Bay Area Air District

CLEAN AIR FOR ALL

Appendix A

BARCAP Region Greenhouse Gas Emissions Inventory

March 2026

Bay Area Regional Climate Action Plan

BARCAP Region Greenhouse Gas Emissions Inventory

GHG Inventory Technical Appendix of BARCAP Report

October 2025

BARCAP REGION EMISSIONS INVENTORY

SUMMARY REPORT FOR GREENHOUSE GASES

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Glossary

Abbreviation	Definition
ABAG	Association of Bay Area Governments
BAAD	Bay Area Air District (also known as the Air District)
BAAQMD	Bay Area Air Quality Management District (also known as the Air District)
BARCAP	Bay Area Regional Climate Action Plan
CAP	Criteria Air Pollutant
CARB	California Air Resources Board
CADF	California Department of Finance
CEC	California Energy Commission
CEPAM	California Emission Projection Analysis Model
CFCs	Chlorofluorocarbons
CH_4	Methane
CO_2	Carbon Dioxide
EIA	Energy Information Administration
EMFAC	EMission FACtors Model
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GWP	Global Warming Potential
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
IPCC	Intergovernmental Panel for Climate Change
MSA	Metropolitan Statistical Area
$MMTCO_2e$	Million Metric Tons of Carbon Dioxide-Equivalent
N_2O	Nitrous Oxide
PFCs	Perfluorocarbons
PM_{10}	Particulate Matter (inhalable particles with diameter $\leq$ 10 micrometers)
$PM_{2.5}$	Particulate Matter (fine inhalable particles with diameter $\leq$ 2.5 micrometers)
PTO	Permits-to-Operate
SFBA	San Francisco Bay Area
SF_6	Sulfur Hexafluoride
TAC	Toxic Air Contaminant
TOG	Total Organic Gases
USEPA	United States Environmental Protection Agency
USDA	United States Department of Agriculture
VMT	Vehicle Miles Traveled

EXECUTIVE SUMMARY

Inventory Overview

The Bay Area Air District (Air District) is the regional government agency responsible for the regulation of air pollution from stationary sources within the San Francisco Bay Area (SFBA). The Air District's jurisdiction includes Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, southwestern Solano, and southern Sonoma counties. The agency maintains inventories of emissions for criteria air pollutants (CAPs), greenhouse gases (GHGs), and toxic air contaminants (TACs) to:

- Comply with statutory emissions reporting requirements;
- Provide inputs for regional air quality modeling to estimate pollutant concentrations and exposures;
- Support the development of new regulations and amendments to existing regulations to reduce emissions; and
- Support regional and local air quality and climate action planning and policy initiatives.

The Air District's GHG emissions inventory is an accounting of annual emission estimates of major climate-warming pollutants resulting from human activities (also known as anthropogenic emissions) that are grouped by source category for each county. This report presents an overview of the regional GHG emissions inventory from 2000[1] to 2050 across an eight-county jurisdiction developed for the Bay Area Regional Climate Action Planning (BARCAP) Initiative. The BARCAP is the Air District's regional climate action plan for the Northern and Central Bay Area region, developed under funding from the United States Environmental Protection Agency's (USEPA) Climate Pollution Reduction Grant. The BARCAP covers the same jurisdiction as the Air District but does not include Santa Clara County, which is considered by the USEPA as part of a neighboring and separate planning area for their CPRG program. The pollutants covered in the GHG emissions inventory are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and several long-lived gases with high Global Warming Potentials (GWPs)[2] such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), as well as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). Although CFCs and HCFCs have been banned, and their use phased out,[3] historical emissions and residual emissions from legacy equipment are included in the GHG emissions inventory.

Exposure to ambient levels of these pollutants is not directly harmful to human health. However, these pollutants are primary drivers of climate change, which in turn has negative air quality and health impacts in the SFBA. For example, rising temperatures due to global warming increases heat stress and accelerates ozone and secondary particulate matter formation; and more severe wildfires elevate exposure to harmful pollutants. The GHG emissions from fuel combustion and other sources are often accompanied by emissions of co-emitted criteria air pollutants and toxic air contaminants which have direct local air quality and health impacts. Additional discussions about climate and air quality related health impacts can be found in Chapter 5 of the BARCAP report.

The regional source category-level GHG emissions inventory is estimated in alignment with state and federal methodologies, based on detailed research to gather data for the following key variables:

- Activity data or throughput – a measure of emission-generating processes, operations, and services.
- Emission factors – values that represent the amount of a GHG pollutant emitted per unit quantity of the activity or throughput; and
- Control factors – quantitative measure of the reduction in GHG pollutant emissions achieved through pollution-control devices or regulated changes in facility operations.

Forecasted and certain historical emissions are derived using growth profiles. For future projections, growth profiles are developed based on selected socio-economic indicators that characterize how activity data for source categories are expected to evolve over time. For historical backcasting, when direct activity data are unavailable, growth profiles are developed to estimate historical activity levels and emissions.

Emissions Summary

This section presents four key perspectives useful to understanding GHG emissions:

- By sector (i.e., source types)
- By pollutant
- By geographic area (by county)
- By year (i.e., trends and forecasts)

Contribution by sector

The BARCAP GHG emissions inventory follows an inventory framework consistent with California's GHG inventory categorization scheme. GHG emissions source categories are grouped into six economic sectors,[4] which are aligned with CARB's sector definitions:[5]

- Transportation
- Buildings
- Industrial
- Power
- Waste
- Agriculture

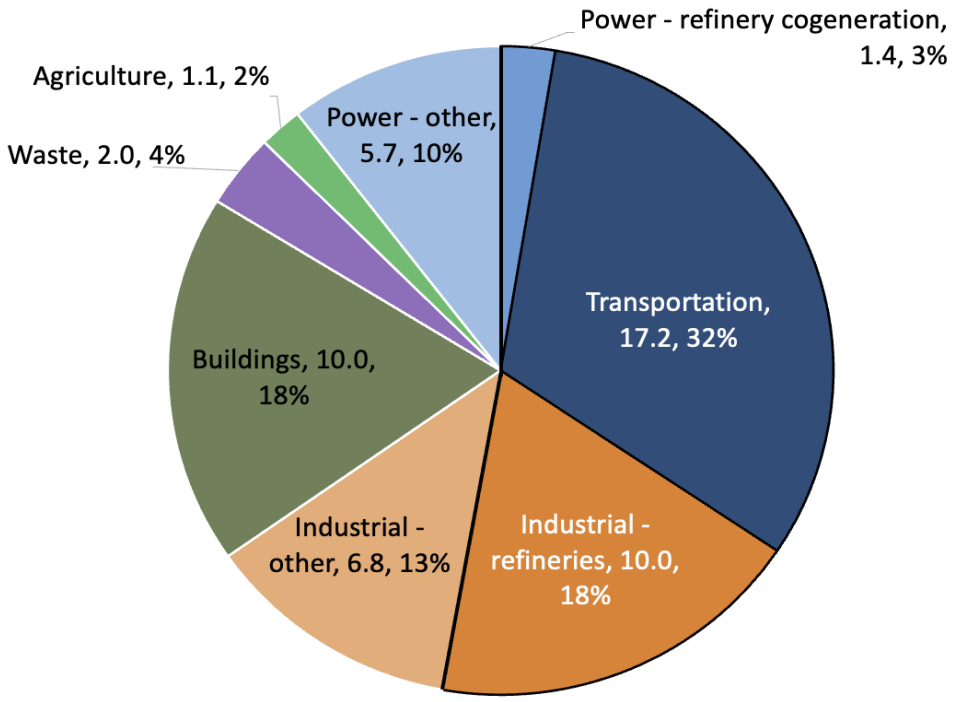


Figure 1: 2022 GHG emissions inventory by sector for the BARCAP region ($MMTCO_2e$).

The annual GHG emissions from all six sectors for the BARCAP region for the base year 2022 is approximately 54.1 million metric tons of CO_2-equivalent ($MMTCO_2e$), which represents about 15% of California's 2022 statewide GHG emissions in 2022.[6] Transportation (32%) is the largest contributing sector in the BARCAP region, followed by the industrial (31%) sector (Figure 1). The buildings sector contributes about 18% and the power sector contributes about 13% to the annual GHG inventory. The waste and agriculture sectors combined contribute less than 6% of the regional total.

As currently defined for the BARCAP, the transportation sector only accounts for GHG emissions from the combustion (end-use) of fossil fuels to move people and goods (e.g., tailpipe emissions from on-road motor vehicles, fuel combustion exhaust from ships and airplanes, etc.). However, every lifecycle stage of fossil fuel extraction, processing, and use for the transportation sector generates GHG emissions. While the BARCAP region has negligible fossil fuel extraction sources, processing of fossil fuels for the transportation sector at the BARCAP region's refineries contributes significantly to the industrial sector emissions, accounting for over 60% (~10 MMTCO2e) of that sector's total GHG emissions. In addition, on-site cogeneration of electricity for use at these refineries, categorized under the power sector, adds another 1.4 MMTCO2e or 20% to that sector's total. When combined with the transportation sector emissions, the GHG emissions related to transportation that are associated with both production (extraction and processing) and consumption (combustion) of fossil fuels account for over half of the total regional GHG emissions in 2022 (53% or 28.6 $MMTCO_2e$), as seen by the sectors outlined in black in Figure 1.

The BARCAP region is heavily urbanized and thereby the share of transportation sector in the regional GHG emissions inventory is larger than its corresponding share in the national emissions inventory (32% versus 28%).[7] In the BARCAP region, GHG emissions from the buildings sector are primarily attributable to space- and water-heating (combined total of 67% of the sector's emissions) and the use of refrigerants and solvents in buildings (21% of building sector emissions). Due to relatively high population density in urban areas, the buildings sector accounts for a higher share of the region's emissions as compared to the national average (18% versus 13%). The power sector represents a lower share in the regional GHG inventory compared to the national average (13% versus 25%), largely because a greater portion of the region's electricity is produced from renewable sources such as wind, solar, hydrothermal, etc., reducing the region's reliance on natural gas-fired power plants.

A subsector breakdown of the base year 2022 GHG emissions inventory is provided in Figure 4 and Table 3.1 in Section 3 of this appendix. Emissions data for the Air District's regional GHG inventory, which includes the full jurisdiction of the Air District including Santa Clara County, are presented in an interactive online dashboard on the Air District's emissions inventory webpage.[8]

Contribution by pollutant

Reviewing the pollutant composition in the BARCAP GHG inventory is useful to identify different types of GHGs associated with different sources. Analyzing the pollutant distribution in the BARCAP region compared to the national profile reveals distinct sources and emissions characteristics unique to the region. The contribution of CH_4 (>6%) and N_2O (~2%), which are primarily emitted from waste management, animal agriculture, soil management, and petroleum production systems, is a smaller share in the BARCAP GHG inventory compared to their contribution at the national level of 11% for CH_4 and 6% for N_2O.[9] In the BARCAP region, high-GWP gases like HFCs and PFCs, emitted from a variety of sources such as refrigeration, air conditioning, fire suppressants, and insulation, etc., represent a significant proportion of GHG emissions from the buildings sector (>20%, Figures 4 and 5). This results in a higher overall regional contribution (~6% of the regional GHG total) of high-GWP gases than that in the national inventory (~3%). CO_2, largely produced through fuel combustion, remains the most prevalent GHG pollutant in the region (>86% of the regional inventory; see Figure 5).

