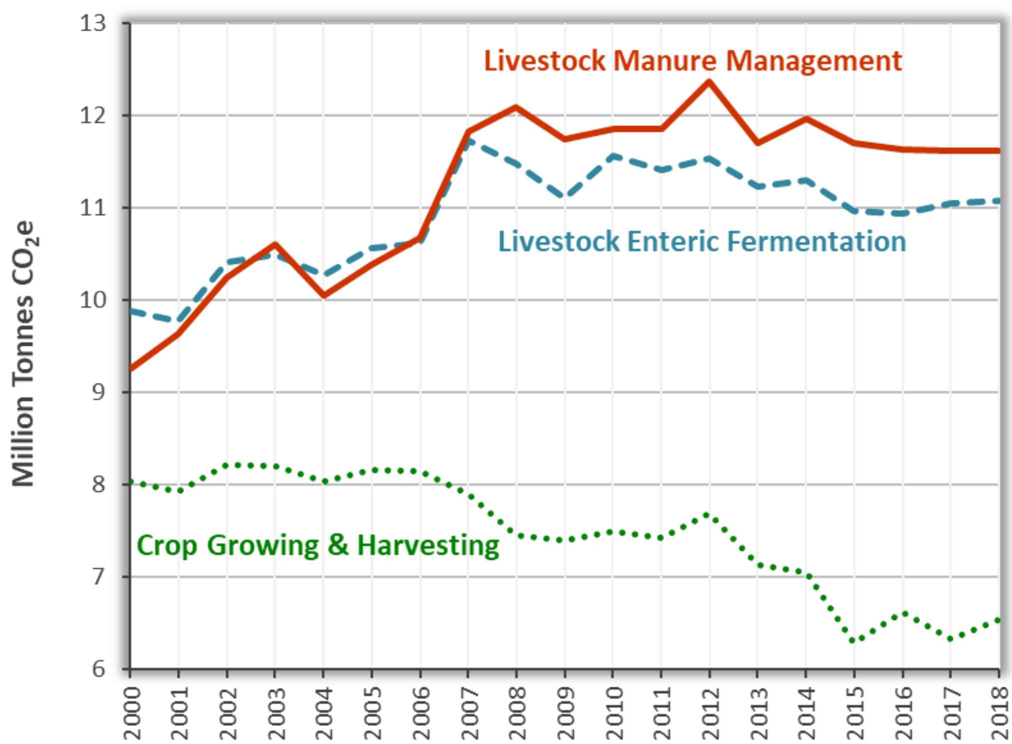


Figure 16. Agricultural Emissions. This figure presents the trends in emissions from livestock manure management and enteric fermentation, as well as emisisons from crop growing and harvesting, which include fertilizer application, soil preparation and distrubances, and crop residue burning.

High Global Warming Potential Gases

In 2018, High Global Warming Potential (high-GWP) gases comprised 4.8 percent of California's emissions. The GHG inventory tracks high-GWP gas emissions from releases of ozone depleting substance (ODS) substitutes, SF_6 emissions from the electricity transmission and distribution system, and gases that are emitted in the semiconductor manufacturing process. (ODSs are also high-GWP gases, but are outside the scope of the IPCC accounting framework and AB 32.) Of these tracked categories, 98 percent of high-GWP gas emissions are 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 2018, refrigeration and air conditioning equipment contributed 91 percent of ODS substitutes emissions.

Emissions of ODS substitutes are expected to continue to grow as they replace ODS being phased out under the Montreal Protocol [5]. Emissions of ODS have decreased significantly since they began to be phased out in the 1990s and dropped below ODS substitutes emissions for the first time in 2015. ODS emissions continued to drop in 2018. The combined emissions of ODS and ODS substitutes have been steadily decreasing over time as ODS are phased out, even as emissions from ODS substitutes continue to increase. Of the four main sub-sectors within the ODS substitutes category (Transportation, Commercial, Industrial, and Residential), only the Transportation Sector has seen an emissions decrease. The transportation refrigeration units (TRU) Airborne Toxic Control Measure adopted in 2004 has reduced transportation sector emissions by limiting the charge size of TRUs beginning in January 2010, reducing leakage rates, and lowering end-of-life losses for passenger vehicle air conditioning systems [17]. Figures 17a and 17b show ODS substitute's emissions.

