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CALIFORNIA
AIR RESOURCES BOARD

California Greenhouse Gas Emissions for 2000 to 2017

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. The inventory for 2017 shows that California's GHG emissions continue to decrease. In 2017, emissions from GHG emitting activities statewide were 424 million metric tons of CO_2 equivalent ($MMTCO_2e$), 5 $MMTCO_2e$ lower than 2016 levels and 7 MMTCO2e below the 2020 GHG Limit of 431 $MMTCO_2e$. Consistent with recent years, these reductions have occurred while California's economy has continued to grow and generate jobs. Compared to 2016, California's GDP grew 3.6 percent while the carbon intensity of its economy declined by 4.5 percent. The most notable highlights in the inventory include:

- For the first time since California started to track GHG emissions, in-state and total electricity generation from zero-GHG sources (for purposes of the GHG inventory, these include solar, hydro, wind, and nuclear) exceeded generation from GHG-emitting sources.
- The transportation sector remains the largest source of GHG emissions in the state, but saw a 1 percent increase in emissions in 2017, the lowest growth rate over the past 4 years.
- Emissions from all other sectors have remained relatively constant in recent years, although emissions from high Global Warming Potential (GWP) gases have continued to increase as they replace Ozone Depleting Substances (ODS) banned under the 1987 Montreal Protocol.

Figure 1 shows the statewide GHG emissions as compared to the 2020 GHG Limit.

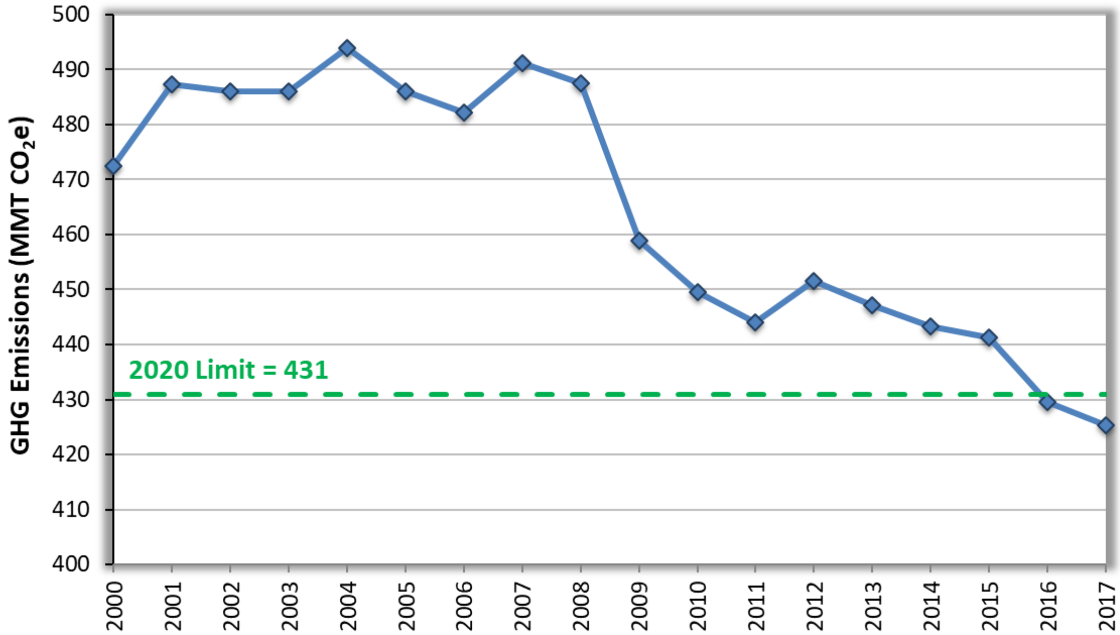


Figure 1. California GHG Emissions Trends. This figure shows the emission trends between 2000 and 2017 as compared to the 2020 statewide GHG limit of 431 $MMTCO_2e$.

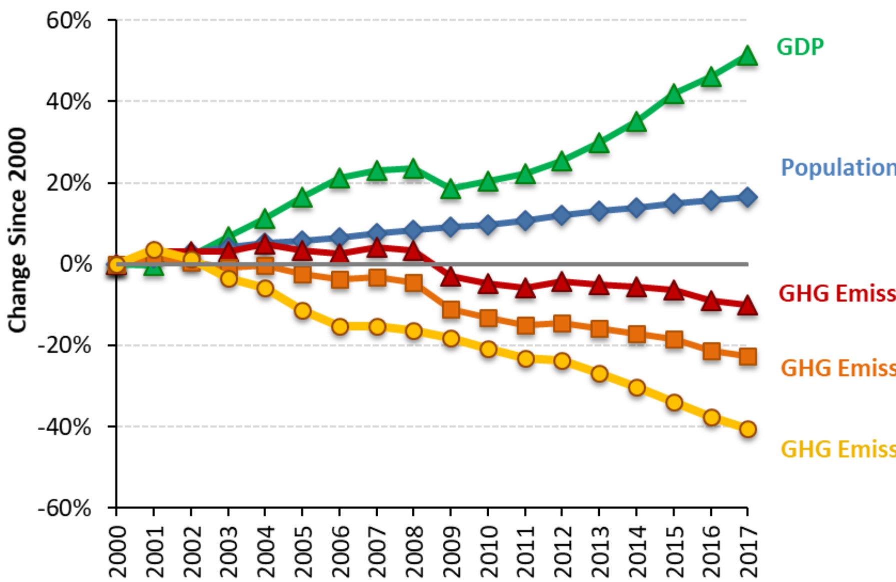
Introduction

The GHG inventory is an important tool in tracking 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 the 1990 levels by 2030). The 2019 edition of the GHG inventory includes the emissions of the seven GHGs identified in AB 32[1] for the years 2000 to 2017 and uses an inventory scope and framework consistent with international and national GHG inventory practices.[2] 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[3], and ozone depleting substances (ODS), which are being phased out according to a 1987 international treaty[5]. ODS are now being substituted with hydrofluorocarbons, which are pollutants specified in AB 32.

Statewide Trends of Emissions and Indicators

In 2017, emissions from statewide emitting activities were 424 million metric tons of CO_2 equivalent ($MMTCO_2e$), which is 5 $MMTCO_2e$ lower than 2016 levels. 2017 emissions have decreased by 14 percent since peak levels in 2004 and are 7 $MMTCO_2e$ below the 1990 emissions level and the State's 2020 GHG limit. Per capita GHG emissions in California have dropped from a 2001 peak of 14.1 tonnes per person to 10.7 tonnes per person in 2017, a 24 percent decrease.[4,19] 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 2017, the carbon intensity of California's economy has decreased by 41 percent from 2001 peak emissions while simultaneously increasing GDP by 52 percent. In 2017, GDP grew 3.6 percent while the emissions per GDP declined by 4.5 percent compared to 2016.[22] Figures 2(a)-(c) on the next page show California's growth alongside GHG reductions.

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



Metric	Associated 2017 Value
GDP	2.6 trillion (2012 $)
Population	39.6 million
GHG Emissions	424.1 $MMTCO_2e$
GHG Emissions per Capita	10.7 metric tons CO_2e per person
GHG Emissions per GDP	164 metric tons CO_2e per million dollars

Figure 2b. California Total and Per Capita GHG Emissions

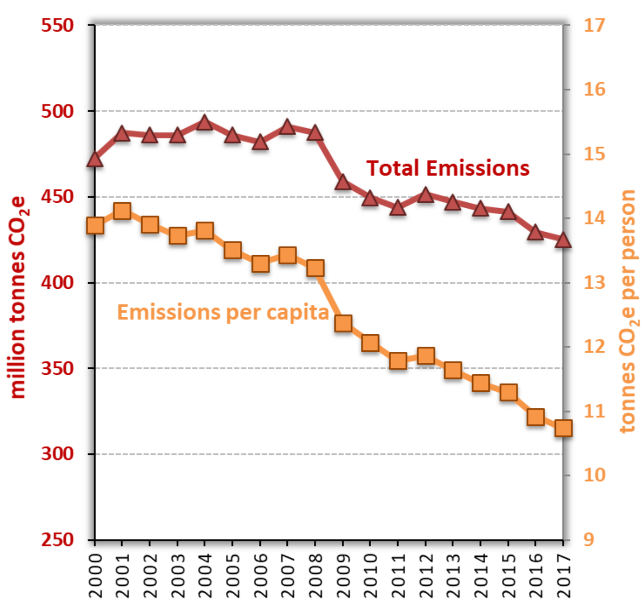
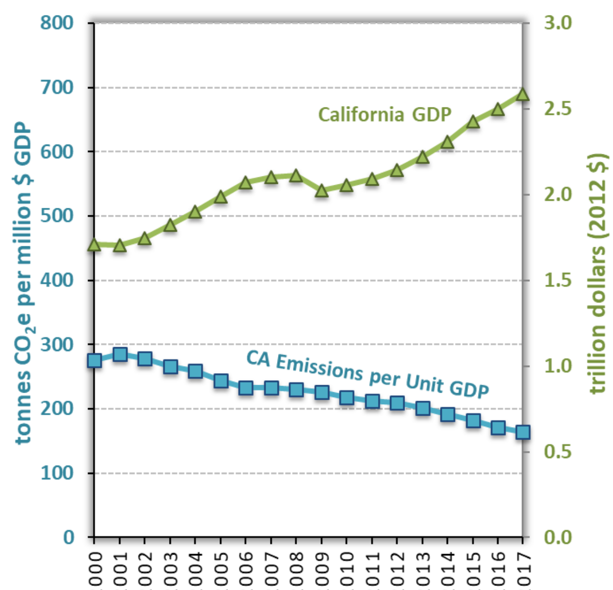