Contribution by county

Evaluating the geographic distribution of GHG emissions across the BARCAP region identifies those counties with the largest contributions to GHG emissions and the sectors driving those emissions Figure 2 shows the distribution of annual regional GHG emissions by county across the BARCAP region. Contra Costa County is attributed to having the highest GHG emissions (~45%) in the region, due mostly to the presence of large sources in the industrial sector (e.g., refineries) and in the power sector (e.g., power plants) located in this county. The southern Solano County, which accounts for 10% of the BARCAP region's GHG emissions despite only having 4% of the Bay Area's population, is also largely impacted by industrial sources. In the other seven counties that have fewer heavy industries, the

transportation and buildings sectors account for the majority of county-level GHG emissions. A detailed breakdown of emissions by county is provided in Table 3.2 in Section 3 of this appendix.

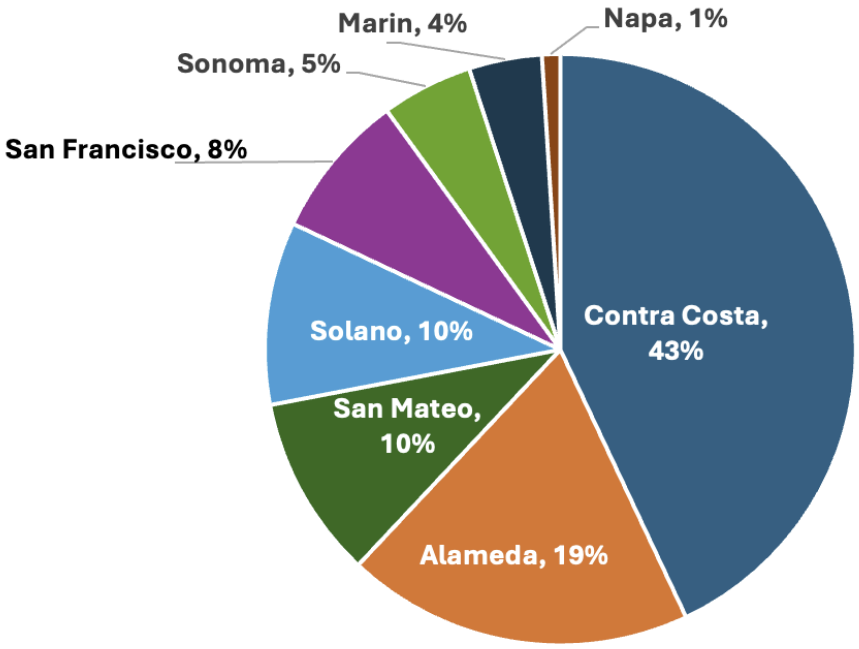


Figure 2: 2022 GHG emissions inventory by county for the BARCAP region ($MMTCO_2e$)

Trends and forecasts

A time series of historical GHG emissions along with projected future emissions allows the Air District to assess the progress the region has made in achieving its climate objectives and future policy goals. Overall, the BARCAP region's GHG emissions have dropped from 62.2 $MMTCO_2e$ in 2000 to 54.1 $MMTCO_2e$ in 2022 marking a 13% reduction, consistent with the declining trend in California's state inventory (19.8% decrease) and the U.S. national inventory (14.5% decrease) over the same period.[10] Most of the GHG emissions reductions in the BARCAP region are attributed to the transportation (-23%), industrial (-9%), and power (-23%) sectors as shown in Figure 6, largely due to regulations in goods movements and the use of renewable sources for energy generation. This downward trend is partially offset by an increase in GHG emissions from the buildings (+14%) sector, indicating an increasing demand for energy from the Bay Area's growing population and businesses. A significant decline in GHG emissions is predicted in the buildings sector, primarily due to the Air District's Regulation 9 Rule 4 and Regulation 9 Rule 6,[11] which require newly installed natural gas furnaces and water heaters to meet a zero nitrogen oxides (NO_X) emissions standard starting with water heaters in 2027.

Contents of Summary Report

The BARCAP GHG inventory reflects methodological advancements over the previous inventory.[12] This report summarizes the key findings resulting from this latest inventory update. Section 1 discusses the general scope of the inventory including geographic coverage, key pollutants, and sector hierarchy schema. Section 2 presents the general methodology used to develop the inventory based on source characteristics and availability of supporting data sources. Section 3 provides a breakdown of the regional GHG emissions by process, sector, and pollutants, and highlights key observations at the regional and sector level. Finally, Section 4 provides an overview of key assumptions and limitations in the emissions estimates and identifies areas for future improvement.

1. INVENTORY SCOPE AND ORGANIZATION

This section provides an overview of the BARCAP GHG inventory, which includes geographical area covered by the plan, identification of the key pollutants, and a description of the source sectors and subsectors using an organizational hierarchy schema.

1.1. GEOGRAPHY

The BARCAP GHG inventory covers eight counties including Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, southwestern Solano, and southern Sonoma counties (see Figure 3). Only GHG emissions that are generated or produced in the portions of Solano and Sonoma counties that are part of the Air District's jurisdiction are accounted for in this inventory.

Figure 3: Map of the BARCAP region that includes six full and two partial (Solano and Sonoma) counties

Each county in the BARCAP region has unique and diverse characteristics that serve as key predictors of trends likely to influence future activity and, in turn, estimated GHG emissions. The Air District has

relied on these predictors which include population distribution, socioeconomic data, goods consumption patterns, etc. to project future growth or change in GHG emissions across sectors and subsectors. As shown in Table 1.1, these predictors vary significantly among counties and highlight the complexities in quantifying the base year emissions and predicting future activities summarized in this report.

Table 1: Selected demographic and socio-economic indicators by county for the BARCAP region for 2022.

County[a]	Area in acres[b] (%)[c]	Human Population[d] (%)[c]	Total Natural Gas Consumed in Millions of Therms[e] (%)[c]	Automobile Registration Count[f] (%)[c]	Total Electricity Consumed in Giga Watt-Hours[e] (%)[c]
Alameda	473,639 (20)	1,643,683 (30)	377 (17)	1,035,244 (29)	10,395 (29)
Contra Costa	506,953 (21)	1,149,841 (21)	892 (41)	807,986 (22)	8,338 (24)
Marin	331,834 (14)	255,459 (5)	66 (3)	188,149 (5)	1,293 (4)
Napa	502,039 (21)	135,564 (3)	39 (2)	93,614 (3)	1,029 (3)
San Francisco	30,080 (1)	840,575 (15)	214 (10)	386,770 (11)	5,121 (14)
San Mateo	289,647 (12)	742,051 (13)	204 (10)	562,003 (16)	4,177 (12)
Solano	132,846 (5)	312,919 (6)	248 (12)	208,801 (6)	2,279 (7)
Sonoma	145,060 (6)	412,502 (7)	107 (5)	290,573 (8)	2,477 (7)

a: Only represents the Air District portion of Solano and Sonoma counties.
b: Solano and Sonoma counties portions of the Air District are 48% and 37%, respectively.
c: The numbers in parentheses indicate percentage relative to the whole region.
d: Data is obtained from the California Department of Finance for the year 2022. Solano and Sonoma counties population portions within the Air District are 70% and 86%, respectively.
e: Data is obtained from the California Energy Commission for 2022. Solano's and Sonoma's energy consumption is derived from the proportional distribution of human population of the Air District portions of the two counties (70% for Solano and 86% for Sonoma, respectively).
f: Registration data are obtained from the California Department of Motor Vehicles for 2022. The Solano and Sonoma counts are derived from the proportional distribution of human population of the Air District portions of the two counties (70% for Solano and 86% for Sonoma, respectively).

1.2. POLLUTANTS

The greenhouse gases covered in the BARCAP regional emissions inventory align with those included in United States Environmental Protection Agency's National Emissions Inventory[13] and California Air Resources Board's statewide GHG emissions inventory.[14] The BARCAP GHG inventory includes emissions of the following GHG pollutants:

- **Carbon Dioxide (CO_2)**: CO_2 is a major emission by-product of all fossil fuel (e.g., natural gas, gasoline, diesel, wood, etc.) combustion processes, and to a minor extent the biological decomposition of all organic material (e.g., animal waste, compost, agricultural residues, etc.), noted as CO_2_bio in the emissions inventory. CO_2_bio emissions are from biogenic sources and

are excluded from the total anthropogenic GHG emissions in the BARCAP inventory. See Section 4 -Uncertainties and Future Improvements for more information on CO_2_bio.

- **Methane (CH_4)**: CH_4 is a major constituent of natural gas. In the BARCAP region, CH_4 is primarily emitted from leakage of natural gas across the oil and gas and energy infrastructure, anaerobic decomposition of solid and liquid organic waste (at municipal landfills and wastewater treatment plants), direct emissions from livestock and other agricultural operations, and to a lesser extent, incomplete combustion of fossil fuels.

- **Nitrous Oxide (N_2O)**: N_2O is primarily emitted from nitrification and denitrification processes in soils (arising from fertilizer use for both agricultural and commercial/residential purposes). Other emission sources include tailpipe emissions from automobiles, incomplete combustion of fossil fuels, and organic waste decomposition at municipal landfills and wastewater treatment plants.

- **Fluorinated Gases**: These long lasting GHGs are synthetically generated (human-produced) and emitted as fugitive losses across a variety of households, commercial and industrial applications and processes. Fluorinated gases included in this inventory are:
  - Hydrofluorocarbons (HFCs),
  - Perfluorocarbons (PFCs),
  - Sulfur Hexafluoride (SF_6),
  - Chlorofluorocarbons (CFCs), and
  - Hydrochlorofluorocarbons (HCFCs).

  These gases are typically inert, and they stay in the atmosphere for hundreds of years once emitted; therefore, local and federal regulations are focused on phasing out their use. CFCs and HCFCs were widely used as refrigerants and solvents until ozone depleting substances were banned as part of a 1989 global agreement under the Montreal Protocol.[15] Minor contributions of CFCs and HCFCs are included in the GHG inventory due to recycling and salvage of pre-ban and legacy equipment. HFCs and PFCs are substitutes for ozone depleting substances and are widely used as refrigeration and air conditioning agents, solvents, and aerosols. They are also byproducts of semiconductor manufacturing process. Emissions of these pollutants occur across all major sectors and are collectively represented as one group, known as high-global warming potential (GWP) gases. SF_6 is the most potent man-made GHG per Intergovernmental Panel on Climate Change (IPCC) and is used as an insulating gas in electrical transmission equipment (e.g., circuit breakers). Most of the fluorinated gases are emitted in exponentially smaller quantities as compared to CO_2, CH_4, and N_2O; however, due to their extremely high GWPs (described below), the combined emissions of these fluorinated high-GWP gases are a significant portion of the overall GHG inventory.

The BARCAP GHG inventory incorporates the GWPs reported in the IPCC Fifth Assessment report, released in 2014,[16] which includes impacts of climate feedback in GWP calculations. The GWP value of each GHG reflects the climate forcing caused by a kilogram of emissions relative to the same mass of carbon dioxide (CO_2). Thus, GWP of CO_2 is set equal to one while all other GHG pollutants have GWP

relative to CO_2. The GWP of a GHG is determined by the intensity of infrared absorption and how long emissions remain in the atmosphere. GWPs are calculated using a set time horizon. The GWPs used for the BARCAP GHG inventory are considered over a 100-yr timeframe, consistent with the approach adopted by the USEPA and CARB for their GHG inventories. Since the effective radiative impact of short-lived GHGs (e.g., CH_4 has a lifetime of 10-12 years) is more profound over a shorter time-horizon, the Air District may use short-term GWPs (such as 20 years) for estimating emissions inventories for rulemaking and climate action purposes.