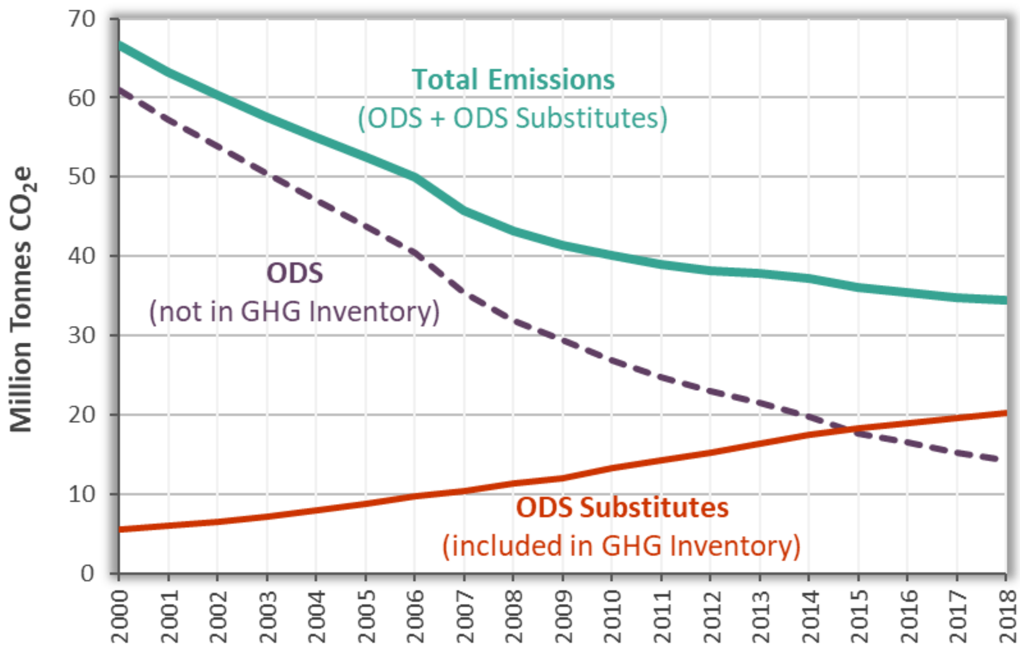


Figure 17a. Trends in ODS and ODS Substitutes Emissions. This figure presents the trends in emissions from ODS Substitutes, ODS, and their sum ("Total Emissions"). ODS Substitutes emissions are specified in IPCC Guidelines and AB 32 and are included in the inventory. ODS are also GHGs, but are tracked separately outside of the inventory.

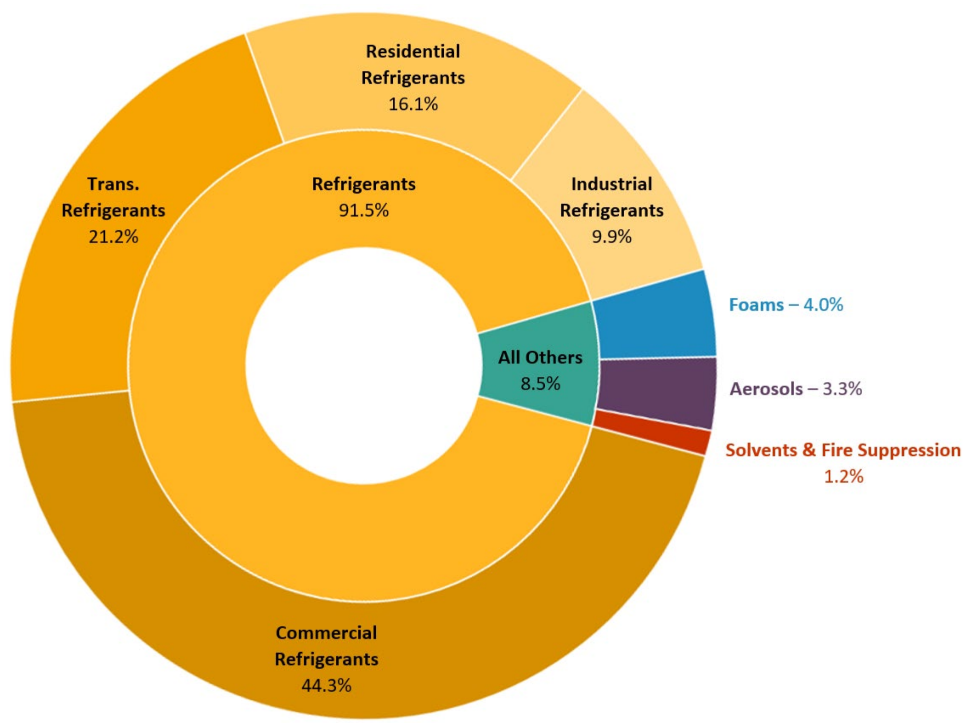


Figure 17b. ODS Substitutes Emissions by Category. This figure presents the breakdown of ODS substitutes emissions by product type and sector category in 2018. Refrigerants used in various sectors make up the majority of ODS substitutes emissions.