Figure 2c. Carbon Intensity of California's Economy



Figures 2(a)-(c). California's GHG emissions, population, GDP, GHG per capita, and carbon intensity of the economy. Figure 2(a) shows percent change in GHGs 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 mobile sources, intrastate aviation, rail, and watercraft account for 40 percent[a] of Statewide emissions in 2017. The annual increase in transportation emissions in 2017 has slowed down slightly compared to the previous 3 years. Emissions from the electricity sector account for 15 percent of the inventory and show another large drop in 2017 due to a large increase in renewable energy. For the first time since California started to track GHG emissions, California uses more electricity from zero-GHG sources (for the purpose of the GHG inventory, these include hydro, solar, wind, and nuclear energy) than from GHG-emitting sources for both in-state generation and total (in-state plus imports) generation in 2017. The industrial sector has seen a slight emissions decrease in the past few years, and remains at 21 percent of the inventory. Emissions from high-GWP gases have continued to increase as they replace ODS banned 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 2017 emissions by sector into additional level of sub-sector categories.

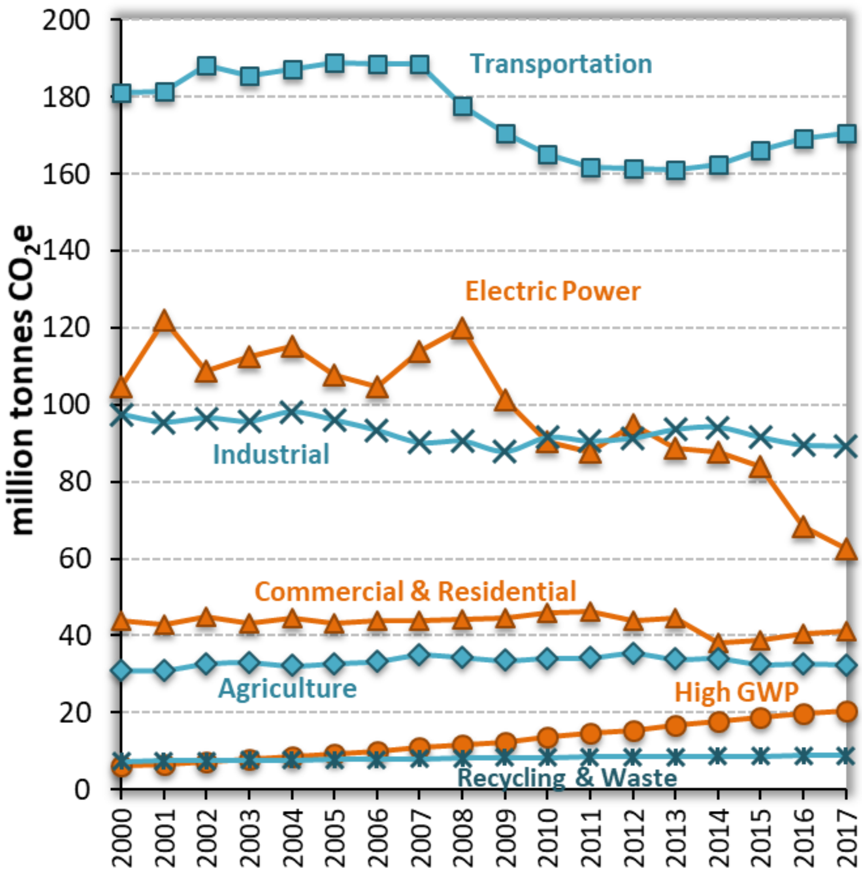


Figure 3. Trends in California GHG Emissions. This figure shows changes in emissions by Scoping Plan sector between 2000 and 2017. Emissions are organized by the categories in the AB 32 Scoping Plan.

[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 production.

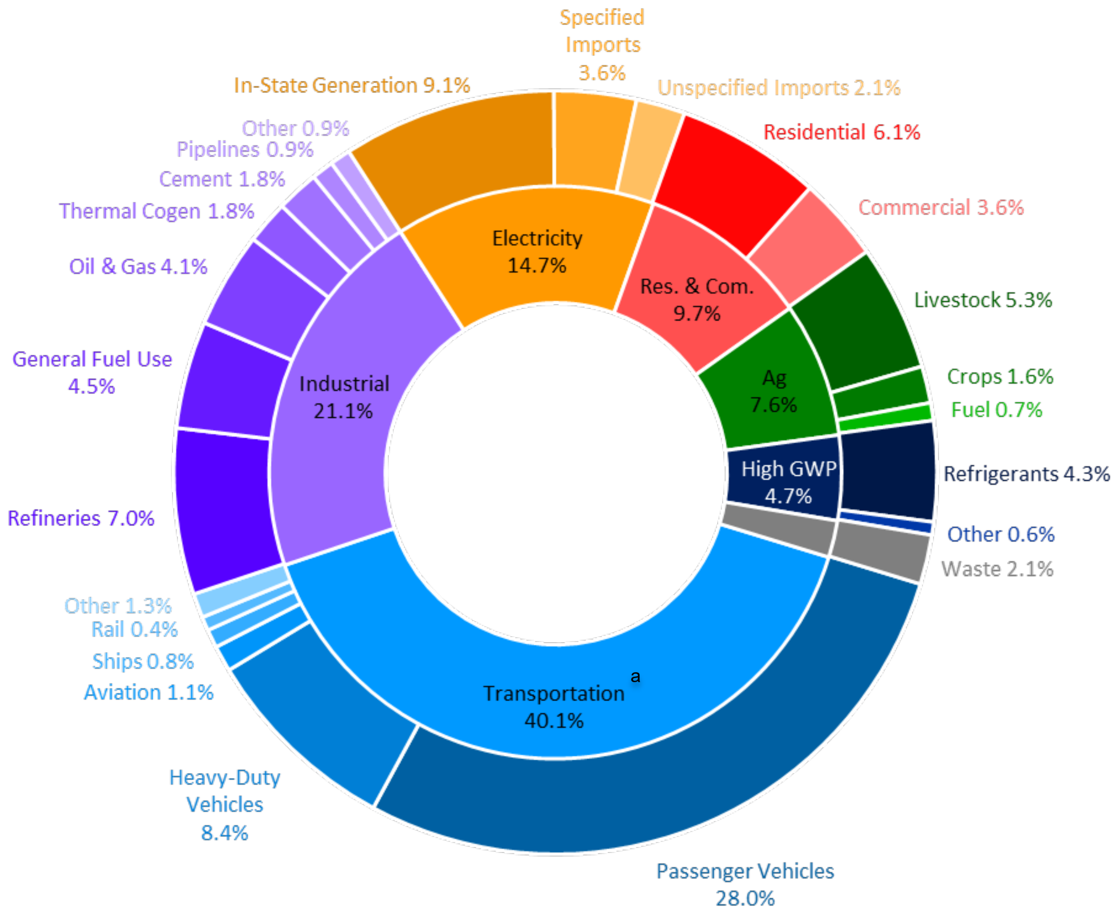


Figure 4. 2017 GHG Emissions by Scoping Plan Sector and Sub-Sector Category. This figure breaks out 2017 emissions by sector into an additional level of sub-sector categories. The inner ring shows the broad Scoping Plan sectors. The outer ring breaks out the broad sectors into sub-sectors or emission categories under each sector.

[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 production.

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. All emissions in this report are expressed in 100-year GWP from the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report (AR4),[2] consistent with current international GHG inventory practices.

Transportation Sector

The transportation sector remains the largest source of GHG emissions in 2017, accounting for 40 percent[a] of California's GHG inventory. Contributions from the transportation sector[b] include emissions from combustion of fuels utilized 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.