1.3. BASE YEAR

The BARCAP GHG inventory covers annual emission estimates from permitted and non-permitted stationary sources, as well as on-road and off-road mobile sources, from 2000 to 2050. The year 2022 serves as the base year for this emissions inventory as it is the latest year with comprehensive assessment conducted to estimate total emissions across all source categories and sectors. The inventory for this base year is used as a reference point or benchmark to:

- Track trends in emissions over time to evaluate progress towards achieving targets;
- Develop current and future GHG-related analysis scenarios; and
- Support development of local climate action plans and mitigation strategies.

The year 2022 emissions include effects of adopted regulations but exclude the influence of non-enforceable climate protection guidelines and recommended policies. Socioeconomically, year 2022 is also considered a representative “business as usual” year, reflecting a return to typical activity levels following the COVID-19 pandemic. In some cases, emissions may be estimated using the pre-pandemic base year 2019 when data for 2022 are unavailable. The GHG emissions for 2023 and beyond are typically projected based on the base year emissions under a business-as-usual scenario.

1.4. ORGANIZATIONAL HIERARCHY

The BARCAP GHG inventory follows an inventory framework that aligns with CARB’s GHG inventory categorization scheme to:

- Use emission factors and methodology by source category consistent with CARB’s statewide GHG emissions inventory;[17]
- Extract source category-specific emissions inventory for criteria air pollutants (CAPs) at a county-scale from CARB’s California Emissions Projection Analysis Model,[18] and to use CAPs as surrogates to derive and proportion GHG emissions; and,
- Leverage growth projections from CARB’s 2022 Scoping Plan for Achieving Carbon Neutrality (Scoping Plan)[19] to forecast future GHG emissions for equivalent source categories, wherever applicable.

The regional GHG inventory is classified into four levels with the first level based on the economic sector, followed by two lower levels describing the general and specific processes generating the emissions, respectively. These three sector levels are ultimately linked to the source-category level, the most granular grouping in which emissions are reported in this GHG inventory, as shown below:

In Level 1 classification, GHG emission sources are classified across six economic sectors,[20] which align with USEPA' s classification and are also used by CARB to develop and implement GHG emission reduction strategies:

- **Transportation** – The transportation sector encompasses emissions from all mobile sources including on-road vehicles (passenger cars, light and heavy-duty trucks, and buses etc.) and all non-road transportation modes (aircraft, locomotives, ships, etc.). It is the largest contributor of the six assumed sectors to California's GHG emissions, primarily due to combustion of fossil fuels. The contribution of this sector to GHG emissions would grow larger if upstream emissions associated with production and processing of transportation-related fuels were included in this group instead.

- **Buildings** – This sector includes direct emissions from energy consumption in buildings, such as heating, cooling, cooking, lighting, and appliance use, as well as some off-road machinery (e.g., lawn and garden equipment, airport ground support equipment, etc.). The primary emissions sources are combustion of natural gas and other fuels for space and water heating, and fugitive emissions of high-GWP gases from refrigeration and air conditioning systems.

- **Industrial** – The industrial sector includes emissions from manufacturing, construction, petroleum refining, and oil and gas extraction activities, as well as some off-road machinery (e.g., construction and mining equipment, etc.). It encompasses emissions from the combustion of fossil fuels for energy, chemical reactions during industrial processes, and fugitive emissions from equipment leaks and other sources. Key currently operating and/or now shutdown industrial sources in this sector include refineries, cement plants, food processing facilities, and chemical manufacturing that are permitted by the Air District.

- **Power** – This sector covers emissions from the production of electricity at power plants and cogeneration facilities located within the BARCAP region. GHG emissions arise from the combustion of fossil fuels (such as natural gas) to produce electrical energy and fugitive leaks of methane from natural gas infrastructure at power plants. GHG emissions from imported electricity generated outside the BARCAP region are not included in the regional emissions

total. A review of annual power content labels of the BARCAP region's electricity retailers[21] indicates that, increasingly, most of the electricity consumed in the BARCAP region is generated from less carbon-intensive or carbon-free renewable energy sources (e.g., wind, solar, hydroelectricity, etc.). This trend lowers the demand for fossil fuel-based electricity from local generation sources.

- **Waste** – This sector includes emissions from the treatment and disposal of solid waste and wastewater at facilities located within the BARCAP region. It is conceivable that a minor fraction of this waste disposal and treatment activity may occur at facilities located outside the Air District's geographical jurisdiction. Major sources include methane emissions from landfills, emissions from composting and anaerobic digestion, and nitrous oxide emissions from wastewater treatment processes.

- **Agriculture** – The agriculture sector encompasses emissions from agricultural activities, including crop cultivation and livestock production. Key sources of emissions are enteric fermentation in ruminant animals (producing methane), manure management, fertilizer application (leading to nitrous oxide emissions), and fuel combustion for agricultural equipment. Agricultural practices also influence carbon sequestration in soils and vegetation, which is covered for all land classification types in Appendix B – 2022 Natural and Working Lands Inventory.

The definition and source composition of the economic sectors, along with exceptions to account for organizational differences at the regional level, are presented in more detail in Appendix A1.

Each economic sector is then split into four groups under Level 2, aggregated by the general processes generating GHG emissions:

- **Fuel Combustion** – This group includes emissions from combustion of all gaseous, liquid and solid fuels in internal or external combustion engines to produce energy and/or heat and steam to perform work.

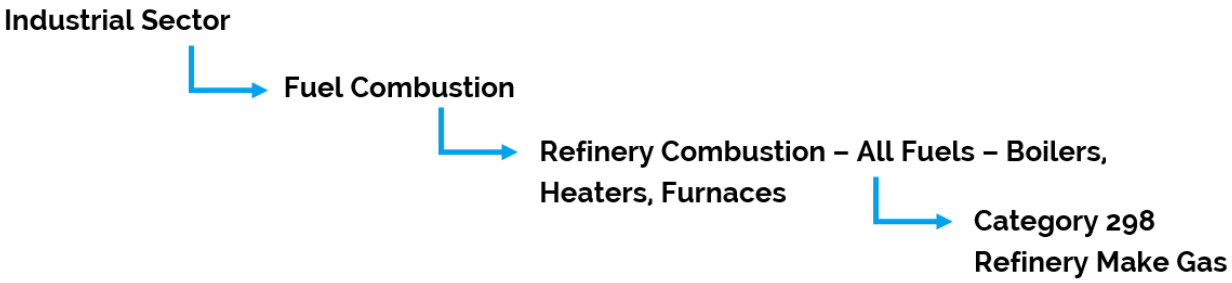
- **Process** – This group includes GHG emissions resulting from chemical, physical and biological processes within various source categories such as petroleum refining, manufacturing processes, waste management, enteric fermentation in livestock, etc.

- **Fugitive and Evaporative** – This group includes GHG emissions from intentional and unintentional leaks such as natural gas leakage across the oil and gas infrastructure, fugitive losses of SF_6 at circuit breakers, refrigerant leaks, etc.

- **Other Combustion** – This group includes GHG emissions from combustion of non-energy sources like controlled agricultural burns and waste incineration, or fires of accidental nature (e.g., structural, automobile, wildland fires, etc.).

The third level is a categorization of more detailed and similar processes grouped together called 'subsectors' (e.g., type of emissions equipment, type of fuel burned, size of source device, type of chemical or biological process). There are over 50 subsectors in the regional GHG inventory (see Appendix A2 for a detailed list) and some examples include aircraft, domestic wastewater treatment, commercial cooking, residential natural gas combustion, etc.

At the category level, the Air District starts by estimating emissions for over 560 unique source categories that are grouped into one of 55 Level 3 subsectors, which are then aggregated by general processes at Level 2 and finally catalogued by economic sector in Level 1. An example depicting this organization hierarchy is provided below. Appendix A2 summarizes the sector-process-subsector hierarchy that each of the 560+ GHG source categories fall under.



2. INVENTORY METHODOLOGY

The Air District uses a production-based approach to develop the BARCAP GHG inventory, focusing mainly on emissions released directly into the atmosphere from sources located within the region. This differs from a consumption-based approach, which attributes emissions to regional consumers by accounting for the full life-cycle emissions of goods and services consumed locally, regardless of where those emissions occur globally.

2.1. SOURCE TYPES

Emissions are estimated for each of the 560+ unique sources in the inventory based on the fundamental characteristics of the source. Emission sources generally fall into three main types depending on the emissions estimation methodology that is applicable:

- **Permitted Stationary Sources**: These sources (and related processes) are subject to the Air District's permitting requirements and the facilities with these sources have been issued permits to operate (PTO). Most of these sources are often referred to as 'point' sources due to their emissions characteristics. Some key characteristics of these sources include:

    - Most permitted source emissions are released at a fixed, defined location, such as a stack, but there are exceptions. The Air District also permits diffuse area sources including fugitive emissions from stockpiles and leaks from multiple pressure relief valves.
    - Emissions are required to be reported or calculated for each source at regular intervals, typically annually.
    - A bottom-up approach is typically used for emissions estimation (further explanation below).
    - These sources often involve combustion equipment.
    - Examples: fuel combustion emissions from reciprocating engines, prime and backup diesel generators, and industrial boilers.

- **Non-permitted Stationary Sources**: These sources are not subject to the Air District's permitting requirements and do not need a PTO, although they could be located at facilities that have obtained a PTO for other emissions sources. These sources are often referred to as 'area' sources due to their emissions characteristics. Some key characteristics of these sources include:

    - Emissions originate from numerous diffuse points that may be difficult to locate or track individually.
    - Emissions are not required to be systematically reported or calculated.
    - Emissions estimation method may involve either a bottom-up or a top-down scaling approach.
    - These sources often involve fugitive emissions or diffuse processes.

- Examples: biologically produced methane emissions at closed landfills, anaerobic decomposition at wastewater treatment plants, and livestock manure management emissions.

- **Mobile Sources**: These sources (and related processes) are subject to federal and state-level regulations but are not within the Air District's regulatory authority. These sources are usually grouped into on-road and off-road source categories. Some key characteristics of these sources include:

  - Emissions originate from sources that typically move from place to place as they operate.
  - Source activities are not tracked individually (e.g., vehicle miles traveled per vehicle) but are typically estimated as an aggregate for the whole source group (e.g., total vehicle miles for light-duty vehicles).
  - Emission rates can vary by emission process (e.g., running exhaust, start exhaust, idling exhaust, tire or brake wear, etc.); hence emissions factors are process dependent.
  - To account for vehicle/equipment fleet complexities, the Air District uses modeling tools (e.g., EMFAC2021 for on-road sources and OFFROAD2021 for off-road sources) that apply a bottom-up, top-down, or a hybrid calculation approach for emissions estimation.
  - Examples: exhaust, tire wear, and brake wear emissions from passenger cars, heavy-duty trucks, and buses; exhaust emissions from bulldozers, forklifts, and tractors; exhaust emissions from ships and aircraft.

2.2. EMISSION CALCULATIONS

As previously mentioned, the Air District typically uses two types of estimation approaches—a bottom-up or a hybrid method—to estimate GHG emissions, depending on source types and available calculation support data.

Bottom-up Permitted Source Approach

Permitted sources are stationary operations that emit air pollution into the atmosphere at fixed location(s) within a facility, and for which the Air District has issued a PTO (e.g., steam reforming at refinery hydrogen plants).