Recycling and Waste

Emissions from the recycling and waste sector include CH_4 and N_2O emissions from landfills and from commercial-scale composting. Emissions from recycling and waste, which comprise two percent of California's GHG inventory, have grown by 19 percent since 2000. Landfill emissions are primarily CH_4, and they account for 96 percent of the emissions in this sector,[h] while compost production facilities make up the remaining fraction of emissions.

The amount of emissions from a landfill is the difference between the methane generated from waste decomposition and the methane captured by landfill gas collection and control system. The annual amount of solid waste deposited in California's landfills grew from 39 million short tons in 2000 to its peak of 46 million short tons in 2005, followed by a declining trend until 2012, after which deposited waste amounts have seen a steady rise over time [18]. Landfill methane generation is 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 [19]. Figures 18 and 19 show trends in landfill emissions and activities that drive emissions.

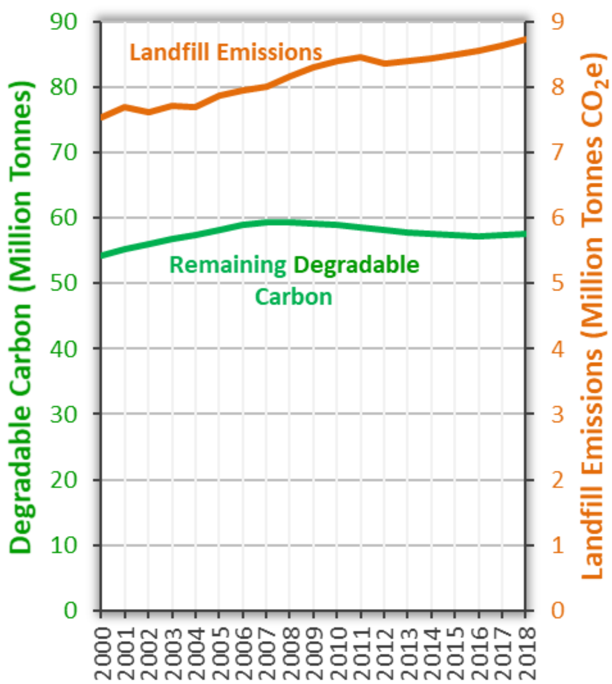


Figure 18. Landfill Methane Emissions. This figure presents trends in landfill emissions and the amount of degradable carbon remaining in California landfills. The latter drives the amount of emissions generated by landfills. The color of a trend line matches the color of its corresponding vertical axes label.

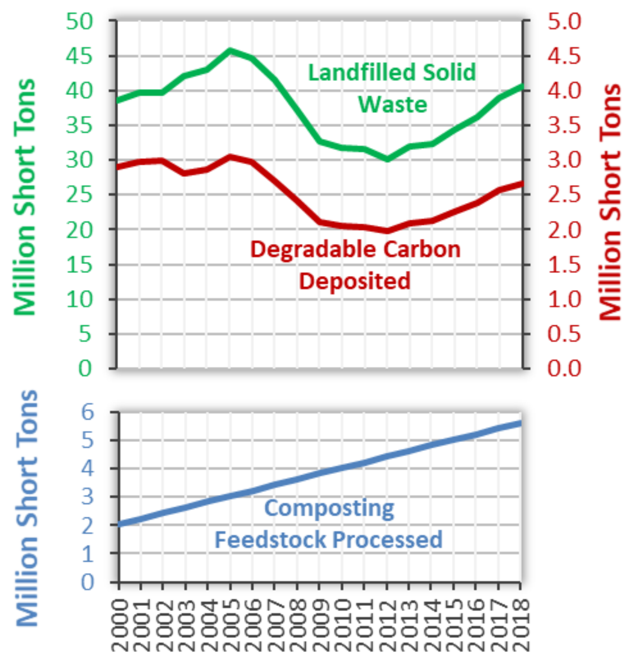


Figure 19. Landfill Waste. The top panel presents the annual amounts of solid waste deposited into California landfills and the amount of degradable carbon contained in the solid waste. The color of a trend line matches the color of its corresponding vertical axes label. The bottom panel shows estimated amounts of compost feedstock processed by the state's composting facilities.

[h] CARB's GHG inventory methodology has been using an assumption of 75 percent methane capture efficiency, consistent with common practice nationally.