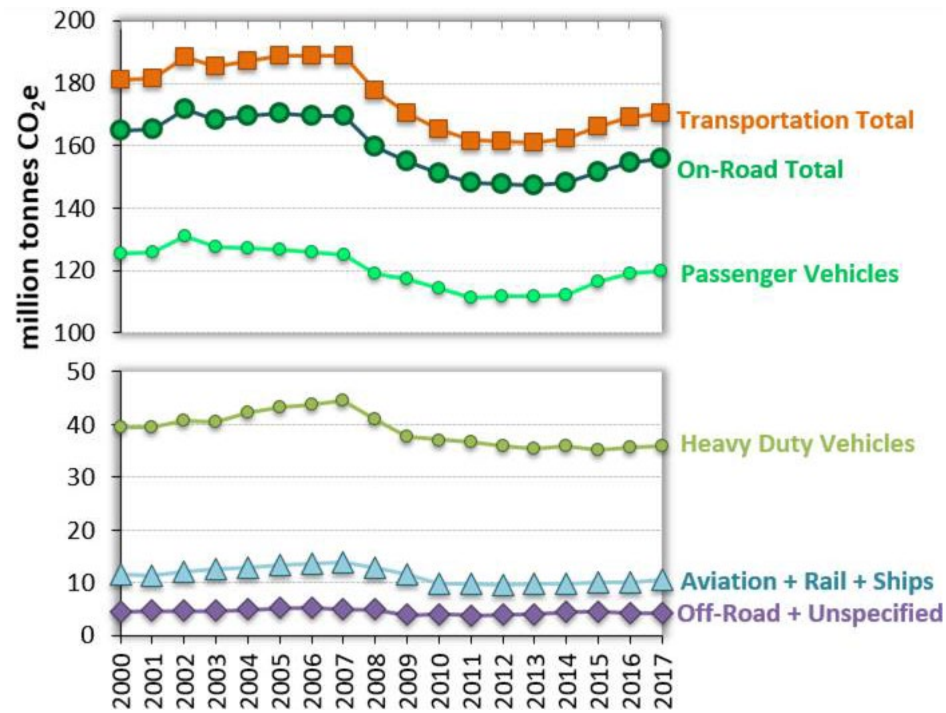


Figure 5. Overview of GHG Emissions from the Transportation Sector. "Transportation Total" is the sum of "On-Road Total," "Aviation + Rail + Ships," and "Off-Road + Unspecified." "On-Road Total" is the sum of "Passenger Vehicles" and "Heavy Duty Vehicles." The size of the symbols denotes the summing; larger symbols indicate what is summed to "Transportation Total" and small circles indicate what is summed to "On-Road Total."

The figures on the following page show the trends in emissions and fuel for in-state use 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. Consistent with the *IPCC Guidelines for National GHG Inventories*[7] 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." 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 targets. Biogenic CO_2 emissions data are available on the CARB webpage.[8]

[a] 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 production.

[b] 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. For transportation fuels, the portions of upstream emissions released outside of California's borders are tracked by the Low Carbon Fuel Standard (LCFS) program and are not included or tracked in this version of the GHG emission inventory.

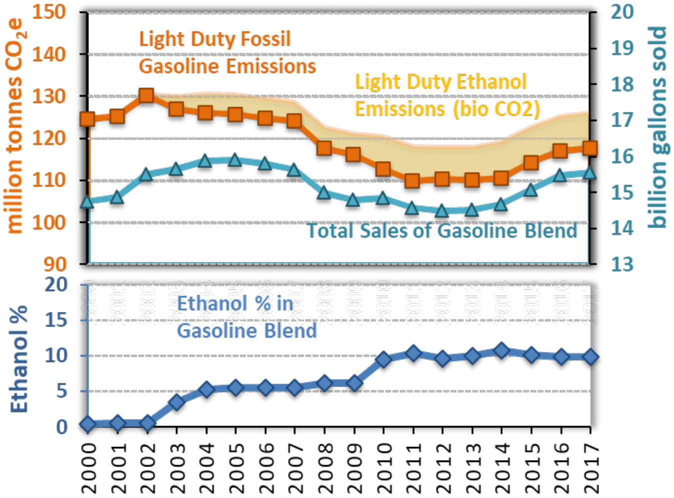


Figure 6. Trends in On-Road Light Duty Gasoline Emissions. In the top panel, the yellow shaded region represents CO_2 emissions from the ethanol-component of the fuel blend, which is not counted toward the statewide GHG targets. The orange line includes emissions from the fossil gasoline component of the fuel blend, as well as the CH_4 and N_2O emissions from the ethanol-component of the fuel blend, and these are included in the statewide GHG targets 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.

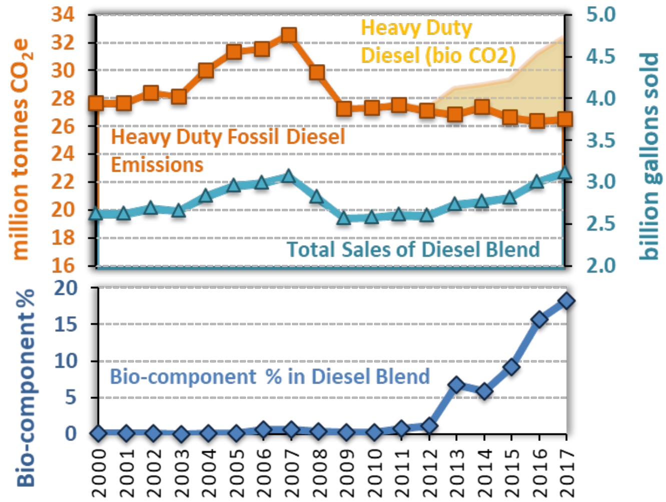


Figure 7. Trends in On-Road Heavy Duty Diesel Vehicle Emissions. In the top panel, the yellow shaded region represents CO_2 emissions from the bio-component (biodiesel and renewable diesel) of the fuel blend, which is not counted toward the statewide GHG targets. The orange line includes emissions from 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, which are counted towards the statewide GHG targets. 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 were relatively constant from 2002 through 2007, declined through 2013, then increased by 9.0 $MMTCO_2e$ (or 6 percent) from 2013 to 2017. Emissions from gasoline used in on-road vehicles are the main driver of that increase. 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 drive down emissions over time; but population growth, lower fuel prices, more consumer and economic activity, and higher overall employment are factors that may increase fuel use. Biofuels such as ethanol, biodiesel, and renewable diesel can displace fossil fuels and reduce the amount of fossil-based CO_2 emissions released into the atmosphere. The percent of biodiesel and renewable diesel in the total diesel blend have shown a significant growth in recent years, going from 1 percent in 2012 to 18 percent in 2017.

Electric Power

Emissions from the electric power sector comprise 15 percent of 2017 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 cogeneration emissions attributed to electricity generation) and emissions from imported electricity.

GHG emissions from the electricity sector declined by 9 percent in 2017 compared to 2016. The overall decrease in carbon intensity of California's electricity generation is driven primarily by the large increase in zero-GHG and renewable energy resources due in part to California's Renewable Portfolio Standard (RPS) and the Cap-and-Trade Program.

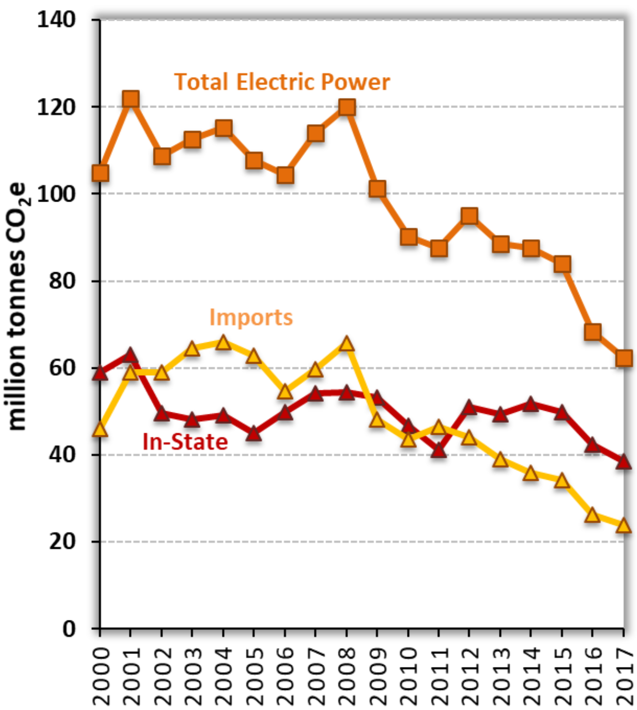


Figure 8. GHG Emissions from the Electric Power Sector. This figure shows trends in emissions of in-state electricity generation, emissions associated with electricity imported from outside of California, and the total electric power sector emissions, which is the sum of in-state generation and imports.