During the permitting process, the Air District collects site-specific information from the operating facility and/or determines from published literature, e.g., U.S. Environmental Protection Agency's (USEPA) AP-42,[22] source characteristics including maximum throughput, emission factors by pollutant, and temporal profile. The Air District may require an abatement device to be installed, in which case control factors will be incorporated to account for the reduced emissions. Facilities that hold an Air District PTO are required to renew their permit periodically (this period varies based on facility and source types). Upon renewal, the facilities are requested to provide updates on the source characteristics and throughput

since the past permit issuance (typically, twelve months). The throughput, emission factors, and control factors, stored in the Air District's permitting database, are used to estimate annual emissions at the source level for each county using the following equation:

$$\text{Base Year(s) Emissions}_{\text{source i, pollutant}} = \text{Activity Data}_{\text{source i}} \times \text{Emission Factor}_{\text{pollutant}} \times \text{Control Factor}_{\text{pollutant}} \times \text{GWP}_{\text{pollutant}}$$

$$\text{Base Year(s) Emissions}_{\text{county, pollutant}} = \sum_{i=1}^{N} \text{Emissions}_{\text{source i, pollutant}}$$

Where:

- **Base Year(s)** are any years for which source category-specific activity data are available and hence emissions can be directly derived.
- **Activity Data** are the throughput or activity (e.g., amount of fuel consumed, number of goods produced, counts of sources operated, etc.) at the source/equipment level. This data is typically provided by the facility during permit renewal.
- **Emission Factor** is a rate that expresses the mass of a specific pollutant emitted per unit of activity. For example, emission factors can be stated as tons of CO_2 per gallon of gasoline burned or pounds of N_2O per million standard cubic feet of natural gas combusted. GHG emissions are calculated by applying emission factors to activity data reported by facilities, which are verified or validated through source tests. When source-specific emission factors are unavailable (which is common), the Air District uses default factors derived from published literature such as USEPA's AP-42 or CARB's Mandatory Reporting Requirement[23] for Greenhouse Gases.
- **Control Factor** is a fractional ratio (between 0 and 1) to account for estimated reduction in emissions as a result of Air District's regulations or installation of a control device.
- **GWP** is the Global Warming Potential that measures the warming potential of different greenhouse gases by quantifying their radiative forcing, or the ability to trap heat, relative to CO_2. The current version of the GHG emissions inventory incorporates the GWPs reported in the Fifth Assessment report of the Intergovernmental Panel for Climate Change,[24] when calculated on a 100-year basis with climate-carbon feedback included.
- **N** is the number of permitted or non-permitted sources in a county.

Bottom-up Non-Permitted Source Approach

Non-permitted sources are diffuse, areawide sources (e.g., agricultural soil management) or small-scale stationary and exempt sources (e.g., cargo handling equipment) that typically fall outside of the Air District's direct permitting authority. As a result, GHG emissions from these sources are not systematically reported to the Air District but are estimated based on publicly available throughput or activity data for the BARCAP Region. The base year emissions estimates, using a bottom-up approach, are commonly derived by applying the following equation. Most of the terms in the equation below are defined above.

$$\text{Base Year(s) Emissions}_{\text{county, pollutant}} = \text{Activity Data}_{\text{Air District}} \times \text{Emission Factor}_{\text{pollutant}} \times \text{Fraction}_{\text{county}} \times \text{Fraction}_{\text{in Air District}} \times \text{Control Factor}_{\text{pollutant}} \times \text{GWP}_{\text{pollutant}}$$

Where:

- **Fraction$_{\text{county}}$** is the fraction of total regional emissions (between 0 and 1) estimated to be allocated to a particular county.
- **Fraction$_{\text{in Air District}}$** is an additional allocation (between 0 and 1) to account for the fraction of Solano and Sonoma County emissions that are within the Air District's jurisdiction.

Non-Permitted and Mobile Source Hybrid Approach

For some non-permitted source categories (e.g., vegetation and structural fires, high-GWP gases, etc.) and for most mobile sources (on-road and off-road categories except for the aviation subsector), source-by-source or equipment-level activity data or emission factors at county-scale are often incomplete or unavailable. In such cases, a hybrid (or custom) calculation approach is adopted to utilize a combination of bottom-up estimation and top-down scaling that starts off with a pre-existing bottom-up emissions inventory, developed for a region, state, or the nation. Scaling factors, based on key determinants such as population, housing units, and motor vehicle fuel sales, etc. are derived. These scaling factors are then applied to 1) proportion emissions from the larger inventory to each county in the region (top-down), or 2) adjust estimated emissions to reflect real-world scenarios. The scaling approach is explained with the formula below. A few of the terms in the equation below have been defined previously.

$$\text{Base Year(s) Emissions}_{\text{county, pollutant}} = \text{Emissions}_{\text{pre-existing, pollutant}} \times \text{Scaling Factor}_{\text{Air District}} \times \text{Control Factor}_{\text{pollutant}} \times \text{GWP}_{\text{pollutant}}$$

Where:

- **Emissions$_{\text{pre-existing, pollutant}}$** is the pre-existing source category emissions inventory developed for the region, state, or nation by USEPA or CARB.
- **Scaling Factor$_{\text{Air District}}$** is a representative fraction of the original inventory emissions (between 0 and 1) developed for the BARCAP region using activity proxies, surrogate socioeconomic indicators, pollutant ratios etc. (for example, population, motor vehicle fuel sales, electricity consumed, employment, etc.) to apportion the emissions to the BARCAP region county level or adjust the modeled county-level emissions to reflect a real-world scenario.

2.3. HISTORICAL AND FUTURE PROJECTION

Once base year emissions are determined, historical backcasting and forecasting of emissions relative to the base year are conducted at a source category level, using growth profiles as follows:

$$\text{Historical Emissions}_{\text{year, county}} = \text{Base Year(s) Emissions}_{\text{county}} \times \text{Growth Factor}_{\text{year, backcasting}}$$

$$\text{Future Emissions}_{\text{year, county}} = \text{Base Year Emissions}_{\text{county}} \times \text{Control Factor}_{\text{pollutant}} \times \text{Growth Factor}_{\text{year,forecasting}}$$

Where:

- **Base Year(s)** are the years for which activity data are available and emissions are directly derived.
- **Historical** refers to all years prior to the base year(s) where activity data are unavailable and emissions are extrapolated from the base year(s) emissions.
- **Future** refers to all years following the base year(s) for which the Air District forecasts emissions by applying growth factors.
- **Control Factor** is a ratio (between 0 and 1) to account for estimated additional future control and reduction in base year emissions, beyond effective control in the base year.
- **Growth Factor** is a fractional ratio (between 0 and 1) representing the normalized growth of emissions relative to the base year value. The growth profile is source specific and can be based on projected activity or other socio-economic indicators such as population.

It is important to note that when forecasting emissions, the additional control factor described above is applied to future years only in that scenario where an existing Air District regulation has not reached its full implementation or enforcement by the base year based on the schedule set in the rule.

2.4. QUALITY ASSURANCE PROTOCOL

The primary objectives for the BARCAP are to develop reliable inventories for each of the GHG-emitting sectors in the BARCAP region, and to identify options for reducing emissions from those sectors. As per the USEPA's CPRG guidelines, the BARCAP was required to develop and implement a quality assurance program that promotes confidence in the developed emissions inventory and all subsequent policy initiatives and regulatory programs based on the inventory estimates.

Accordingly, all quality objectives and criteria are aligned with the overall BARCAP objectives and laid out in a Quality Assurance Project Plan[25] (QAPP). The BARCAP GHG inventory is subject to a data review and quality control process that is described in the QAPP. All activities under this project will conform to the QAPP. The quality system used for this project is the joint responsibility of the Air District Project Manager (PM), Task Leaders (TLs), Technical Reviewers (TRs), and an organizationally independent Quality Assurance (QA) Manager.

A detailed quality assessment is applied to each of the six major sectors during the GHG inventory development process with a seven-step planned quality assessment and control activity (for each sector). This seven-step approach includes:

- Determining quality of existing Air District inventory for the BARCAP region
- Identifying, researching, and collecting other published data
- Characterizing the data
- Assessing data for accuracy and applicability

- Deriving emissions estimates
- Verification of quality
- Quantification of reduction measure options

The Air District followed the QAPP guidelines as required by the CPRG grant to assure quality of the data and validity of the inventory process, as reviewed and approved by an independent Quality Assurance (QA) manager.

3. EMISSIONS SUMMARIES AND TRENDS

This section provides a closer look into the GHG emission inventory, including process and subsector level apportionment, county breakdown by sector, and long-term emissions trends up to 2050.

3.1. EMISSIONS BY PROCESS

The majority of GHG emissions in the BARCAP region are attributed to fuel combustion (~80%), as summarized in Table 2. Although chemical and biological process emissions account for only 14% of the region's total GHG emissions, their contributions to industrial (27%), waste (>99%), and agriculture (89%) sectors are much higher. Fugitive leaks and evaporative losses make up the remaining emissions (7%), primarily consisting of CH_4 and high-GWP gases.

Table 2: Contribution of Level 2 general processes to the greenhouse gas emissions inventory for 2022.

Region	Emissions (as %)			
	Fuel Combustion	General Process	Evaporative & Fugitive	Other Combustion
BARCAP	79.3%	13.7%	7%	<0.1%

3.2. EMISSIONS BY SUBSECTOR

Figure 4 presents a sunburst chart that visually represents the major Level 3 subsectors within each of the Level 1 economic sectors contributing to the BARCAP GHG emissions inventory. The chart conveys the relative contribution of each subsector as a percentage of total regional GHG emissions. The inner ring displays the proportional emissions share of the six economic sectors, while the outer ring breaks down each economic sector's share into its major contributing subsectors (see Table 3 for the GHG emissions by subsector used to derive Figure 4).

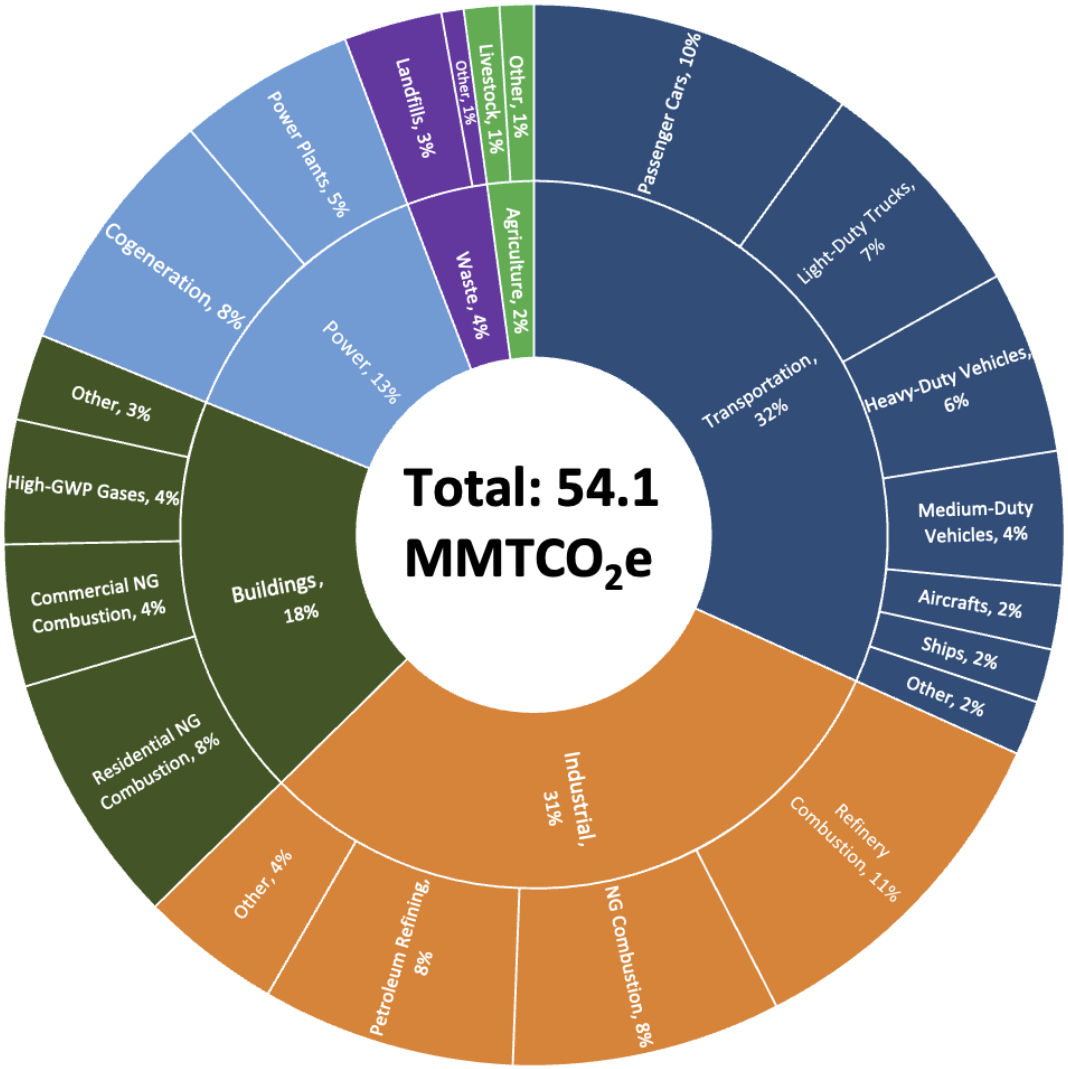


Figure 4: Level 1 (sector) and grouped Level 3 (subsector) contributions to the BARCAP regional greenhouse gas emissions inventory for 2022.