Additional Information

International GHG Inventory Practice of Recalculating Emissions for Previous Years

Consistent with the IPCC GHG inventory guidelines, recalculations are made to incorporate new methods or reflect updated data for all years from 2000 to 2017 to maintain a consistent inventory time series. Therefore, emission estimates for a given calendar year may be different between editions as methods and supplemental data are updated. For example, in the 2019 edition, total 2017 emissions were estimated to be 424.1 MMTCO_2e. In the 2020 edition, recalculation revised the 2017 emissions to 424.3 MMTCO_2e, reflecting refinements and updates to methodology and information gained since 2019. Analyses of emission trends, including the emissions increase of 1.0 MMTCO_2e between 2017 and 2018, are based on the recalculated numbers in the 2020 edition of the inventory. A description of the method updates can be found here:
https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2018/ghg_inventory_00-18_method_update_document.pdf

Global Warming Potential Values

In accordance with the IPCC GHG inventory guidelines, California's GHG Inventory uses the 100-year GWPs from the IPCC 4th Assessment Report, consistent with the national GHG inventories submitted by the U.S. and other nations to the UNFCCC. However, other CARB programs may use different GWP values. For example, the SLCP Reduction Strategy [4] 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.

Sources of Data Used in the GHG Emission Inventory

Statewide GHG emissions are calculated using several data sources. One data source is from reports submitted to the California Air Resources Board (CARB) 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 per year of combustion and process emissions, all facilities belonging to certain industries, and all electricity importers to submit an annual GHG emissions data report directly to CARB. Reports from facilities and entities that emit more than 25,000 metric tons of CO_2e per year are verified by a CARB-accredited third-party verification body. More information on MRR emissions reports can be found at: https://ww2.arb.ca.gov/mrr-data

CARB also relies on data from other California State and federal agencies to develop the annual statewide GHG emission inventory for the State of California. These additional sources include, but are not limited to, data from the California Energy Commission, California Department of Tax and Fee Administration, California Geologic Energy Management Division, Department of Food and Agriculture, CalRecycle, U.S. Energy Information Administration, and U.S. Environmental Protection Agency (U.S. EPA). All data sources used to develop the GHG Inventory are listed in the GHG Emission Inventory supporting documentation at:

https://ww2.arb.ca.gov/ghg-inventory-data

The main GHG inventory page is located at:

https://ww2.arb.ca.gov/our-work/programs/ghg-inventory-program

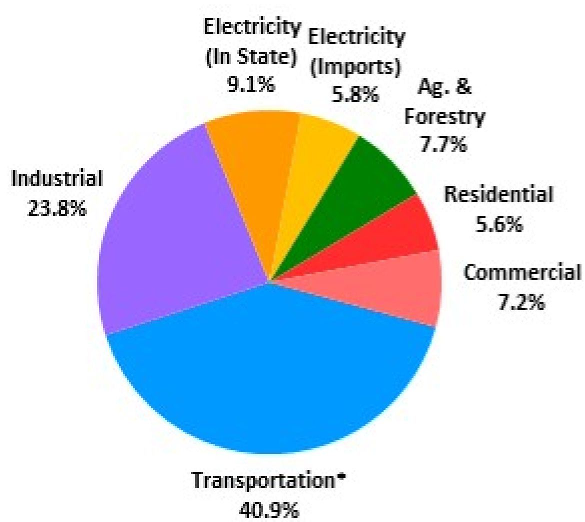
Other Ways of Categorizing Emissions in the Inventory

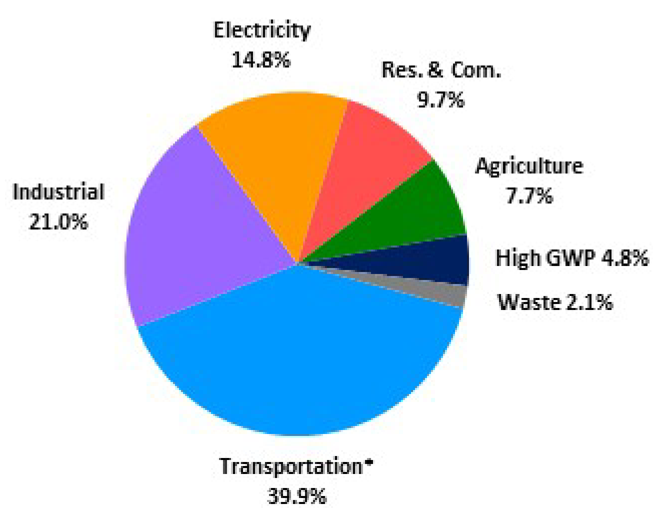
There is more than one way of organizing emissions by category in an inventory. Each year, CARB makes the GHG inventory available in three categorization schemes:

- The Scoping Plan Categorization organizes emissions by CARB program structure. (This is the categorization scheme used in this report.)
- The Economic Sector/Activity Categorization generally aligns with how sectors are defined in the North America Industry Classification System (NAICS).
- The IPCC Categorization groups emissions into four broad categories of emission processes. This format conforms to international GHG inventory practice and is consistent with the national GHG inventory that U.S. EPA annually submits to the United Nations.