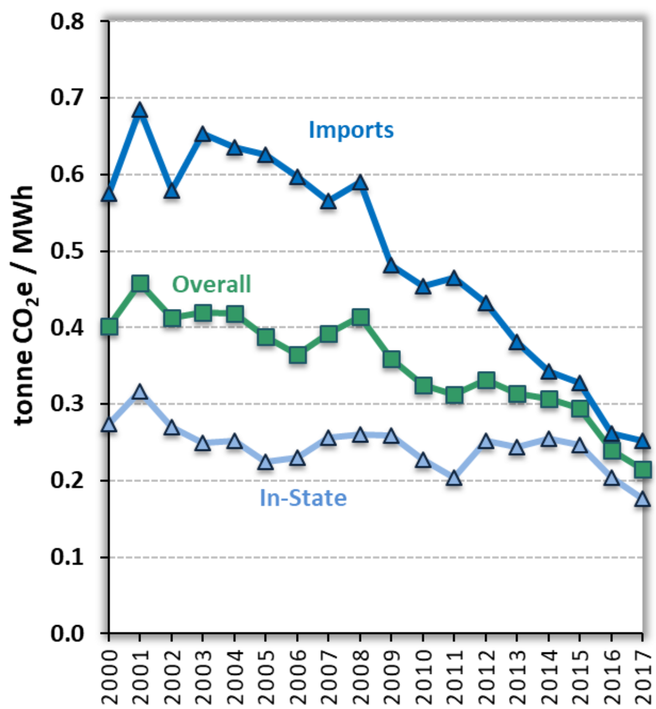


Figure 9. GHG Intensity of Electricity Generation.[c] This figure shows trends in GHG intensities of electricity generated by in-state power plants, electricity imported from outside of California, and the overall GHG intensities aggregating both in-state generation and electricity imports.

[c] 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.

In 2017, 52 percent of total electricity generation (in-state generation plus imported electricity) came from zero-GHG generation sources (for purposes of the GHG inventory, these include solar, wind, large and small hydropower, and nuclear). Electric power emissions dropped 6 $MMTCO_2e$ from 2016 to 2017 due to increased supplies of renewable energy displacing fossil-fuel generation.

In-state solar generation grew 26 percent between 2016 and 2017. Solar and wind power make up 22 percent of the total in-state generation in 2017. Between 2011 and 2017, in-state solar generation saw significant growth as rooftop photovoltaic solar generation increased six-fold[11] and total solar generation (commercial-scale plus rooftop solar) increased 13 times during that period.[11, 12] In-state wind energy generation ramped up through 2013, but its trend has remained relatively constant since 2013.[12]

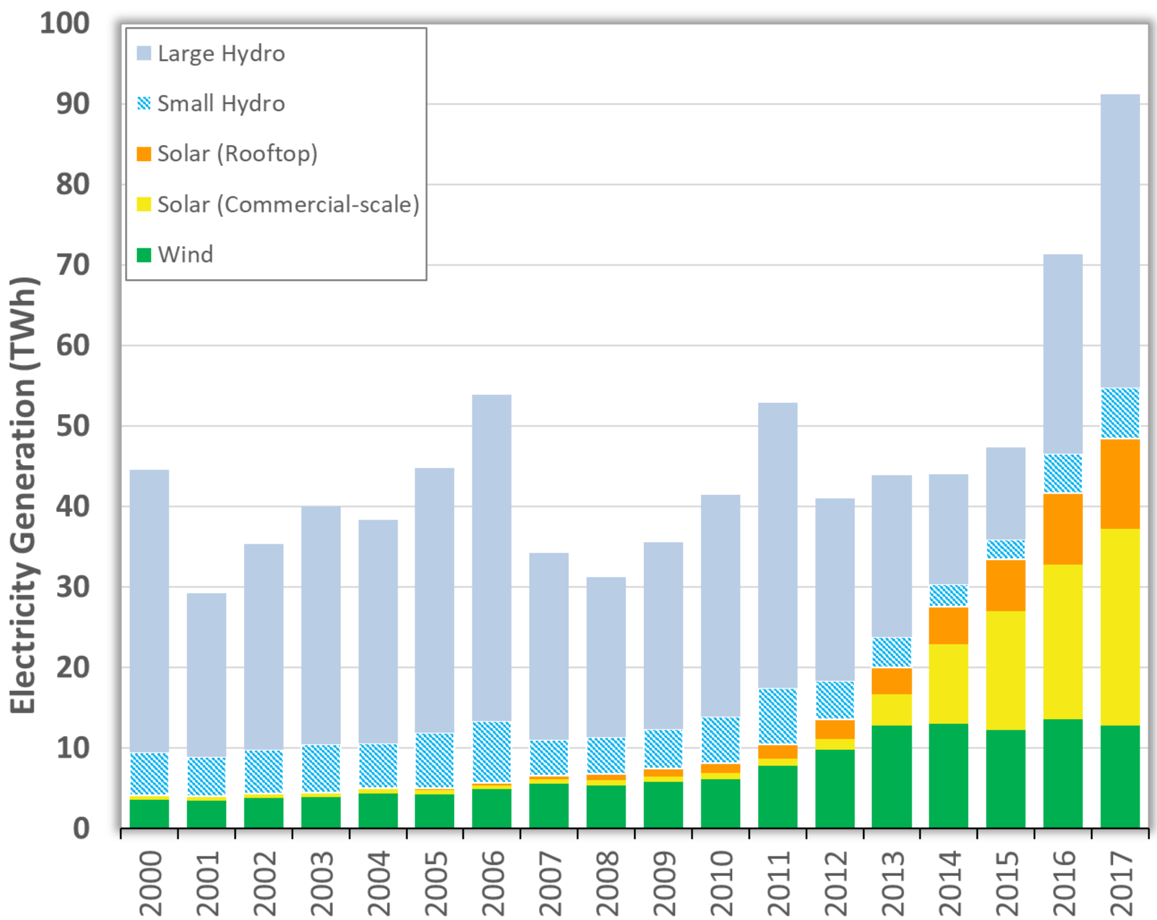


Figure 10. In-State Hydro, Solar, and Wind Electricity Generation. This figure shows the amounts of electricity generated by California's in-state wind power projects, large commercial-scale solar power projects, rooftop solar panels, and hydropower generation stations. The unit is in terawatt-hour (1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

Trends in the types of in-state generation and imported electricity sources are presented in the figures below. In-state natural gas generation complements the year-to-year fluctuations in zero-GHG resources. Comparing the fractions of total imports in 2011 and 2017, solar generation went from 0.02 percent to 2.9 percent, and wind generation went from 2.7 percent to 6.2 percent.

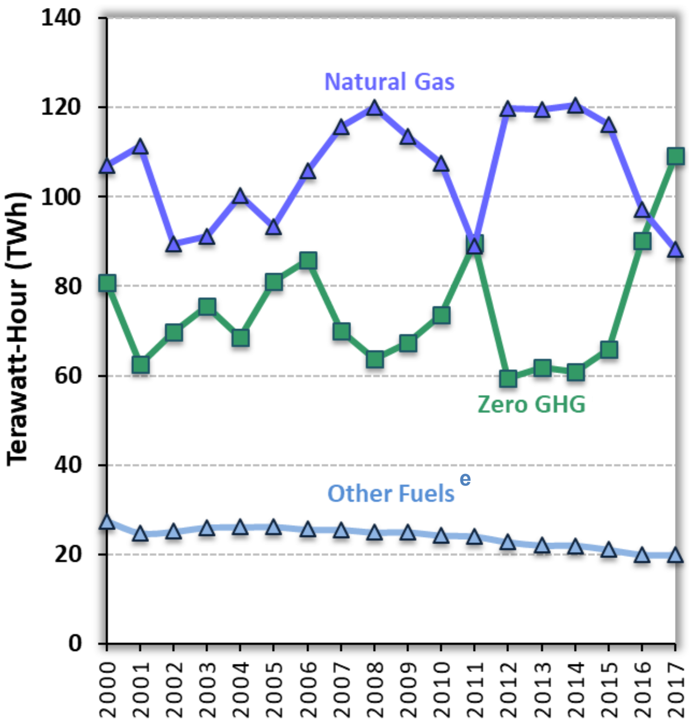


Figure 11a. In-State Electricity Generation by Fuel Type. This figure shows the amounts of electricity generated by in-state natural gas power plants, zero-GHG sources (which includes solar, wind, hydro, and nuclear), and other generation sources. The footnote e below provides a list of other generation sources included in the "Other Fuels" line.