The following bullets highlight trends and changes in the current 2022 base year GHG emissions compared to the previous 2015 base year inventory:[26]

- As indicated in Figure 4 and Table 3, in year 2022, passenger vehicles (10% of total regional GHG emissions) and light-duty trucks (7%) contribute the largest share of GHG emissions to the transportation sector (31% and 22%, respectively), which is consistent with results from the 2015 GHG inventory.

- In the industrial sector, combustion of all fuels in boilers, heaters and flares at refineries (11%), non-refinery natural gas combustion (>8%), and petroleum refining process emissions (~8%) are major regional GHG sources. Refinery-related operations account for over 60% of the current industrial sector GHG emissions. In past inventories, oil refineries accounted for over 70% of GHG emissions in this sector. The transition of two refineries to process renewable feedstocks and a noted reduction in their throughput are expected to result in overall reduction of industrial sector GHG emissions in the future. The sector may see further reductions in GHG emissions from the petroleum refining subsector as gasoline consumption in the transportation sector continues to decline.

- Combustion of natural gas in the residential subsector (8%) and commercial subsector (<5%) are the major sources of GHGs in the buildings sector. Emissions in this sector are predicted to decline as regional regulations requiring the use of zero-NO_X appliances come into effect (see Emissions Trends).

- Power plants and cogeneration combined (13%) are major power sector emissions sources in the region. Electrification of buildings and transportation are expected to increase electricity demand, potentially leading to higher GHG emissions from the power sector. However, this projected increase is mitigated by the BARCAP region's growing reliance on electricity generated from renewable sources.

- About 2% of regional GHG total (or one-third of the cogeneration subsector emissions) are attributed to self-generated electricity production at petroleum refineries. As regional demand for fossil-based transportation fuels declines, crude oil throughput processed at the BARCAP region's refineries is expected to decrease as well, which would lead to a corresponding reduction in GHG emissions from this subsector within the power sector.

- Fugitive emissions from fluorinated high-GWP gases across all sectors account for 6% of the regional GHG inventory.

- Landfills constitute the largest share of GHG emissions within the waste sector and are also the largest source of CH_4 emissions, although they only account for a little more than 3% of the BARCAP GHG inventory.

Presently, the transportation sector only accounts for GHG emissions from the combustion (end-use) of fossil fuels to move people and goods (e.g., tailpipe emissions from on-road motor vehicles, fuel combustion exhaust from ships and airplanes, etc.). However, every lifecycle stage of fossil fuel extraction, processing, and use for the transportation sector generates GHG emissions. While the BARCAP region has negligible fossil fuel extraction sources, processing of fossil fuels for the transportation sector at the BARCAP region's refineries contributes significantly to the industrial sector emissions, accounting for over 60% (~10 MMTCO2e) of that sector's total GHG emissions. In addition, on-site cogeneration of electricity for use at these refineries, categorized under the power sector, adds another 1.4 $MMTCO_2e$ or 20% to that sector's total. When combined with the transportation sector emissions, the GHG emissions related to transportation that are associated with both production (extraction and processing) and consumption (combustion) of fossil fuels account for over half of the total regional GHG emissions in 2022 (53% or 28.6 $MMTCO_2e$**).**

Table 3: Sector and subsector contributions to the BARCAP region's greenhouse gas emissions inventory for 2022.

Sector	Sub-sector	Emissions ($MMTCO_2e$)	Emissions (% in sector)	Sector	Sub-sector	Emissions ($MMTCO_2e$)	Emissions (% in sector)
Transportation	Passenger Cars	5.35	31.1%	**Industrial**	Refinery Combustion – All Fuels - Boilers, Heaters and Flares	5.78	34.5%
	Light-Duty Trucks	3.79	22.1%		Non-Refinery Combustion - Natural Gas - Boilers, Heaters and Furnaces	4.44	26.5%
	Heavy-Duty Vehicles	3.02	17.6%		Petroleum Refining	4.18	25.0%
	Medium-Duty Vehicles	2.19	12.8%		Off-Road Equipment	0.68	4.1%
	Aircraft	1.05	6.1%		High-GWP Gases	0.4	2.4%
	Ships	0.89	5.2%		Other (Non-Refinery Combustion - Natural Gas - Boilers, Heaters and Furnaces, Refinery and Non-Refinery Combustion – All Fuels - Turbines & Engines etc.)	1.25	7.5%
	Other (High-GWP Gases, Buses, etc.)	0.89	5.2%		**Total**	**16.73**	
	Total	**17.18**		**Buildings**	Residential Combustion - Natural Gas	4.17	41.8%
Power	Cogeneration	4.16	58.8%		Commercial Combustion – Natural Gas	2.33	23.4%
	Power Plants	1.81	25.6%		High-GWP Gases	2.07	20.8%
	Consumption	1.11	15.7%		Other (Fuel Distribution, Natural Gas Leakage etc.)	1.4	14.0%
	Total	**7.08**			**Total**	**9.97**	
Waste	Landfills	1.61	80.9%	**Agriculture**	Livestock	0.58	50.9%
	Domestic Wastewater Treatment	0.24	12.1%		Agricultural Soil Management	0.44	38.6%
	Other (Composting, Industrial Wastewater Treatment, etc.)	0.14	7.0%		Other (Agricultural Equipment, etc.)	0.12	10.5%
	Total	**1.99**			**Total**	**1.14**	

3.3. EMISSIONS BY COUNTY

Table 4 provides a detailed breakdown of the distribution of GHG emissions by county across the BARCAP region.

- Most of the BARCAP region's refineries (industrial sector) and power plants (power sector) are located in Contra Costa County. The demand for natural gas in this county is therefore relatively high (Table 1 in Section 1 – Inventory Scope and Organization) and the county's GHG emissions consequently account for 45% of the BARCAP region's total GHG emissions. The concentration of heavy industry and dependence on natural gas also make Contra Costa County one of the few counties in the BARCAP region where the transportation sector is not the primary source of GHG emissions at the county level.

- Similarly, Solano County's largest source of GHG emissions is the industrial sector due in part to the presence of refinery operations. Emissions from the transportation sector are less than half those from the Industrial sector.

- Alameda, Marin, Napa, San Mateo and Sonoma counties, which have less heavy industry, follow a traditional trend with most of the GHG emissions coming from the transportation (vehicle fuel-use) and buildings (space- and water-heating) sectors. The GHG emissions of these two sectors in these counties are proportionally aligned with vehicle registration counts and the county population (shown in Table 1), respectively.

- The buildings sector emissions are the largest GHG source in San Francisco County exceeding the transportation sector. This is primarily due to the prevalence of commercial real estate and office spaces in the county, which drives up natural gas combustion-related GHG emissions from space- and water- heating, while the high urban density and a robust public transportation network drive down the demand and need for private vehicles in the county.

Table 4: Sector contributions to the BARCAP regional greenhouse gas emissions inventory for each county for 2022.

County	Sector	Emissions ($MMTCO_2e$)	Emissions (% in county)	County	Sector	Emissions ($MMTCO_2e$)	Emissions (% in county)
Alameda	Agriculture	0.12	1.2%	**San Francisco**	Agriculture	0.01	0.2%
	Commercial + Residential	2.48	24.2%		Commercial + Residential	2.03	49.3%
	Electricity Generation	0.69	6.7%		Electricity Generation	0.24	5.8%
	Industrial	0.88	8.6%		Industrial	0.2	4.9%
	Transportation	5.52	53.9%		Transportation	1.61	39.1%
	Waste Management	0.54	5.3%		Waste Management	0.04	1.0%
	Total	**10.24**			**Total**	**4.12**	
Contra Costa	Agriculture	0.22	0.9%	**San Mateo**	Agriculture	0.05	1.0%
	Commercial + Residential	1.91	8.1%		Commercial + Residential	1.59	30.9%
	Electricity Generation	5.48	23.4%		Electricity Generation	0.17	3.3%
	Industrial	12.21	52.0%		Industrial	0.24	4.7%
	Transportation	3.29	14.0%		Transportation	2.73	53.0%
	Waste Management	0.36	1.5%		Waste Management	0.49	9.5%
	Total	**23.46**			**Total**	**5.15**	
Marin	Agriculture	0.17	8.1%	**Solano** (Bay Area Air District portion only)	Agriculture	0.15	2.9%
	Commercial + Residential	0.6	28.7%		Commercial + Residential	0.45	8.6%
	Electricity Generation	0.05	2.4%		Electricity Generation	0.33	6.3%
	Industrial	0.04	1.9%		Industrial	2.89	55.0%
	Transportation	1.08	51.7%		Transportation	1.26	24.0%
	Waste Management	0.14	6.7%		Waste Management	0.18	3.4%
	Total	**2.09**			**Total**	**5.25**	
Napa	Agriculture	0.15	13.4%	**Sonoma** (Bay Area Air District portion only)	Agriculture	0.27	10.5%
	Commercial + Residential	0.27	24.1%		Commercial + Residential	0.64	25.0%
	Electricity Generation	0.04	3.6%		Electricity Generation	0.08	3.1%
	Industrial	0.11	9.8%		Industrial	0.17	6.6%
	Transportation	0.49	43.8%		Transportation	1.2	46.9%
	Waste Management	0.06	5.4%		Waste Management	0.18	7.0%
	Total	**1.12**			**Total**	**2.56**	

3.4. EMISSIONS BY POLLUTANT

Figure 5 provides a breakdown of the GHG emissions by pollutant in million metric tons of CO_2 equivalents for the six economic sectors.