Although this report uses the Scoping Plan Categorization in the presentation and discussion of emissions, the Economic Sector/Activity Categorization is also often used by the public. The difference between the Scoping Plan Categorization and the Economic Sector/Activity Categorization are as follows: (1) High-GWP gases are shown as its own category under the Scoping Plan categorization, but under the economic sector categorization, they are included as part of the economic sectors where they are used. (2) The recycling and waste sector is shown as its own category under the Scoping Plan categorization but is included as part of the industrial sector under the Economic Sector/Activity Categorization.

The figures below show the Scoping Plan Categorization and the Economic Sector/Activity Categorization side-by-side. Detailed data for these categorization schemes can be accessed from CARB webpage at: https://ww2.arb.ca.gov/ghg-inventory-data





*The transportation sector represents tailpipe emissions from on-road vehicles and direct emissions from other off-road mobile sources. It does not include emissions from petroleum refineries and oil production, which are included in the industrial sector.

**Percentages may not add up to 100 percent due to rounding.

Figure 20a. 2018 GHG Emissions by Economic Sector.** This figure shows the relative size of 2018 emissions by economic sector.

Figure 20b. 2018 GHG Emissions by Scoping Plan Category. This figure shows the relative size of 2018 emissions, organized by the categories in the AB32 Scoping Plan.

Uncertainties in the Inventory

CARB is committed to continually working to reduce the uncertainty in the inventory estimates. The uncertainty of emissions estimates in the inventory varies by sector. The data reported under MRR is subject to third-party verification, ensuring a high level of accuracy. Other non-MRR sources, mainly non-combustion, biochemical processes, have varying uncertainty depending on the input data and the emission processes.

Natural and Working Lands Ecosystem Carbon Inventory and Wildfire Emissions

CARB has also developed a Natural and Working Lands (NWL) Ecosystem Carbon Inventory ("the NWL Inventory") separate from this GHG Inventory [1]. The NWL Inventory quantifies ecosystem carbon stored in plants and soils in California's Natural and Working Lands (including forest, woodland, shrubland, grassland, wetland, orchard crop, urban forest, and soils) and tracks changes in carbon stock over time. The NWL inventory report can be accessed here: https://ww2.arb.ca.gov/nwl-inventory.

Fire has served a natural function in California's diverse ecosystems for millennia, such as facilitating germination of seeds for certain tree species, replenishing soil nutrients, clearing dead biomass to make room for living trees to grow, and reducing accumulation of fuel that lead to high-intensity wildfires. Fire also impacts human health and safety, and releases GHGs and other air pollutants. Greenhouse gas emissions from wildfires are tracked separately when compared to anthropogenic sources due to carbon cycling. Anthropogenic emissions from fossil fuels come from geological sources, which are part of the slow carbon cycle, where carbon pools change over the course of many millennia (e.g., fossil fuel formation). In contrast, the fast carbon cycle, in which carbon moves between pools over months to centuries, includes natural emission sources, such as wildfires, plant decomposition and respiration. The depletion of fossil fuels through their combustion has led to an increase in ambient CO_2 concentrations; however, wildfire emissions are part of a fast carbon cycle that is balanced by vegetation growth. In recent years the frequency and magnitude of wildfires have been prolific across California. In an effort to contextualize the GHG emissions from wildfires, emissions estimations are available here: https://ww2.arb.ca.gov/wildfire-emissions

Figure References

Figure Number	Reference
Figure 1	[9]
Figure 2a	[8] [9] [10]
Figure 2b	[8] [9]
Figure 2c	[9] [10]
Figure 3	[9]
Figure 4	[9]
Figure 5	[9]
Figure 6	[9]
Figure 7	[9]
Figure 8	[9]
Figure 9	[9] [11] [12]
Figure 10	[11] [12]
Figure 11	[11] [12]
Figure 12	[13]
Figure 13	[9]
Figure 14	[9] [15]
Figure 15a	[9] [14]
Figure 15b	[9] [14]
Figure 16	[9]
Figure 17a & 17b	[9] [17]
Figure 18	[9]
Figure 19	[9] [18]
Figure 20a & 20b	[9]

Reference

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