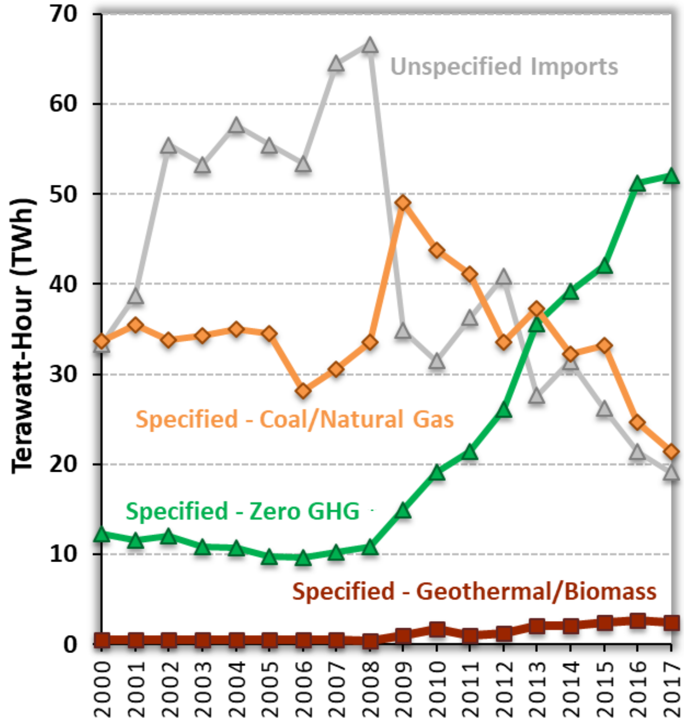


Figure 11b. Imported Electricity by Generation Type. This figure shows the amounts of imported electricity that are specified as fossil fuel (coal and natural gas), zero-GHG sources (solar, wind, hydro, and nuclear), and geothermal and biomass, as well as unspecified electricity imports.

[e] "Other Fuels" include energy generations 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, and CH_4 and N_2O emissions from biomass power plant, are included in the statewide total for comparing to the 2020 GHG target.

Industrial

Emissions from the industrial sector contributed 21 percent of California's total GHG emissions in 2017. 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 result from clinker production in cement plants and hydrogen production for refinery use, account for approximately a seventh of the emissions in the industrial sector. Emissions from this sector show a slight decrease in emissions in the past three years.

Refineries and hydrogen production represent the largest individual source in the industrial sector, contributing 33 percent of the sector's total emissions. The refinery emissions have remained relatively constant in the past few years, aside from a decrease in 2015 resulting from Exxon Mobile's Torrance refinery temporary shutdown between February 2015 and May 2016.

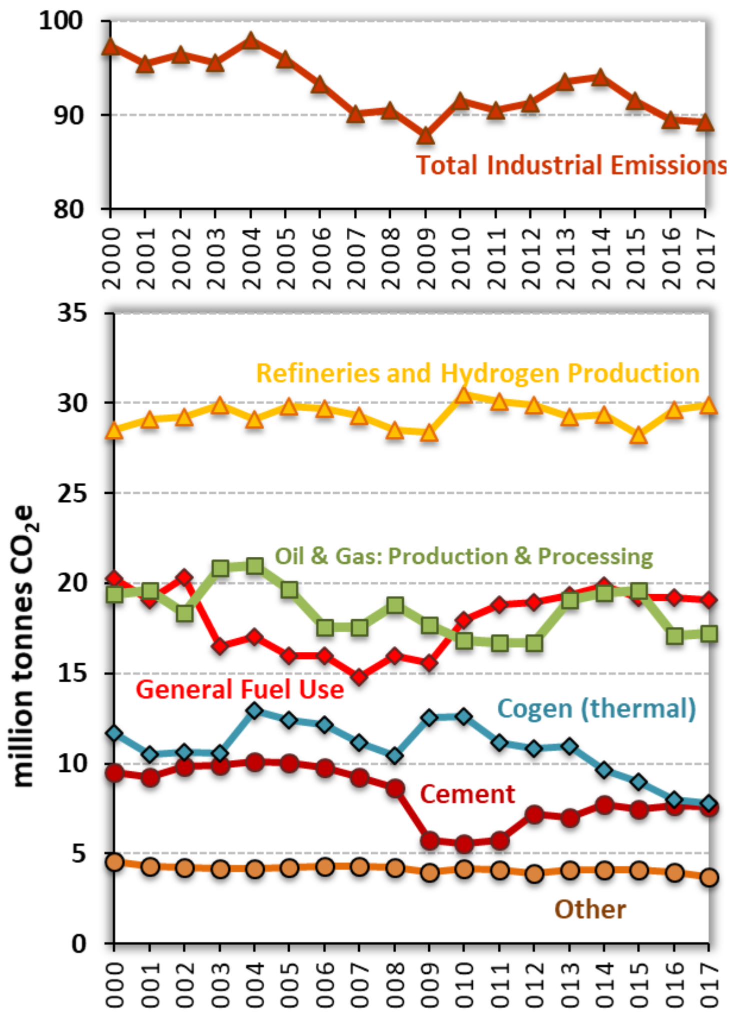


Figure 12. Industrial Sector Emissions. The top panel of this figure shows the overall emissions trend of the total industrial sector. The bottom panel shows emissions trends by sub-sector – summing the bottom panel will equal the top panel. In accordance with the IPCC Guidelines, the cogeneration category under the industrial sector includes only the portion of 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.

Emissions from oil and gas extraction represent 19 percent of the industrial sector emissions. Oil and gas extraction emissions remained relatively constant from 2016 to 2017. Emissions from the natural gas transmission and distribution sector have remained relatively constant over the entire time series.

General fuel use by industries gradually increased from 2009 through 2014, but have decreased in the past three years. In 2009 and 2010, 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 shut down or become non-operational in recent years and further contributed to the downward trend in cogeneration emissions.

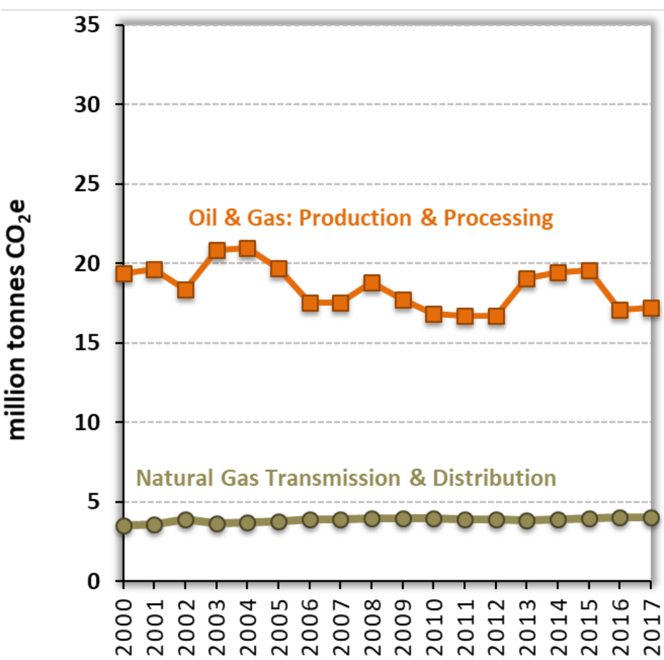


Figure 13a. Oil and Gas Sector Emissions. This figure shows the emissions trends of the oil and gas production and processing sector and the natural gas transmission and distribution sector.

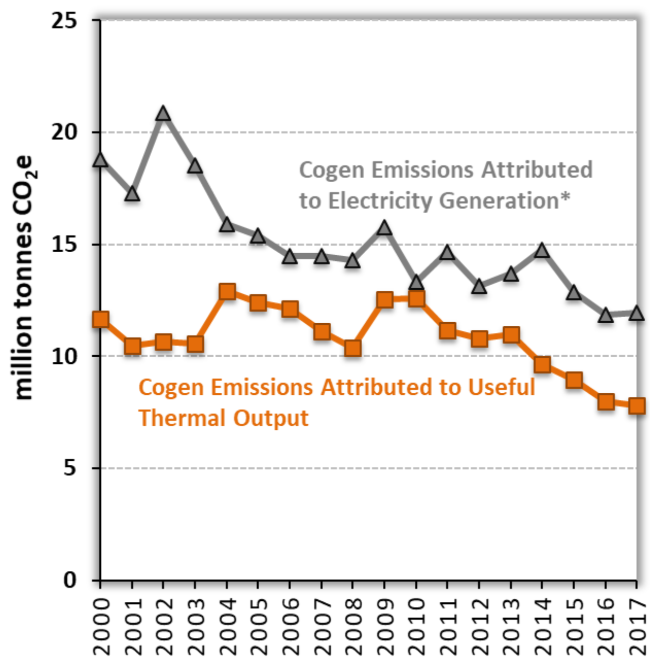


Figure 13b. Industrial Cogeneration Emissions. This figure shows the emissions from cogeneration facilities over time. *Cogeneration emissions attributed to electricity generation are categorized under the electric power sector consistent with the IPCC Guidelines. The electricity emissions are shown in this figure for the purpose of putting cogeneration emissions into context.

Commercial and Residential Fuel Combustion

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 use (e.g., air-conditioning, lighting, washer and dryer, refrigerator, etc.) is 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 population growth. In 2017, emissions increased slightly compared to 2016 due to a rise in residential natural gas use.

The number of residential housing units has grown steadily from 12.2 million units in 2000 to 14.1 million units in 2017.[14] Emissions per housing unit dropped steadily from 2000 through 2014. Emissions per housing unit has generally followed the heating degree day index,[13] an estimate of the heating energy needed in a given year. Emissions from fuel use by the commercial sector have grown by 10 percent since 2000; however, during the same period, commercial floor space grew by 25 percent. As a result, the commercial sector also exhibits a slight decline in fuel use per unit space.

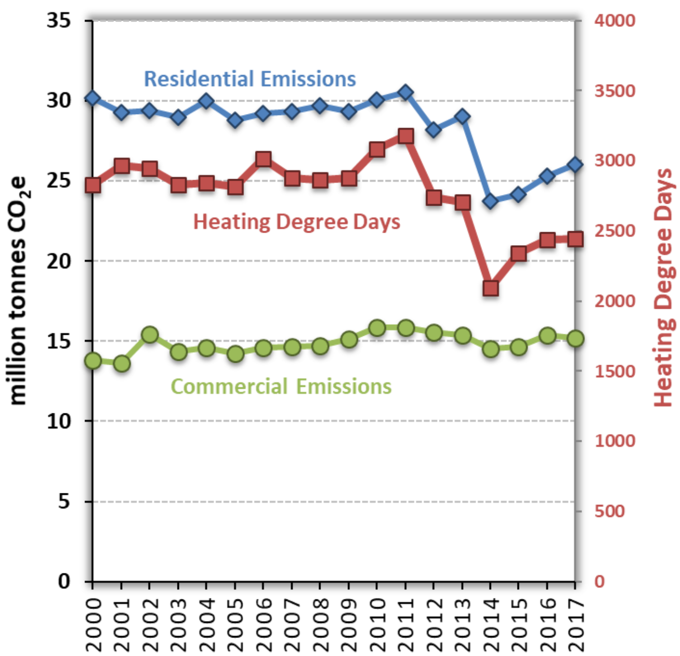


Figure 14. Emissions from Residential and Commercial Sectors. Emissions from the residential and commercial sectors are compared with heating degree days, an estimate of the heating energy need in a given year. Residential and commercial emissions correspond to the left vertical axis. Heating degree days correspond to the right vertical axis.

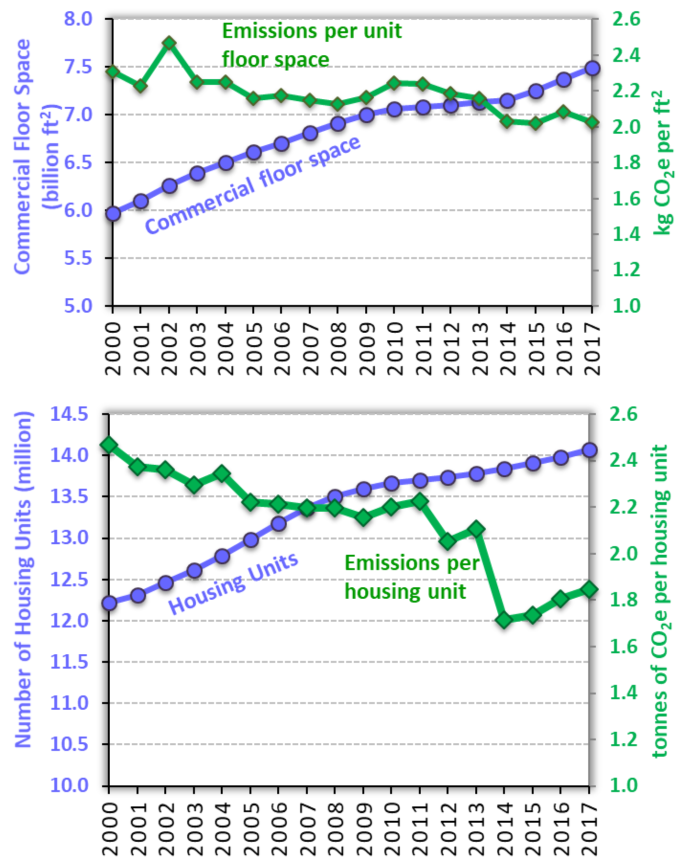


Figure 15. Emissions per Unit Floor Space and Residential Housing Unit. The top panel shows total square feet of commercial floor space and the emissions per square feet of commercial floor space. The bottom panel shows number of residential housing units and emissions per housing unit. The color of a trend line matches the color of its corresponding vertical axes label.

Agriculture

California's agricultural sector contributed approximately 8 percent of statewide GHG emissions in 2017, 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 disturbance, and crop residue burning), and fuel combustion associated with stationary agricultural activities (water pumping, cooling or heating buildings, and processing commodities). The emissions for mobile equipment used in agricultural activities are accounted for in the Transportation Sector.

Livestock accounted for approximately 70 percent of agricultural emissions, which were generated primarily in the form of CH_4 from enteric fermentation and manure management. Dairy facilities are a major source of GHG emissions in California, accounting for roughly 60 percent of agricultural emissions. GHG emissions from dairy manure management and enteric fermentation followed an increasing trend between 2000 and 2007 as the industry expanded, and remained relatively constant since 2007. Dairy cow population has seen a decreasing trend in recent years, while beef cattle population fluctuates from year to year, though available data indicates a slight increase in beef cattle population between 2016 and 2017. Emissions in 2017 are 16 percent higher than 2000 levels. SB 1383 sets a goal of a 40 percent reduction of 2013-inventoried methane by 2030 and was written in part to reduce livestock methane.[15] Livestock are estimated to contribute roughly half of California's methane emissions.

Emissions from the growing and harvesting of crops have generally been declining since 2000.[16] The long term trend of emissions reduction from 2000 to 2017 corresponds to a reduction in crop acreage (which leads to an associated decrease in synthetic fertilizer use)[17] and large-scale changes in irrigation management practices. Specifically, California agriculture has been shifting from flood irrigation towards sprinkler and drip irrigation. The decrease from 2016 to 2017 is due to the continued shift from flood to alternative irrigation methods[18, 19] and climatic factors that affects the amount of N_2O produced from synthetic fertilizer (e.g., precipitation, min/max temperature, and day length). Crop production accounted for 20 percent of agriculture emissions in 2017.

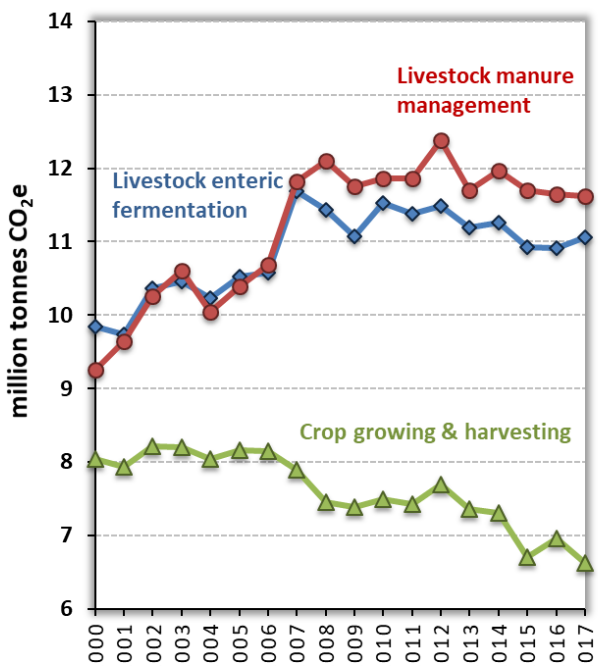


Figure 16. Agricultural Emissions. This figure presents the trends in emissions from livestock manure management and enteric fermentation, as well as emisisons from crop growing and harvesting, which include fertilizer application, soil preparation and distrubances, and crop residue burning. Emissions from mobile equipment are not included here.

High Global Warming Potential Gases

In 2017, High Global Warming Potential (high-GWP) gases comprised 4.7 percent of California's emissions. The GHG inventory tracks high-GWP gas emissions from releases of ozone depleting substance (ODS) substitutes only (ODSs are also high-GWP gases, but are outside the scope of the IPCC accounting framework and AB 32), emissions from the electricity transmission and distribution system, and gases that are emitted in the semiconductor manufacturing process. Of these tracked categories, 97 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 2017, refrigeration and air conditioning equipment contributed 90 percent of ODS substitutes emissions.

Emissions of ODS substitutes are expected to continue to grow as they replace ODSs banned 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 2017. 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 and reducing leakage rates and lowering end-of-life losses for passenger vehicle air conditioning systems.

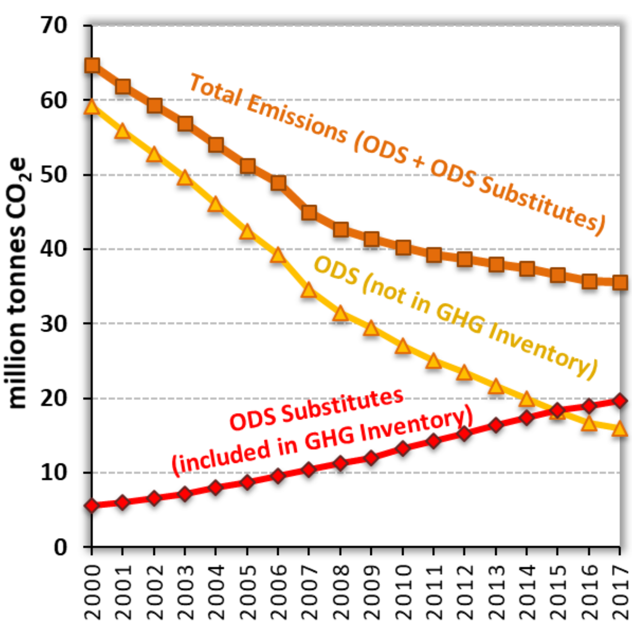


Figure 17a. Trends in ODS and ODS Substitutes Emissions. This figure presents the trends in emissions from ODS Substitutes, ODS, and their sum ("Total Emissions"). ODS Substitutes emissions are specified in IPCC Guidelines and AB 32 and are included in the inventory. ODS are also GHGs, but are tracked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

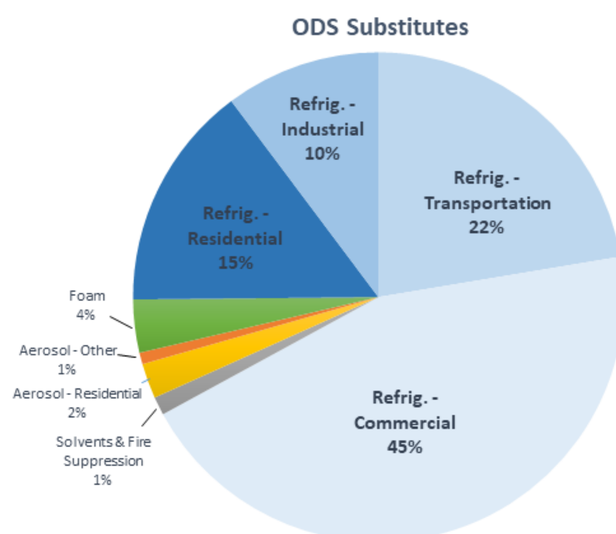


Figure 17b. ODS Substitutes Emissions by Category. This figure presents the breakdown of ODS substitutes emissions by product type and sector category in 2017. Refrigerants ("Refrig.") used in various sectors make up the majority of ODS substitutes emissions.

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 2 percent of California's GHG inventory, have grown by 20 percent since 2000. Landfill emissions account for 96 percent of the emissions in this sector,[f] 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, after which the waste amounts have seen a steady rise over time.[20] 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.[21] The amount of methane emitted to the atmosphere as a fraction of the total amount of methane generated from the decomposition of accumulated waste has gradually declined over time as more landfills install landfill gas collection and control systems and existing systems are operated more efficiently as a result of CARB's Landfill Methane Control Measure.

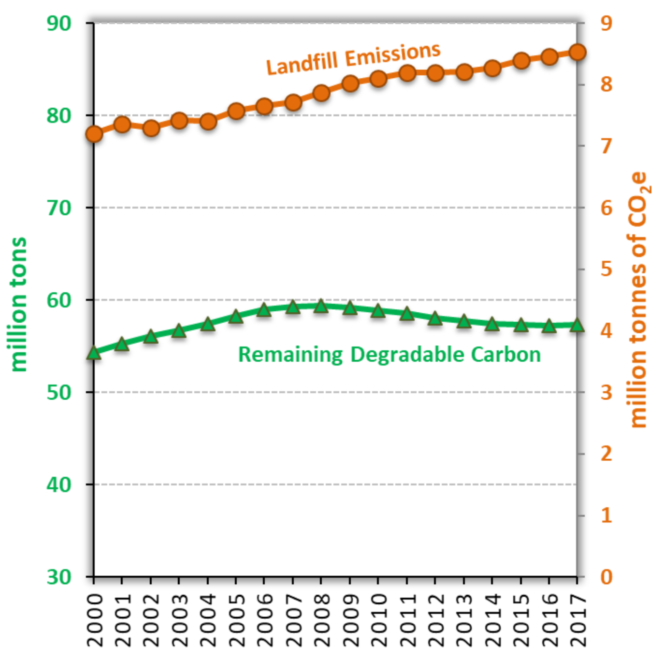


Figure 18. Landfill Methane Generation and Emissions. This figure presents trends in landfill emissions and the amount of degradable carbon remained in the landfill. The latter drives the amount of emissions emitted from the landfill. The color of a trend line matches the color of its corresponding vertical axes label.

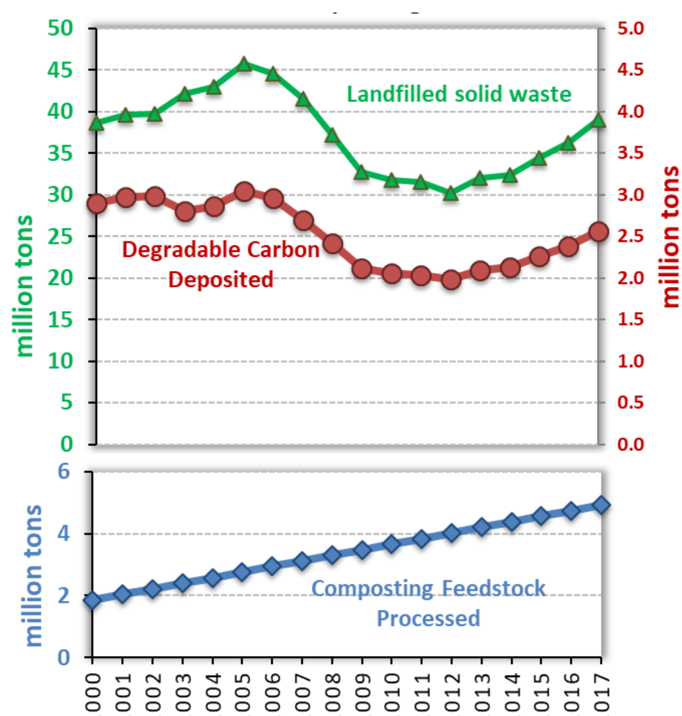


Figure 19. Landfill Waste. The top panel presents the annual amounts of solid waste deposited into landfill and the amount of degradable carbon contained in the solid waste. The color of a trend line matches the color of its corresponding vertical axes label. The bottom panel shows estimated amounts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

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

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 2016 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 2018 edition, total 2016 emissions were estimated to be 429.4 $MMTCO_2e$. In the 2019 edition, recalculation revised the 2016 emissions to 429.0 $MMTCO_2e$, reflecting updated methods and information gained since 2018. Analyses of emission trends, including the emissions drop of 5 $MMTCO_2e$ between 2016 and 2017, are based on the recalculated numbers in the 2019 edition of the inventory. A description of the method updates can be found here: https://www.arb.ca.gov/cc/inventory/pubs/reports/2000_2017/ghg_inventory_00-17_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 Strategy[3] 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 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 CARB. Reports from facilities and entities that emit more than 25,000 metric tons of CO_2e are verified by a CARB-accredited third-party verification body. More information on MRR emissions reports can be found at: http://www.arb.ca.gov/cc/reporting/ghg-rep/reported-data/ghg-reports.htm

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, Board of Equalization, Department of Conservation/Division of Oil, Gas, and Geothermal Resources, 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: 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

Other Ways of Categorizing Emissions in the Inventory

There are 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 any of these categorization schemes can be accessed from CARB webpage at:
http://www.arb.ca.gov/cc/inventory/data/data.htm

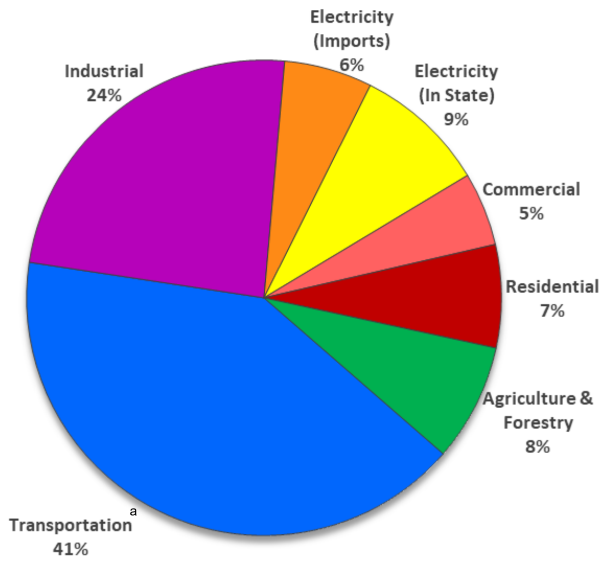


Figure 20a. 2017 GHG Emissions by Economic Sector. This figure shows the relative size of 2017 emissions by economic sector.

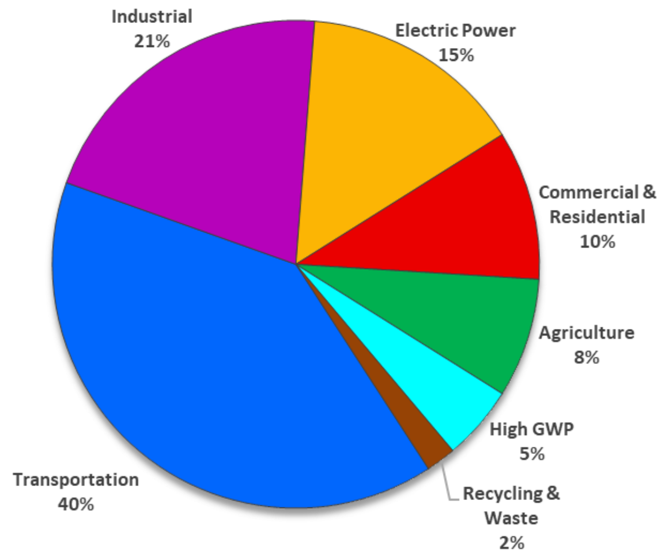


Figure 20b*. 2017 GHG Emissions by Scoping Plan Category. This figure shows the relative size of 2017 emissions, organized by the categories in the AB32 scoping plan.

[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 production.

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

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. Non-combustion, biochemical processes, have varying uncertainty depending on the input data and the emission processes.

Natural and Working Lands Emissions Inventory

CARB has also compiled a natural and working lands (NWL) emissions inventory, which was published in December of 2018. This inventory tracks carbon stocks and stock change in California's natural and working lands (including forest, woodland, shrubland, grassland, wetland, orchard crop, urban forest, and soils) and is separate from the anthropogenic inventory. The NWL inventory report can be accessed here: https://www.arb.ca.gov/cc/inventory/sectors/forest/forest.htm.

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Reference

1. State of California (2006). California Health and Safety Code, Division 25.5, Part 1, Chapter 3, Section §38505(g). Available at: https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=HSC&division=25.5.&title=&part=1.&chapter=3.&article=

2. Intergovernmental Panel for Climate Change (2007). 4th Assessment Report – Climate Change (AR4). Available at: https://www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html.

3. California Air Resources Board (2017). Short-Lived Climate Pollutant (SLCP) Strategy. Available at: https://www.arb.ca.gov/cc/shortlived/shortlived.htm.

4. California Department of Finance (2019). E-6. Population estimates and components of change by county 2010–2017. Available at: http://www.dof.ca.gov/Forecasting/Demographics/Estimates/E-6/.

5. United Nations Environmental Programme (UNEP) (2015). Treaties and Decisions - The Montreal Protocol on Substances that Deplete the Ozone Layer. Information available at: https://www.unenvironment.org/ozonaction/who-we-are/about-montreal-protocol.

6. California Air Resources Board (2014). First update to the climate change scoping plan building on the framework pursuant to AB32: California's global warming solutions act 2006. Available at: https://www.arb.ca.gov/cc/scopingplan/scopingplan.htm

7. Intergovernmental Panel on Climate Change (2006a). IPCC Guidelines for National Greenhouse Gas Inventories, Volume 1 - General Guidance and Reporting, Eggleston H.S., Buendia L., Miwa K., Ngara T., and Tanabe K. (eds.), IGES, Japan. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/.

8. California Air Resources Board (2019). GHG Emission Inventory (GHG EI) 2000-2017. Data and documentation is available on-line at: https://www.arb.ca.gov/cc/inventory/data/data.htm.

9. California Air Resources Board (2019). CARB staff estimate using fuel heat content values consistent with the CARB GHG Emission Inventory (GHG EI) 2000-2017 methodology.

10. California Department of Motor Vehicles (2019). California Motor Vehicle Fuel Types by County, January 1, 2018. https://www.dmv.ca.gov/portal/wcm/connect/2156a052-c137-4fad-9d4f-db658c11c5c9/MotorVehicleFuelTypes_County.pdf?MOD=AJPERES&CVID=

11. California Energy Commission (2019). Personal Communication between Larry Hunsaker of the California Air Resources Board and Asish Gautam of the California Energy Commission.

12. U.S. Energy Information Administration (2019). Electricity - Form EIA-923 detailed data with previous form data (EIA-906/920). Available at: https://www.eia.gov/electricity/data/eia923/.

13. National Oceanic and Atmospheric Administration (2019). Heating and Cooling Degree Days. Available at: ftp://ftp.cpc.ncep.noaa.gov/htdocs/products/analysis_monitoring/cdus/degree_days/archives/Heating%20degree%20Days/monthly%20states/ .

14. U.S. Census Bureau (2019). State Housing Units Estimates. Available at: https://www.census.gov/programs-surveys/popest.html.

15. State of California (2016). Senate Bill No. 1383. Available at: https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB1383

16. California Department of Food & Agriculture (2019). Statistics and Trends Annual Tables and Data. Available at: https://www.cdfa.ca.gov/dairy/dairystats_annual.html

17. U.S. Department of Agriculture (2019). National Agricultural Statistics Service. Available at: https://quickstats.nass.usda.gov/.

18. CDWR (2019). Irrigation Surveys. Available at: https://water.ca.gov/Programs/Water-Use-And-Efficiency/Land-And-Water-Use/Statewide-Irrigation-Systems-Methods-Surveys.

19. UC Davis (2019). Cost and Return Studies. Available at: https://coststudies.ucdavis.edu/

20. CalRecycle (2019). Landfill Tonnage Reports, 2000-2016. Available at: https://www2.calrecycle.ca.gov/LandfillTipFees/.

21. Intergovernmental Panel on Climate Change (2006b). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5-Waste. IPCC Waste Model. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html.

22. California Department of Finance (2019). California Gross Domestic Product. Available at: http://www.dof.ca.gov/Forecasting/Economics/Indicators/Gross_State_Product/

23. California State Board of Equalization (2018). Fuel Taxes Division Statistics & Reports - Motor Vehicle Fuel. Accessed online at: https://www.cdtfa.ca.gov/taxes-and-fees/spftrpts.htm

24. California Air Resources Board (2018). Summary of 2008 to 2016 data from California's Greenhouse Gas Mandatory Reporting Program. Reported emissions are available at: https://ww2.arb.ca.gov/mrr-data.

25. California Department of Finance (2019). Residential and non-residential construction annual data 2000-2019. Available at: http://www.dof.ca.gov/Forecasting/Economics/Indicators/Construction_Permits/.

26. California Department of Finance (2019). E-5 Population and Housing Estimates for Cities, Counties, and the State, 2011 – 2019. Available at: http://dof.ca.gov/Forecasting/Demographics/Estimates/E-5/

27. Glenn Gallagher; Tao Zhan; Ying-Kuang Hsu; Pamela Gupta; James Pederson; Bart Croes; Donald R. Blake; Barbara Barletta; Simone Meinardi; Paul Ashford; Arnie Vetter; Sabine Saba;

Rayan Slim; Lionel Palandre; Denis Clodic; Pamela Mathis; Mark Wagner; Julia Forgie; Harry Dwyer; Katy Wolf (2013). High-Global Warming Potential F-gas Emissions in California: Comparison of Ambient-Based versus Inventory-Based Emission Estimates, and Implications of Refined Estimates. Environmental Science & Technology, 48 (2), 1084-1093