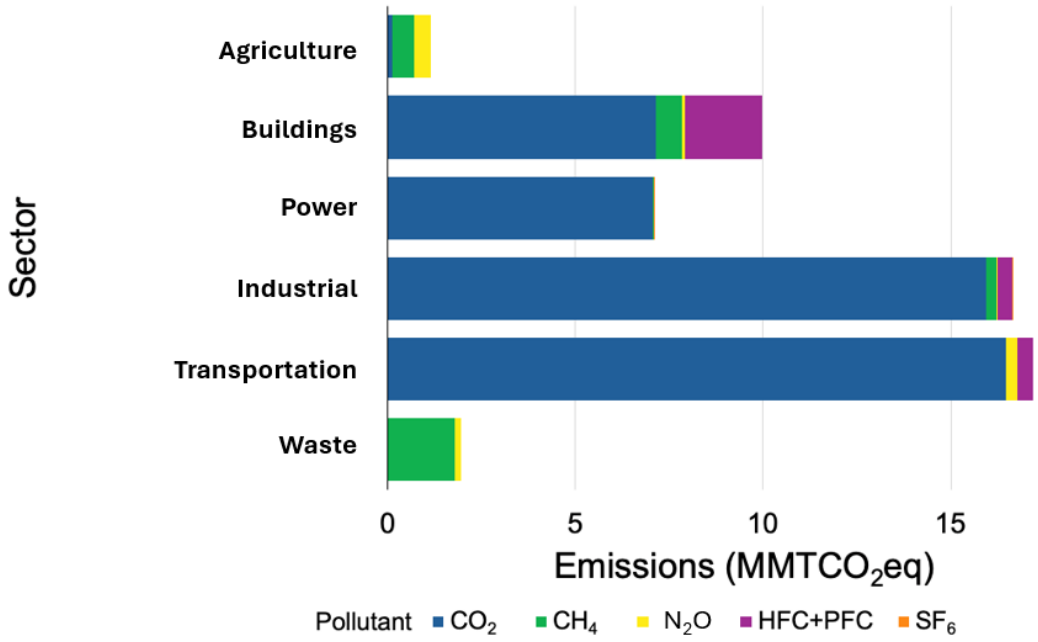


Figure 5: Pollutant contributions by sector to the BARCAP region's greenhouse gas emissions inventory for 2022.

- CO_2 is the predominant GHG pollutant representing 86% of the GHG emissions in the BARCAP region, mostly from combustion of fuels from goods movement and passenger cars in the transportation sector, space heating in the buildings sector, electricity production in the power sector, and petroleum refining in the industrial sector.

- About half of the BARCAP region's CH_4 emissions (>6% of the regional GHG inventory) are emitted from the landfill subsector in the waste sector; however, recent measurement studies have indicated that the real-world emissions may be higher than what is estimated using a bottom-up inventory approach (see Section 4 – Uncertainties and Future Improvements).

- About 45% of all N_2O emissions in the BARCAP region can be attributed to the agriculture sector, mostly due to fertilizer use.

- Nearly 6% of regional GHG emissions are attributed to leakages and fugitive losses of fluorinated high-GWP gases (including HFCs, PFCs, CFCs, HCFCs, and SF_6), a majority of

which occur in the building sector. With the adoption of SB1206 in 2022, HFCs will be phased out in California by 2033, to be replaced with lower-GWP and/or non-GHG options.[27] The regulation will not impact existing appliances that use high-GWP gases as refrigerants, solvents, or aerosols until they are replaced or re-filled (SB1206 prohibits the sale of bulk virgin HFCs while allowing the sale of reclaimed HFCs).

3.5. EMISSIONS TRENDS

Figure 6 presents the change in GHG emissions for each sector over time.

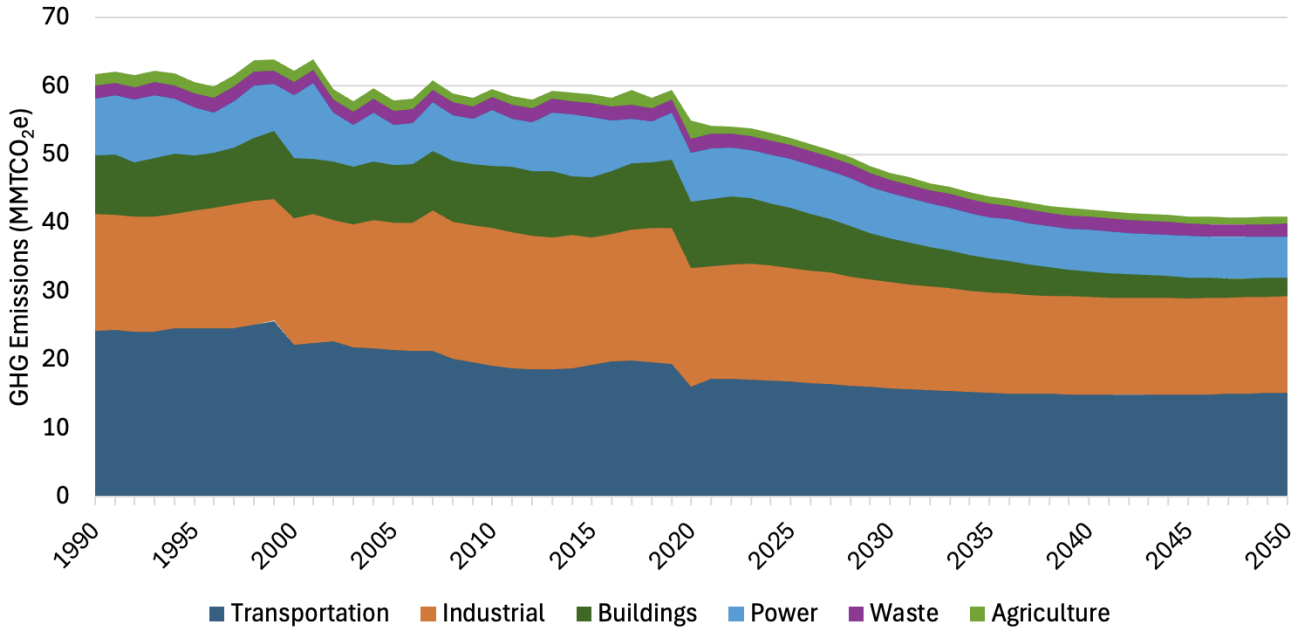


Figure 6: Changes in GHG emissions (in $MMTCO_2e$) by sector over time

Historical Trends

- The BARCAP region's total GHG emissions have dropped from 62.2 $MMTCO_2e$ in 2000 to 54.1 $MMTCO_2e$ in 2022, representing a 13% change, primarily resulting from reduction in emissions in the transportation (-23%), industrial (-9%), and power (-23%) sectors.

- The decline in GHG emissions from the power sector is largely driven by the growing proliferation of renewable energy, which has reduced SFBA's reliance on natural gas for power production. This trend is further strengthened by an increase in residents opting to purchase cleaner and renewable energy through public Community Choice Aggregators.[28]

- Over the past two decades, declining natural gas use in electricity generation has been offset by the increased demand for natural gas use for space- and water- heating in the buildings sector, driven by the BARCAP region's tech-driven economic growth and rising population.

Forecasts

- Projected annual GHG emissions by 2050 are expected to decline in the BARCAP region across major sectors including transportation (-12%), industrial (-16%), and power (-15%), relative to year 2022. This anticipated trend reflects the impact from California's aggressive reduction of fossil fuel reliance and promotion of zero-emission transportation,[29] the state's cap and trade system that disincentivizes and puts a cap on 'allowed' industrial sector GHG emissions,[30] and the continuing decarbonization of the BARCAP region's electric power generation mix as evident from California Energy Commission's retail electricity annual power content label data.[31]

- In comparison, annual GHG emissions of the buildings sector is currently expected to decline by 73% by 2050. This is primarily due to the Air District's Regulation 9 Rule 4 and Regulation 9 Rule 6,[32] which requires new water heaters and furnaces to meet a zero-NO_x emissions standard starting with water heaters in 2027. Currently, only water and space heaters operating on electricity can meet this standard, and thus there are substantial projected GHG co-benefits. Those co-benefits may not be fully realized if alternative natural gas-fired appliances which can meet the zero-NO_X emissions standard are used instead.

- It is expected that high-GWP emissions will decline significantly as state regulations like SB1206 expedite the phase out of HFCs in California by 2033, and result in eventual replacement with lower-GWP and/or non-GHG options.[33]

4. UNCERTAINTIES AND FUTURE IMPROVEMENTS

The BARCAP GHG inventory reflects methodological advancements over the previous base year 2015 inventory.[34] Nonetheless, limitations remain in the latest emissions estimation—ranging from incomplete datasets and uncertain assumptions to high variability in some source categories. Understanding these limitations is essential for accurate interpretation and proper application of emissions data. Below are several illustrative, though not exhaustive, examples of limitations and considerations:

- **Uncertainty in Estimations:** All emissions inventories involve qualitative and quantitative uncertainties. Source categories estimated using top-down scaling methods from statewide or national inventories often have higher uncertainties due to coarse spatial and temporal resolution.

- **Variability in Emission Factors**: Emission factors, particularly for fugitive and leak-related sources, can vary widely due to differences in operational practices and equipment performance. These emission factors are often derived from limited or outdated reference data and research, which may not reflect current field conditions. As a result, emission estimates based on these factors may differ significantly from source test results and may also diverge from estimates generated through other measurement-based methods.

- **Data Lag Between Base Year and Release Year**: The estimation of emissions inventory is always evolving, because there is an inherent lag between the base year chosen for inventory development and its release year, following complete quality assurance and review process. The base year is usually selected to be the year for which the most recent and complete datasets are readily available during inventory development. However, compiling the inventory involves time-consuming processes, including updating methodologies, aggregating and validating data, conducting quality assurance, and preparing supporting documentation. For example, the current inventory estimates for the transportation sector are based on CARB's EMFAC2021 model. CARB has released the updated EMFAC2025 model (May 2025), which incorporates revised vehicle activity data, updated emission factors, and the effects of newly adopted on-road mobile source regulations for the 2021–2024 period. These updates are not reflected in the current inventory yet but will be incorporated in future inventory updates.

- **Forecasting assumptions**: Emission forecasts assume business-as-usual trends that consider routine operations only and regulations currently adopted and in-force. These projections do not account for unexpected emission incidents, socioeconomic disruptions (e.g., pandemics, economic recessions), or future policy statutory or regulatory changes. This is also a notable difference from the approach taken in the previous GHG emissions inventories,[35] which anchored on a scenario that included some "likely" policies.

- **Uncertainties in CH_4 emissions inventories**: Measurement studies performed within the Bay Area and in California[36] indicate that methane emissions from waste management processes (including landfills, wastewater treatment and composting) and from refineries are likely to be

significantly underestimated in the bottom-up inventories. Methodological improvements are needed to more accurately quantify emissions from these subsectors in future inventories.

- **Classification of biogenic CO_2**: In line with CARB protocols,[37] CO_2 emissions from biogenic sources such as ethanol combustion, landfill biogas, or organic decay from composting and landfills are excluded from total anthropogenic GHG emissions. These emissions are estimated and reported as biogenic CO_2; they are considered part of the natural carbon cycle and therefore excluded from the inventory totals. However, CH_4 emissions from these sources are considered anthropogenic and are included in the inventory, as these emissions are assumed to not have occurred if the carbon from the feedstock (or source) had decomposed naturally. Similarly, wildfire CO_2 emissions are also excluded, even if their higher frequency and intensity in the state is indirectly linked to anthropogenic climate change.

- **Scope of electricity generation emissions**: The regional inventory includes direct emissions from electricity generation facilities located within the BARCAP region, regardless of where the electricity is consumed. These emissions fall under the regulatory jurisdiction of the Air District. In contrast, indirect emissions from electricity imported into the region (generated outside the BARCAP region and whether fossil- or non-fossil-based) are excluded from this inventory to maintain a production-based accounting framework aligned with the Air District's regulatory jurisdiction.

- **Scope of landfill subsector emissions**: Similar to the issue of import and export of electricity, it is currently assumed that all waste produced in the BARCAP region is processed and buried at landfills that are located within the Air District's jurisdiction. If a significant amount of the regional waste is transported to landfills outside of BARCAP region boundaries, the landfill GHG emissions total could be quite different from that calculated on a per-capita consumption basis.

- **Aircraft subsector emissions methodology**: The current inventory for the aviation subsector has a base year of 2023 (due to greater representativeness of data following the COVID pandemic) and uses Air District methodologies. However, future inventory updates will align with a standardized statewide model[38] that is under development, improving consistency with statewide planning efforts and potential aviation-related regulatory initiatives.

APPENDIX A1 – SOURCE COMPOSITION OF SECTORS

For the San Francisco Bay Area GHG emissions inventory, six major sectors have been identified based on an economic classification. These sectors include:

- Transportation,
- Industrial,
- Buildings,
- Power,
- Waste, and
- Agriculture.

The sectors are further divided into sub-sectors (see Appendix A2). The definition and source composition of the economic sectors generally align with the USEPA's classification of GHG emissions sources[39] with some exceptions and deviations to account for differences at the regional level. Definitions for each sector are provided below.

Transportation

The emissions in this sector are comprised of direct and indirect combustion, non-combustion, and process emissions, occurring from complex machines including cars, trucks, aircraft, railroads, ships, off-road equipment etc., whose primary objective is to transport people and goods from one place to another. The emission sources in this sector include, but are not limited to, the following:

- Emission from passenger cars, light duty vehicles, medium duty vehicles, and heavy-duty vehicles;
- Emissions from aircraft, marine vessels, and locomotives;
- On-road and off-road emissions sources which act as a residence / home are also included in the transportation sector (e.g., motorhomes, houseboats, RVs);
- Emissions from the use of lubricants to perform maintenance on on-road and off-road mobile equipment; and
- Emissions of high-GWP gases resulting from the use of air conditioners in vehicles and refrigerated transport.

Emission sources not included in this sector are:

- On-road and off-road emissions sources with wheels and/or ability to move if the primary objective is to provide a service, e.g., lawn mowing and garden equipment (included in buildings sector) or tractors (included in agriculture sector);
- Emissions from transportation of natural gas via pipelines and water through water distribution network (this is considered a service to the general population for commercial, residential, and industrial purposes, and both combustion and non-combustion emissions are excluded from this sector),

- Emissions from off-road equipment that pertains to agricultural activities, and from construction, mining, and industrial activities (included in agriculture and industrial sectors, respectively); and
- Fugitive emissions from all kinds of fueling activities of primary sources included in the transportation sector as well as combustion emissions from support equipment for the fueling (and other support) infrastructure. These emissions are accounted for under the buildings sector (e.g., gasoline dispensing facilities, aircraft ground support equipment, etc.).

Industrial

This sector consists of emissions related to the production of goods and raw materials. This sector includes:

- Direct GHG process emissions that originate at the facility, primarily from combustion processes;
- Emissions resulting from chemical reactions in metal, cement, and mineral production; and
- Leaks from industrial processes, equipment, natural gas, and petroleum systems, including that of high-GWP gases.

Exceptions not included in this sector are:

- Indirect emissions that occur off-site but are associated with the facility's use of electricity (these are included in the power sector); and
- Emissions from food processing of agricultural products, for example, ethanol emissions from wineries and emissions from food processing industries, etc. (included in the agriculture sector).

Buildings

This sector includes the following direct emissions from homes, commercial businesses, office spaces, places of business, worship, and congregation, entertainment venues, etc. (excluding those classified as agricultural and industrial activities):

- Direct emissions resulting from fossil fuel combustion for heating, cooling, and cooking needs, for transport and management of waste and wastewater, and leaks of refrigerants from equipment;
- Direct emissions from all maintenance and service equipment, e.g., lawn mowing equipment, leaf blowers, floor cleaning and polishing, etc.; and
- Direct emissions from use of personal products and consumer goods within commercial and residential facilities.

Emissions sources that are not reported in this sector include:

- Indirect emissions produced by burning fossil fuel at a power plant to generate electricity (that occurs offsite) which is meant for consumption in residential and commercial facilities, such as lighting and for appliances (these emissions are included in the power sector);
- Landfill waste emissions (like CH_4) that are generated from organic waste that originated at commercial and residential facilities (these emissions are included in the waste sector);
- On-site wastewater treatment plant emissions of CH_4 and N_2O, or emissions from sewer network (these emissions are included in the waste sector);
- Energy required to produce and transport clean water consumed at commercial and residential facilities (these emissions are included in the power sector);
- Anaerobic digestion and composting emissions of CH_4 at biogas facilities that supply energy/product to commercial and residential buildings and venues (these emissions are included in the waste sector);
- Emissions/sinks from production of construction materials, for example, upstream emissions from production of cement, emissions and sinks from land use changes, etc. (these emissions are included in the industrial sector); and
- Direct emissions from onsite energy combustion and electricity production for energy-intensive warehouses and factories are typically included in the industrial sector.

Power

This sector includes emissions from activities and processes involved in the generation, transmission, and distribution of electricity within the BARCAP region. These emissions are direct and involve combustion of fossil fuels, such as coal, oil, and natural gas, etc., in a centralized power generation plant to produce electricity, or fugitive/leak-related emissions. This definition is independent of whether the produced electricity is consumed within the BARCAP region or imported. Other sources include:

- Emissions from cogeneration facilities producing both heat and power are included in this sector, even if this heat and power is being consumed within the industrial sector;
- Emissions of sulfur hexafluoride (SF_6), which is an insulation chemical used in electricity transmission and distribution equipment; and
- Onsite emissions from non-fossil fuel source generation facilities, including nuclear, and renewable energy sources like hydroelectricity, biomass, and wind.

A source that is not included in this sector is:

- Indirect emissions from the production of electricity imported from outside of the BARCAP region and used in the region. These emissions are not accounted for in the BARCAP GHG inventory.

Waste

This sector includes direct and fugitive emissions from centralized waste management activities that focus on solid waste, wastewater, industrial, and non-hazardous waste. These activities usually occur at municipal solid waste (MSW) landfills, industrial waste landfills, industrial wastewater treatment, publicly owned wastewater treatment plants (POTWs), composting operations, anaerobic digesters, biogas facilities, and can also include processes like manure spreading / application, waste incineration, etc. Other direct emissions included are as follows:

- Direct emissions from combustion activities occurring at waste management facilities to provide heat and power;
- Fugitive emissions from the urban collection network of sewers, waste pipes, manholes, etc.; and
- Emissions from standalone septic systems.

Sources not included in this sector are:

- Waste management emissions occurring outside of the BARCAP region from management of waste originating within the region;
- Direct emissions from on-site waste treatment at commercial and residential facilities (included in the buildings sector);
- Direct emissions from manure management at animal and dairy farms (included in the agriculture sector); and
- CO_2 emissions from the combustion of biomass, which is considered biogenic.

Agriculture

This sector includes direct emissions from all agricultural and farming activities related to crop and livestock production including land and soil management activities, such as application of synthetic and organic fertilizers, the growth of nitrogen-fixing crops, the drainage of organic soils, livestock enteric fermentation, manure management and storage, soil liming, burning of crop residues, and rice cultivation. All on-site combustion-related activities supplying energy to agricultural equipment (like diesel generators and pumps) and for farm-related activities are included. All emissions sources with wheels and/or ability to move are included if the primary objective is to provide a service to the agricultural industry (e.g., airplane fertilizer application, mechanical cotton picker, etc.). Also included in this sector are wildfires over natural lands and forests.

Organization of sources of high GWP fluorinated gases

The group of emission sources termed fluorinated gases or high-GWP compounds are emitted almost entirely from human-related activities. Their primary sources include:

1. Use of substitutes for ozone-depleting substances (referred to as ODSS compounds) - Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are ODSS that are considered

replacements for chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) because they do not deplete the stratospheric ozone layer. ODSS are high-GWP gases and contribute to the greenhouse gas effect (CFCs and HCFCs are also high-GWP gases). Example applications include refrigerants, aerosol propellants, foam blowing agents, solvents, and fire retardants.

2. Industrial processes such as aluminum and semiconductor manufacturing - PFCs are produced as a byproduct of aluminum production and are used in the manufacturing of semiconductors. Sulfur hexafluoride (SF_6) is used in magnesium processing and semiconductor manufacturing. Nitrogen trifluoride (NF_3) is used in semiconductor manufacturing. HFC-23 is produced as a byproduct of HCFC-22 production and is used in semiconductor manufacturing.
3. Transmission and distribution of electricity - SF_6 is used as an insulating gas in electrical transmission equipment, including circuit breakers.

The GHG emissions from this group of sources and source categories are not considered as a separate sector, as has been done in the past in the Bay Area region's inventory and in the current statewide California GHG inventory. This is because the prevailing logic for sector-level classification of GHG emissions sources is an economic activity driven classification, rather than a chemical family / pollutant-type based classification. Thus, all source categories associated with this group of emissions are assigned to different sectors based on the following logic:

- ODSS are assigned (under high-GWP gas subsectors) to the buildings, transportation, and industrial sectors based on category hierarchy and end-use information.
- Emissions of PFCs, NF_3, SF_6 and any other F-gas that is used for product manufacturing or metal production are assigned to the industrial sector.

Emissions from SF_6 from electrical transmission equipment are assigned to the power sector.

APPENDIX A2 - INVENTORY SOURCE CATEGORIZATION

Level 1 – Sector	Level 2 – General Process	Level 3 – Subsector
Transportation	Fuel Combustion	Aircraft
Transportation	Fuel Combustion	Buses
Transportation	Fuel Combustion	Heavy-Duty Vehicles
Transportation	Fuel Combustion	Light-Duty Trucks
Transportation	Fuel Combustion	Locomotives
Transportation	Fuel Combustion	Medium-Duty Vehicles
Transportation	Fuel Combustion	Motorhomes
Transportation	Fuel Combustion	Motorcycles
Transportation	Fuel Combustion	Passenger Cars
Transportation	Fuel Combustion	Ships
Transportation	Fuel Combustion	Transportation Refrigeration Units
Transportation	Fugitive & Evaporative	Refrigeration, Air Conditioning, Aerosols
Transportation	Other Combustion	Vehicle Fires
Buildings	Fuel Combustion	Airport Ground Support Equipment
Buildings	Fuel Combustion	Commercial Combustion – Natural Gas
Buildings	Fuel Combustion	Lawn and Garden Equipment
Buildings	Fuel Combustion	Light Commercial Equipment
Buildings	Fuel Combustion	Off-Road Recreational Vehicles
Buildings	Fuel Combustion	Residential Combustion – Liquid Fuel
Buildings	Fuel Combustion	Residential Combustion – Natural Gas
Buildings	Fuel Combustion	Residential Combustion – Wood Burning
Buildings	Fugitive & Evaporative	Fuels Distribution
Buildings	Fugitive & Evaporative	Natural Gas Leakage
Buildings	Fugitive & Evaporative	Refrigeration, Air Conditioning, Aerosols, Foam, Fire Protection
Buildings	Process	Commercial Cooking
Industrial	Fuel Combustion	Non-Refinery Combustion – Natural Gas – Boilers, Heaters & Furnaces

Industrial	Fuel Combustion	Non-Refinery Combustion – Non-Natural Gas – Boilers, Heaters & Furnaces
Industrial	Fuel Combustion	Off-Road Equipment
Industrial	Fuel Combustion	Refinery & Non-Refinery Combustion – All Fuels – Turbines & Engines
Industrial	Fuel Combustion	Refinery Combustion – All Fuels – Boilers, Heaters & Flares
Industrial	Fugitive & Evaporative	Metal Recycling & Shredding Operation
Industrial	Fugitive & Evaporative	Natural Gas Leakage
Industrial	Fugitive & Evaporative	Refrigeration, Air Conditioning, Aerosols, Foam, Fire Protection
Industrial	Fugitive & Evaporative	Semiconductor Manufacture
Industrial	Other Combustion	Structural Fires
Industrial	Process	Manufacturing
Industrial	Process	Petroleum Refining
Power	Fuel Combustion	Cogeneration
Power	Fuel Combustion	Power Plants
Power	Fugitive & Evaporative	Transmission & Distribution
Waste	Fuel Combustion	Landfills
Waste	Other Combustion	Incineration
Waste	Process	Ancillary Processes
Waste	Process	Biosolids Land Application
Waste	Process	Composting
Waste	Process	Domestic Wastewater Treatment
Waste	Process	Industrial Wastewater Treatment
Waste	Process	Landfills
Agriculture	Fuel Combustion	Agricultural Equipment
Agriculture	Other Combustion	Agricultural Burns
Agriculture	Other Combustion	Wildfires
Agriculture	Process	Food Processing
Agriculture	Process	Liming
Agriculture	Process	Livestock
Agriculture	Process	Managed Soils

APPENDIX A3 - REFERENCE DATASETS

Listed below is a list of some major data models, repositories, forecasts, and inventories that have been used to derive and generate emissions estimates for the BARCAP GHG inventory. This list is not exhaustive and represents the most commonly referenced and utilized datasets.

- Association of Bay Area Governments – Plan Bay Area (ABAG, 2021; for regional population, employment and other socio-economic data)
- California Air Resources Board (CARB) GHG Emissions Inventory (CARB, 2024; for statewide GHG emissions data from equivalent emission source categories)
- CARB California Emissions Projection Analysis Model database (CEPAM, 2024; for emissions data on criteria air pollutants from Air District emission source categories)
- CARB 2022 Scoping Plan (CARB, 2022; for forecast and growth profiles)
- CARB EMFAC Web Platform (EMFAC, 2021; for data on On-Road Mobile Sources)
- CARB OFFROAD Database (OFFROAD, 2021; for data on Off-Road Mobile Sources including Rail Transport and Marine Vessels)
- California Department of Finance (CADF, 2024; for data on population and employment statistics)
- California Energy Commission (CEC, 2023b; for residential and non-residential fuel and energy consumption data)
- California Solid Waste Information System (CALSWIS, 2024; for activity data on Waste Management sector)
- Intergovernmental Panel for Climate Change (IPCC, 2014; for Global Warming Potentials)
- United States Department of Agriculture National Agricultural Statistics Service (USDA, 2024; for activity data on Agriculture sector)
- United States Environment Protection Agency– AP-42: Compilation of Air Emissions Factors (USEPA, 2024)

[1] The California Air Resources Board (CARB) maintains the responsibility to prepare, adopt, and update the statewide GHG emissions inventory which starts from year 2000 (https://ww2.arb.ca.gov/sites/default/files/classic/cc/inventory/ghg_inventory_tsd_00-14.pdf). In 2006, Assembly Bill 32 required that the CARB determine the statewide GHG emissions level in 1990 and approve a statewide GHG emissions limit for year 2020. CARB does not publish a GHG emissions inventory for the years 1990 to 1999. Although, the Air District's GHG emissions inventory extends from year 1990 to 2050, the inventory estimates for years 1990 to 1999 are generally those that have been extrapolated from year 2000 emissions data and have a higher degree of uncertainty. Thus, any discussion on and analysis of inventory trends in this report focuses on emissions data from year 2000 onwards, which also ensures consistency with the statewide GHG emissions inventory. (https://ww2.arb.ca.gov/sites/default/files/classic/cc/inventory/2000-2020_ghg_inventory_trends.pdf)

[2] "Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change" *Intergovernmental Panel for Climate Change,* Geneva, Switzerland, 151 pp. Available here: https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf

[3] The Montreal Protocol on Substances that deplete the Ozone layer, Office of Environmental Quality, United States Department of State. https://www.state.gov/the-montreal-protocol-on-substances-that-deplete-the-ozone-layer

[4] The sector naming convention for the BARCAP GHG inventory differ slightly from those used in the Air District's regional GHG inventory that covers the Air Districts full 9-county jurisdiction, although emission sources remain the same under the

corresponding sector names. The BARCAP inventory sector names buildings, power, and waste correspond with the sector names commercial + residential, electricity generation, and waste management in the Air District's regional GHG inventory, respectively. All other sector names are the same in both inventories. The slight difference in naming convention is due to the two inventories serving different purposes, with the BARCAP inventory aligning with the sector focus areas for BARCAP measures.

[5] "California's 2000-2022 GHG Inventory Data," *California Air Resources Board*, 2024. https://ww2.arb.ca.gov/applications/california-ghg-inventory-documentation

[6] "California's 2000-2022 GHG Inventory Data," *California Air Resources Board*.

[7] "Inventory of U.S. Greenhouse Gas Emissions and Sinks," *United States Environmental Protection Agency*, 2025. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

[8] Available at https://www.baaqmd.gov/en/about-air-quality/emission-inventory/climate-forcing-pollutants

[9] "Inventory of U.S. Greenhouse Gas Emissions and Sinks," *United States Environmental Protection Agency*.

[10] "California's 2000-2022 GHG Inventory Data," *California Air Resources Board*: "Inventory of U.S. Greenhouse Gas Emissions and Sinks," *United States Environmental Protection Agency*.

[11] Regulation 9 Rule 4: Nitrogen Oxides from Natural Gas-Fired Furnaces, *Bay Area Air Quality Management District*. https://www.baaqmd.gov/rules-and-compliance/rules/reg-9-rule-4-nitrogen-oxides-from-fan-type-residential-central-furnaces; Regulation 9 Rule 6: Nitrogen Oxides Emissions from Natural Gas-Fired Water Heaters, *Bay Area Air Quality Management District*. https://www.baaqmd.gov/rules-and-compliance/rules/reg-9-rule-6-nitrogen-oxides-emissions-from-natural-gasfired-water-heaters

[12] "Greenhouse Gas Emission Estimates and Draft Forecasts", *Bay Area Air Quality Management District, 2017*. Available: https://www.baaqmd.gov/~/media/files/planning-and-research/plans/2017-clean-air-plan/ghg_emissions_and_forecasts_draft.pdf

[13] "Inventory of U.S. Greenhouse Gas Emissions and Sinks," *United States Environmental Protection Agency*

[14] "California's 2000-2022 GHG Inventory Data," *California Air Resources Board*.

[15] "About Montreal Protocol," *United Nations Environment Programme,* 2025. https://www.unep.org/ozonaction/who-we-are/about-montreal-protocol

[16] "Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change" *Intergovernmental Panel for Climate Change*.

[17] "California's 2000-2022 GHG Inventory Data," *California Air Resources Board*.

[18] California Emissions Projection Analysis Model 2024, CEPAM2019v1.04, *California Air Resources Board*, 2024. https://ww2.arb.ca.gov/applications/cepam2019v1-04-standard-emission-tool. Accessed 2024.

[19] "CARB 2022 Scoping Plan for Achieving Carbon Neutrality," *California Air Resources Board*, December 2022, https://ww2.arb.ca.gov/sites/default/files/2023-04/2022-sp.pdf.

[20] The sector naming convention for the BARCAP GHG inventory differ slightly from those used in the Air District's regional GHG inventory that covers the Air Districts full 9-county jurisdiction, although emission sources remain the same under the corresponding sector names. The BARCAP inventory sector names buildings, power, and waste correspond with the sector names commercial + residential, electricity generation, and waste management in the Air District's regional GHG inventory, respectively. All other sector names are the same in both inventories. The slight difference in naming convention is due to the two inventories serving different purposes, with the BARCAP inventory aligning with the sector focus areas for BARCAP measures.

[21] Annual Power Content Labels, *California Energy Commission*, 2023. https://www.energy.ca.gov/programs-and-topics/programs/power-source-disclosure-program/power-content-label

[22] "Compilation of Air Emissions Factors from Stationary Sources", *United States Environment Protection Agency, 2024*. https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors-stationary-sources

[23] "Regulation for the Mandatory Reporting of Greenhouse Gas Emissions", *California Air Resources Board,* 2019. https://ww2.arb.ca.gov/sites/default/files/classic/cc/reporting/ghg-rep/regulation/mrr-2018-unofficial-2019-4-3.pdf

[24] "Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change" *Intergovernmental Panel for Climate Change*.

[25] Quality Assurance Project Plan for The Bay Area Climate Action Planning Initiative, Grant No..: 98T73201; *submitted on*: 12-27-2023; *approved on*: 01-04-2024; available on request.

[26] "Greenhouse Gas Emission Estimates and Draft Forecasts", *Bay Area Air Quality Management District*.

[27] Senate Bill No. 1206, Skinner, 2022. Hydrofluorocarbon gases: sale or distribution. https://ww2.arb.ca.gov/our-work/programs/sb-1206/about

[28] Community Choice Aggregation in California, 2025. https://cal-cca.org/powered/

[29] "CARB 2022 Scoping Plan for Achieving Carbon Neutrality," *California Air Resources Board.*

[30] "Cap and Trade Program," *California Air Resources Board,* 2018. https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program/about

[31] Annual Power Content Labels, *California Energy Commission.*

[32] Regulation 9 Rule 4: Nitrogen Oxides from Natural Gas-Fired Furnaces, *Bay Area Air Quality Management District*. https://www.baaqmd.gov/rules-and-compliance/rules/reg-9-rule-4-nitrogen-oxides-from-fan-type-residential-central-furnaces;

Regulation 9 Rule 6: Nitrogen Oxides Emissions from Natural Gas-Fired Water Heaters, *Bay Area Air Quality Management District*. https://www.baaqmd.gov/rules-and-compliance/rules/reg-9-rule-6-nitrogen-oxides-emissions-from-natural-gasfired-water-heaters

[33] Senate Bill No. 1206, Skinner, 2022.

[34] "Greenhouse Gas Emission Estimates and Draft Forecasts", *Bay Area Air Quality Management District*.

[35] "Greenhouse Gas Emission Estimates and Draft Forecasts", *Bay Area Air Quality Management District*.

[36] Jeong et al., 2016. "Estimating methane emissions in California's urban and rural regions using multitower observations." Journal of Geophysical Research Atmospheres. https://doi.org/10.1002/2016JD025404; Duren et al. 2019. "California's methane super-emitters." Nature. https://www.nature.com/articles/s41586-019-1720-3; Guha et al. 2020. "Assessment of Regional Methane Emission Inventories through Airborne Quantification in the San Francisco Bay Area." Environmental Science & Technology. https://pubs.acs.org/doi/abs/10.1021/acs.est.0c01212

[37] California's 2000-2014 GHG Inventory - Technical Support Document, *California Air Resources Board*, 2016. https://ww2.arb.ca.gov/sites/default/files/classic/cc/inventory/ghg_inventory_tsd_00-14.pdf

[38] California Aircraft Emissions Inventory Draft Technical Documentation for Public Comment, *California Air Resources Board,* 2024. https://ww2.arb.ca.gov/sites/default/files/2024-10/CAI2024%20-%20Main%20Document_Final1021_ada.pdf

[39] Sources of Greenhouse Gas Emissions, https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions