Palo Alto 2022 Citywide Greenhouse Gas Emissions Inventory

1.a. Overview of Methodology for Quantifying Greenhouse Gas Emissions

Cities represent the single greatest opportunity for tackling climate change, as they are responsible for 70 percent of global energy-related carbon dioxide emissions, with transportation and buildings among the largest contributors.[1] The first step for cities to realize their potential is to identify and measure the sources of their emissions. Best practices for identifying these sources and quantifying emissions are to utilize a standardized GHG inventory.

There are two types of Greenhouse Gas (GHG) emissions inventories:

1. **Generation-based GHG inventory** – This measurement method helps a community understand its level of emissions based on community energy use. It includes 1) direct consumption of energy, 2) consumption of energy via the electrical grid, and 3) emissions from the treatment/decomposition of waste. This is the industry-accepted methodology for quantifying community GHG emissions, with emissions reported by emission source category.[2]
2. **Consumption-based GHG inventory** – This measurement method helps a community understand its level of emissions based on consumption. It offers an alternative, more holistic, approach for quantifying emissions within a community, quantifying consumption of goods and services (including food, clothing, electronic equipment, etc.) by residents of a city, with emissions reported by consumption category.

In 2014, World Resources Institute, C40 Cities Climate Leadership Group (C40) and ICLEI – Local Governments for Sustainability (ICLEI)[3] partnered to create a global standard protocol for generation-based GHG inventories. The Global Protocol for Community-Scale GHG Emissions Inventories (GPC) provides a robust framework for accounting and reporting city-wide GHG emissions for a generation-based inventory. The GPC Protocol is the official protocol specified by the Global Covenant of Mayors and defines what emissions must be reported and how. In addition, this inventory draws on methods from the U.S. Community Protocol,[4] which provides more detailed methodology specific to the U.S. It seeks to:

- Help cities develop a comprehensive GHG inventory to support climate action planning
- Help cities establish a base year emissions inventory, set reduction targets, and track their performance
- Ensure consistent and transparent measurement and reporting of GHG emissions between cities, following internationally recognized GHG accounting and reporting principles

[1] See UN Environment Programme, "Cities and Climate Change," https://www.unep.org/explore-topics/resource-efficiency/what-we-do/cities/cities-and-climate-change
[2] There are two reporting frameworks commonly used by cities: the U.S. Community Protocol and the Global Protocol for Communities (GPC). Palo Alto uses the GPC framework.
[3] Formerly the International Council for Local Environmental Initiatives, renamed in 2003 to ICLEI – Local Governments for Sustainability.
[4] U.S. Community Protocol; https://icleiusa.org/us-community-protocol/

- Enable city inventories to be aggregated at subnational and national levels
- Demonstrate the important role that cities play in tackling climate change, and facilitate insight through benchmarking – and aggregation – of comparable data

Palo Alto's first generation-based citywide inventory was completed for 2005 and then extrapolated for 1990 (the baseline year). Beginning in 2010, new citywide GHG inventories were completed annually, enabling Palo Alto to track progress over time.

The 2022 Palo Alto Citywide GHG inventory, completed by Rincon Consultants, follows the calculation and reporting standards outlined in the GPC BASIC reporting level.[5] Inventory calculations were performed using Rincon's GHG Inventory tool and uploaded into ClearPath,[6] a software platform designed for creating generation-based GHG inventories.

GHG emissions from community activities are classified into three main sectors:

- **Stationary Energy** (e.g., building electricity consumption, fugitive natural gas emissions)
- **Transportation** (e.g., on-road passenger vehicles, off-road equipment)
- **Waste** (e.g., solid waste disposal, wastewater treatment and discharge)

Activities taking place within a city can generate GHG emissions that occur inside the city boundary as well as outside the city boundary. To distinguish among them, the GPC groups emissions into three categories based on where they occur:

- **Scope 1:** GHG emissions from sources located within the city boundary, such as stationary fuel consumption.
- **Scope 2:** GHG emissions occurring due to the use of grid-supplied electricity, heat, steam, and/or cooling within the city boundary.
- **Scope 3:** All other GHG emissions that occur outside the city boundary as a result of activities taking place within the city boundary.

This inventory follows the city-inducted framework in the GPC protocol, which totals GHG emissions attributable to activities taking place within the geographic boundary of the city.[7] Under the Basic reporting level as defined by the GPC protocol, the inventory requirements cover scope 1 and scope 2 emissions from stationary energy and transportation, as well as all emissions resulting from waste generating within the city boundary. While the 2022 Inventory follows GPC BASIC reporting standards and aligns with previous GHG emissions inventories, minor updates to calculation methodologies were included in the 2022 Inventory and are discussed in detail below.

Staff did not complete a consumption-based GHG inventory. The California Air Resources Board (CARB) has been tasked with developing an implementation framework and accounting to track

---

[5] GPC Executive Summary; https://ghgprotocol.org/sites/default/files/2022-12/GPC_Executive_Summary_1.pdf
[6] ClearPath tool; https://icleiusa.org/clearpath/
[7] GPC Protocol; https://ghgprotocol.org/sites/default/files/standards/GHGP_GPC_0.pdf

consumption-based emissions over time.[8] In particular, this framework needs to address how to account for the embodied emissions in the food, goods, and services the community purchases not covered by generation-based GHG inventories.

1.b. Palo Alto's 2022 GHG Emissions

In 2022, Palo Alto emitted an estimated 410,157 metric tons (MT) of carbon dioxide equivalent (CO_2e) from the residential, commercial, industrial, transportation, waste, water, and municipal sectors.[9] In comparison to the 1990 base year emissions (which were about 780,000 metric tons), that is a 47.4 percent decrease in total community emissions, despite a population increase of 21.3 percent during that same time period. This equates to 6.1 metric tons of carbon dioxide equivalent (MT CO2e) per Palo Alto resident in 2022 compared to 14 MT CO2e per Palo Alto resident in 1990. The California Air Resources Board's 2017 Scoping Plan Update recommends a goal for local governments of 6 MT C02e per capita by 2030.

Of the 47.4 percent reduction to-date, 50.3 percent came from achieving carbon neutrality for the City's electricity portfolio, 21.8 percent from declines in transportation emissions, 13.2 percent from reduction in natural gas (methane[10]) consumption, 13 percent from declines in solid waste emissions, and 1.6 percent from declines in wastewater-related emissions. In comparison to 2021, that is a 14.2 percent increase in total community emissions.

For citywide emissions sources in 2022, 54.1 percent are from on-road transportation, 35.4 percent are from natural gas (methane) use, and the remainder are from other sources. A comparison of 1990, 2019, 2020, 2021, and 2022 Citywide GHG emissions is shown in Figure 1 and Table 1. The full comparison between the inventories can be found in Attachment B 1990 vs. 2022 Greenhouse Gas Emissions by Sector and Subsector. Additional existing emissions sources that were missing from the 1990 GHG inventory were included in the 2022 GHG inventory to comply with the GPC Basic protocol (Airport Emissions, Off-road Vehicles, Caltrain Commuter Rail, Composting, and Palo Alto Landfill Gas Flaring).

---

[8] Executive Department State of California. (2019). Executive Order B-55-18 to Achieve Carbon Neutrality. https://www.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf.

[9] Carbon dioxide equivalent is a unit of measure that normalizes the varying climate warming potencies of all six GHG emissions, which are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). For example, one metric ton of nitrous oxide is 210 metric tons of CO_2e.

[10] Methane, which is the primary component of natural gas, is a very potent greenhouse gas, with a global warming potential that is 25 times higher than CO2 over a 100-year period.

Figure 1: 1990 vs 2022 Citywide GHG Emissions by Sector

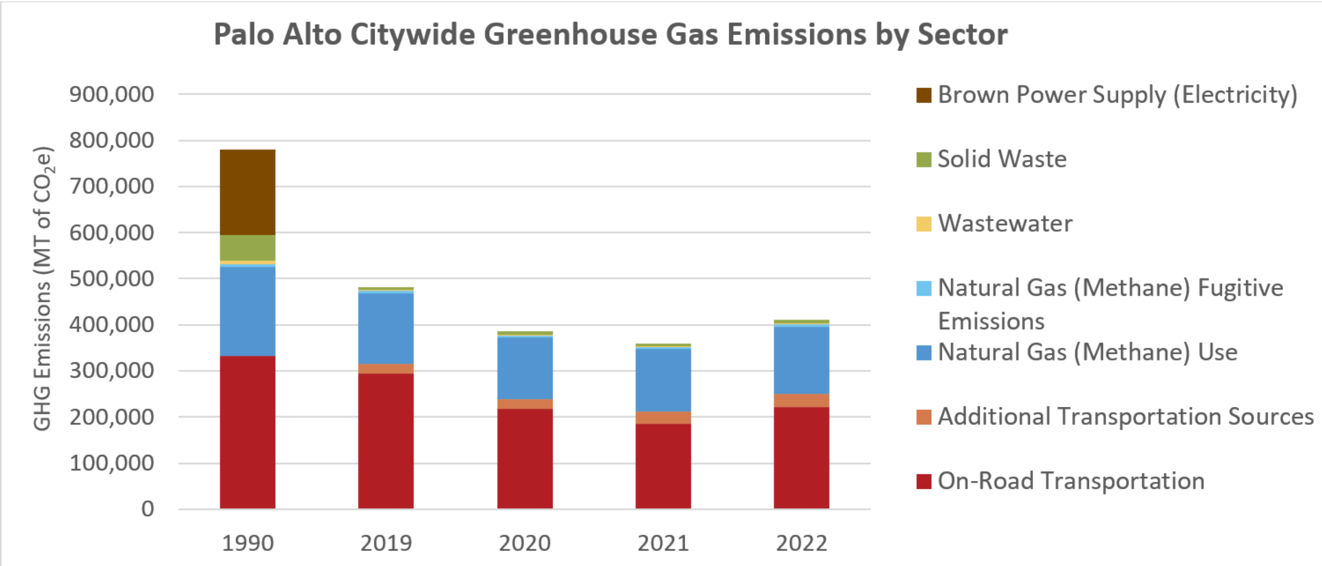
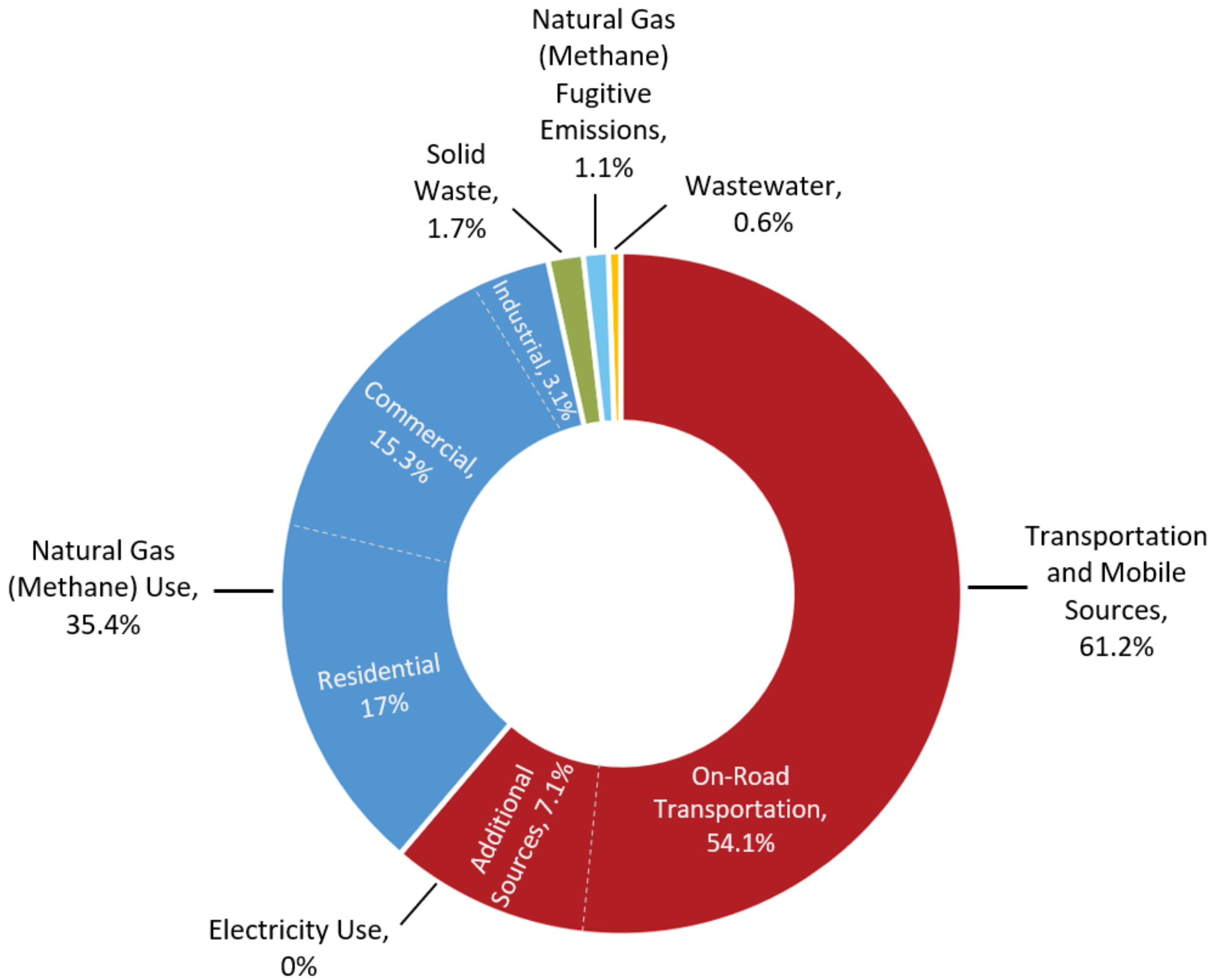


Table 1: 1990 vs 2022 Citywide GHG Emissions by Sector						
Sector	**1990 GHG emissions (MT CO_2e)**	**2019 GHG emissions (MT CO_2e)**	**2020 GHG emissions (MT CO_2e)**	**2021 GHG emissions (MT CO_2e)**	**2022 GHG emissions (MT CO_2e)**	**Percent Change in 2022 from 1990**
On-Road Transportation	331,840	293,413	217,279	185,925	221,923	-33.1%
Additional Transportation Sources		21,668	21,244	25,478	29,140	n/a
Natural Gas (Methane) Use	194,000	153,509	134,365	135,697	144,996	-25.3%
Natural Gas (Methane) Fugitive Emissions	4,718	5,009	4,384	4,427	4,709	-0.2%
Wastewater-Related Emissions	8,504	2,197	1,388	1,262	2,532	-70.2%
Solid Waste	55,057	6,531	6,660	6,522	6,857	-87.5%
Brown Power Supply (Electricity)	186,000					- 100%
Total GHG Emissions (MT CO_2e)	**780,119**	**482,237**	**385,320**	**359,312**	**410,157**	**-47.4%**

As shown in Figure 2, the two largest categories of emissions are transportation and mobile sources (including on-road transportation, airport emissions, off-road vehicles, and Caltrain commuter rail) and natural gas (methane) use (including residential, commercial, and industrial).

Figure 2: 2022 Citywide GHG Emissions by Sector



Transportation and mobile sources include emissions from private, commercial, and fleet vehicles driven within the City's geographical boundaries, as well as the emissions from public transit vehicles and the City-owned fleet. Off-road vehicles include airport ground support, construction and mining, industrial, light commercial, portable equipment, and transportation refrigeration units.

Natural gas (methane) use includes emissions that result from natural gas (methane) consumption in both private and public sector buildings and facilities, and residential, commercial, and industrial sources. Fugitive emissions related to natural gas (methane) consumption are calculated separately and are discussed in Section 1.d. The City's electricity supply has been carbon neutral since 2013, when the City Council approved a Carbon Neutral Electric Resource Plan, committing Palo Alto to pursuing only carbon-neutral electric resources and effectively eliminating all GHG emissions from the City's electric portfolio.

1.c. Transportation and Mobile Sources

In 2022, transportation and mobile sources accounted for 61.2 percent of total citywide GHG emissions in Palo Alto. Although GHG emissions from this sector are 24.3 percent lower than 1990 levels, emissions increased 19 percent between 2021 and 2022. As shown in Table 2, transportation and mobile sources consist of:

- On-Road Transportation – This includes all daily vehicular trips made entirely within the Palo Alto city limits (in-boundary trips), one-half of daily vehicular trips with an origin within Palo Alto city limits and a destination outside of Palo Alto city limits (outbound trips; this assumes that Palo Alto shares half the responsibility for trips traveling from other jurisdictions), and one-half of daily vehicular trips with an origin outside Palo Alto city limits and a destination within Palo Alto city limits (inbound trips; this assumes that Palo Alto shares the responsibility of trips traveling to other jurisdictions). Vehicular trips through Palo Alto are not included because Palo Alto cannot solely implement policies that influence the trip-making behavior. Rather, through trips are assigned to other jurisdictions that can influence either the origin or destination side of the trip-making behavior.
- Airport Emissions – This includes emissions from take-offs and landings from trips that start and end at Palo Alto Airport. This includes emergency services helicopters, sightseeing helicopters, and training flights. Flights that take-off from Palo Alto Airport but land elsewhere, and flights that land in Palo Alto Airport but take-off from elsewhere are not included per GPC Basic Protocol.
- Off-road Vehicles - This includes airport ground support (based on take-offs and landings), construction and mining, industrial (based on employment data), light commercial (based on employment data), portable equipment, and transportation refrigeration units (based on service population). Additionally, two new off-road categories were added to the 2022 Inventory - lawn and garden equipment, and recreational vehicles (based on service population and population, respectively).
- Caltrain Commuter Rail – This includes emissions from Caltrain travel within Palo Alto.

Table 2: 2022 Transportation and Mobile Sources

Subsector	2019 GHG emissions (MT CO_2e)	2020 GHG emissions (MT CO_2e)	2021 GHG emissions (MT CO_2e)	2022 GHG emissions (MT CO_2e)	Percent of Total 2022 Emissions (%)
On-Road Transportation	293,413	217,279	185,925	221,923	54.1%
Airport Emissions	2,192	1,664	2,641	1,837	0.4%
Off-road Vehicles	14,634	15,029	18,961	20,191	4.9%
Caltrain Commuter Rail	4,842	4,552	3,876	7,112	1.7%
Total Transportation & Mobile Sources	**315,081**	**238,523**	**211,403**	**251,063**	**61.2%**

The main driver of GHG emissions from transportation and mobile sources is fuel combustion from internal combustion engine (ICE) vehicles, specifically passenger vehicles, commercial vehicles, and buses (69 percent, 17 percent, and two percent of all transportation GHG emissions, respectively). Since electricity in the City is carbon-neutral, there are no GHG emissions attributed to passenger, commercial, or bus EVs.

The 2022 inventory utilized vehicles miles traveled (VMT) data from Google's Environmental Insights Explorer (EIE) and VMT-weighted emission factors from the California Air Resources (CARB) Emission FACtor (EMFAC) model[11] to estimate GHG emissions from all passenger, commercial, and bus ICE vehicles. Forty-six percent of VMT was from inbound trips, 45% from outbound trips, and 9% from in-boundary trips.

To determine the EV share of passenger VMT, data from CEC's Zero Emissions Vehicle (ZEV) Statistics database was pulled for the City's zip codes. Passenger VMT data was then multiplied by the EV share percentage to determine electric VMT (EVMT) of passenger vehicles allocated to the City. All EVMT was then multiplied by a passenger vehicle energy factor, or electricity (kWh) per mile (EPM), generated from CARB's EMFAC model to determine the total electricity consumption of passenger EVs.

For commercial and bus VMT, Santa Clara County and San Mateo County boundaries were set in CEC's ZEV Statistics database to determine the average EV share percentage of these vehicle categories.[12] Commercial and bus VMT data were then multiplied by their respective EV share percentages to determine EVMT of these vehicle categories.

All electricity consumption from passenger, commercial, and bus EVs were multiplied by the City of Palo Alto Utilities (CPAU) electricity emission factor (zero MT CO_2e/kWh) to determine GHG emissions from on-road, EV transportation.

On-road transportation accounts for approximately 54.1 percent of Palo Alto's total emissions, a 33.1 percent decrease from 1990, but a 19.4 percent increase from 2021. This increase is primarily driven by increased on-road vehicle miles traveled (VMT). In 2022, total on-road VMT increased by 12 percent since 2021, likely due to the shift away from pandemic-level (reduced) driving frequency, returning to the office after working from home, and economic recovery of people returning to Palo Alto for shopping, dining, entertainment, and travel stays.

Off-road transportation accounts for approximately 4.9 percent of Palo Alto's total emissions, a 6.5 percent increase from 2021. GHG emissions from lawn and garden equipment specifically—which are predominantly gasoline-powered equipment—account for less than one percent of total emissions. It is important to note that most of the off-road transportation emissions are

[11] CARB EMFAC v1.0.1.; https://ww2.arb.ca.gov/our-work/programs/msei/on-road-emfac

[12] While these percent EV share estimates also come from CEC's ZEV Statistics database, only county-level data is available for medium- and heavy-duty (i.e., commercial and bus) ZEVs. The average percent EV share for Santa Clara and San Mateo County was used as a proxy for Palo Alto because Palo Alto shares one zip code (94303) with San Mateo, and much I-E/E-I EVMT attributed to Palo Alto is assumed to be between these two counties

based on models at the County level that do not reflect Palo Alto-specific variations. The 2022 inventory sourced Santa Clara County fuel consumption from CARB's OFFROAD model,[13] including airport ground support, construction, mining, industrial, light commercial, portable equipment, and transportation refrigeration units. All attribution factors used to allocate countywide fuel consumption to Palo Alto in 2022 remained the same as previous inventories,[14] except airport ground support. Attributed fuel consumption from each off-road sector was then multiplied by its respective GHG emissions factor (MT CO2e/gallon) depending on fuel type (i.e., gasoline, diesel, or natural gas) to estimate GHG emissions.

Airport emissions account for approximately 0.4% of Palo Alto's total emissions, a 30.4% decrease from 2021. Due to unavailable data, airport ground support in 2022 was attributed based off number of airports in Palo Alto relative to Santa Clara County, in contrast to previous inventory methodology of allocating based off the number of take-offs and landings in Palo Alto.

Caltrain commuter rail emissions account for approximately 1.7 percent of Palo Alto's total emissions, an 83.5 percent decrease from 2021. In the 2021 inventory, total Caltrain commuter rail diesel fuel consumption was sourced from the Peninsula Corridor Joint Power Board, and partially allocated—scaled down—to Palo Alto based off 2019 average weekday ridership (AWR) as 2021 Caltrain ridership was not available. For the 2022 Inventory, the most recently available Caltrain ridership data included calendar year 2022 (CY22) total system annual AWR and fiscal year 2023 (FY23) (November and December only) Palo Alto stations' AWR. In the 2022 Inventory, commuter rail fuel consumption was scaled down and attributed to Palo Alto by dividing the sum of FY23 Palo Alto stations' AWR by CY22 total system annual AWR. Due to no response from the Peninsula Corridor Joint Power Board, Caltrain commuter rail diesel fuel consumption in the 2022 Inventory uses 2020 fuel consumption from Caltrain's 2021 Sustainability Report as is most recently available data.[15] It is assumed that the total fuel consumption and allocation methodology described above is comparable to Palo Alto's share of Caltrain commuter rail emissions in 2022. Caltrain electrification is a key component of the Caltrain Modernization program,[16] with Caltrain scheduled to be electrified by late September 2024. Once the Caltrain Modernization program is complete, most of the Caltrain commuter rail emissions will be eliminated.

1.d Natural Gas (Methane) Use

In 2022, natural gas (methane) emissions accounted for 35.4 percent of total 2022 citywide GHG emissions in Palo Alto, a 6.9 percent increase from 2020 and a 25.3 percent decrease from 1990. As shown in Table 3, Palo Alto's total natural gas (methane) consumption in 2022 was 27,140,144 therms. Residential natural gas (methane) use accounts for 17 percent of total emissions, commercial energy accounts for 15.3 percent of total emissions, and industrial

[13] CARB OFFROAD v1.0.5.; https://arb.ca.gov/emfac/offroad/
[14] Attribution factors are based off demographic data such as population, employment, and service population (except for airport ground support).
[15] Caltrain 2021 Sustainability Report; https://www.caltrain.com/media/30519/download
[16] Caltrain Modernization Program; https://calmod.org/

energy accounts for 3.1 percent of total emissions. In 2022, natural gas (methane) use increased 12.6 percent in the commercial sector, 4.1 percent in the industrial sector and 2.7 percent in the residential sector. While natural gas (methane) usage fluctuates based on factors such as weather and occupant behavior, the increase in natural gas (methane) emissions in the commercial sector is likely due to increased occupancy from returning to the office after working from home, filling commercial building vacancies, and economic recovery - including increased dining, shopping, and visitors returning to Palo Alto.

The City Council unanimously approved Palo Alto's Carbon Neutral Natural Gas Plan on December 5, 2016. The Natural Gas Plan, implemented on July 1, 2017, achieves carbon neutrality for the gas supply portfolio by 1) purchasing high-quality carbon offsets equivalent to our City and community natural gas (methane) emissions; 2) pursuing efficiency strategies to reduce natural gas (methane) use, and 3) seeking opportunities to fund local offsets that finance actual emissions reductions in Palo Alto and the surrounding region. As a bridging strategy, carbon offsets are being purchased in an amount equal to the GHG emissions caused by natural gas (methane) use within the City. Carbon offsets are not included in this citywide GHG inventory.

1Table 3: 2022 Natural Gas (Methane) Use

Subsector	2019 Consumption (Therms)	2020 Consumption (Therms)	2021 Consumption (Therms)	2022 Consumption (Therms)	Percent of Total 2022 Emissions (%)
Residential Energy	13,565,360	12,952,262	12,756,160	13,037,423	17.0%
Industrial Energy	2,707,034	2,253,641	2,294,119	2,372,902	3.1%
Commercial Energy	12,954,768	10,061,842	10,468,041	11,729,819	15.3%
Total Natural Gas (Methane) Use	**28,867,162**	**25,267,739**	**25,518,320**	**27,140,144**	**35.4%**

Natural Gas (Methane) Fugitive Emissions

Natural gas is mainly methane (CH_4), some of which escapes during the drilling, extraction, and transportation processes. Such releases are known as fugitive emissions. The primary sources of these emissions may include equipment leaks, evaporation losses, venting, flaring and accidental releases. Methane is a potent greenhouse gas – approximately 25 times more powerful than carbon dioxide over a 100-year timescale.

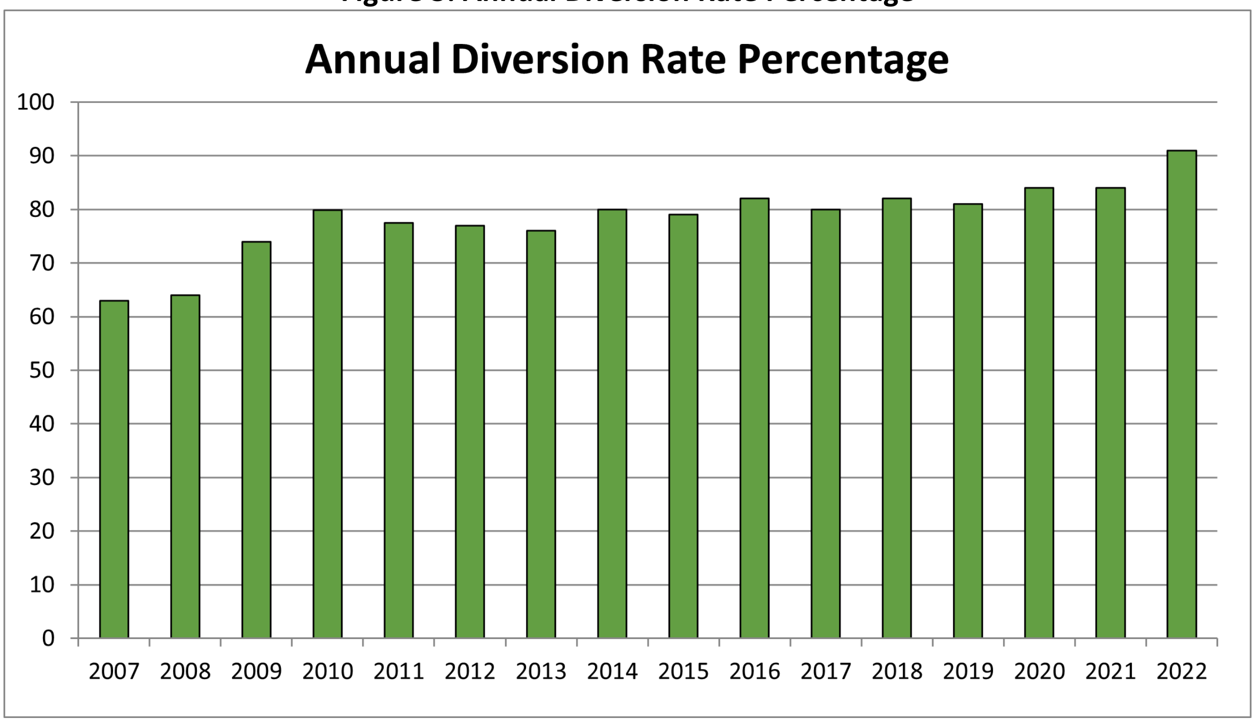
In 2022, natural gas (methane) fugitive emissions accounted for 1.1 percent of total citywide GHG emissions in Palo Alto, an increase of 6.4 percent from 2021 and a decrease of 0.2 percent from 1990. Per the GPC, fugitive emissions from natural gas (methane) are based on overall community consumption and a leakage rate of 0.03 percent.

As mentioned in Section 1.a., the GPC Basic methodology includes GHG emissions attributable to activities taking place within the geographic boundary of the city. As such, the 2022 GHG inventory does not include a category of emissions that are called “upstream emissions,” which includes emissions from extraction of natural gas (methane) and its transportation across the western United States through California to Palo Alto. Leaks during gas extraction and transportation can be very significant, so the actual impacts of natural gas (methane) use can be much more significant than is represented in a formal Citywide GHG inventory.

1.e. Solid Waste

In 2022, Palo Alto's solid waste diversion rate was 91 percent, far exceeding the 50 percent mandate for local jurisdictions. “Diversion” includes all waste prevention, reuse, recycling, and composting activities that “divert” materials from landfills. The City uses the diversion rate to measure progress on waste reduction and resource conservation goals. As shown in Figure 3, the diversion rate of 91 percent is an improvement from the 62 percent rate in 2007 and 84 percent rate in 2021. As part of the 2016 S/CAP Framework, the City Council adopted a goal of 95 percent diversion of materials from landfills by 2030.[17]

Figure 3: Annual Diversion Rate Percentage



Solid waste emissions accounted for 1.7 percent of total 2022 citywide GHG emissions in Palo Alto, a 5.1 percent increase from 2021 and an 87.5 percent decrease from 1990. As shown in Table 4, the 1990 inventory included Palo Alto Landfill Gas Fugitive emissions, whereas the 2022 inventory did not, and the 2022 inventory included composting emissions at the Zero

[17] Sustainability and Climate Action Plan Framework, November 2016; https://www.cityofpaloalto.org/civicax/filebank/documents/64814

Waste Energy Development Company's (ZWED) Dry Fermentation Anaerobic Digestion (AD) Facility in San Jose, CA, composting emissions at the Synagro El Nido Central Valley Composting (CVC) facility in Dos Palos, as well as Palo Alto Landfill Gas Flaring Emissions.

The increase from 2021 in solid waste emissions is due largely to the slight increase in emissions from the closed landfill within Palo Alto, which accounted for 1.3 percent of total waste emissions in 2022. The increase was a result of a slight methodology difference in the emission factor calculation. Waste emissions result from organic material decomposing in the anaerobic conditions present in a landfill and releasing methane (CH_4) – a greenhouse gas much more potent than CO_2. Organic materials (e.g., paper, plant debris, food waste, etc.) generate methane within the anaerobic environment of a landfill while non-organic materials (e.g., metal, glass, etc.) do not. This is why diverting waste from landfills is so important. In 2016, Governor Brown signed Senate Bill 1383 (SB 1383) to reduce GHG emissions from a variety of short-lived climate pollutants, including methane from organic materials disposed in landfills. SB 1383 is the largest and most prescriptive waste management legislation in California since the California Integrated Waste Management Act of 1989 (AB 939) and aspires to reduce statewide disposal of organic waste 75% by 2025 and recover at least 20% of the currently disposed edible food for human consumption by 2025. Palo Alto is in compliance with many of SB 1383 requirements due to the City's progressive zero waste programs and initiatives and is continuing to take initiatives to further reduce organic materials from being disposed in landfills.

In the 2021 citywide inventory, GHG emissions associated with transforming wastewater sludge into compost at Synagro facilities were calculated by taking all compost-bound wastewater sludge produced by the Palo Alto Regional Water Quality Control Plant (RWQCP) and multiplying it by composting emission factors derived from EPA's Waste Reduction Model (WARM) methodology.[18] While taking all compost-bound wastewater sludge produced by the Palo Alto RWQCP is a conservative approach to estimating activity data for wastewater sludge composting emissions, it overestimates the City's share since Palo Alto's RWQCP serves several cities and not all compost-bound wastewater sludge produced is attributed to the City. To avoid overestimating GHG emissions from this source, an attribution factor of 43 percent (the City's service population divided by persons served by Palo Alto's RWQCP) was used in the 2022 citywide inventory to scale down Palo Alto's RWQCP compost-bound wastewater sludge to estimate only the City's share of wastewater sludge composting emissions. The composting emission factor in the 2022 Inventory did not change.

[18] EPA Waste Reduction Model (WARM); https://www.epa.gov/warm

2Table 4: 1990 vs 2022 Solid Waste Emissions by Subsector						
Subsector	1990 GHG emissions (MT CO_2e)	2019 GHG emissions (MT CO_2e)	2020 GHG emissions (MT CO_2e)	2021 GHG emissions (MT CO_2e)	2022 GHG emissions (MT CO_2e)	Percent of Total 2022 Emissions (%)
Composting	Not included	731	1,623	1,256	1,327	0.3%
Palo Alto Landfill Gas Flaring	Not included	281	316	237	233	0.1%
Palo Alto Landfill Gas Fugitive	24,325	n/a[19]	n/a	n/a	n/a	n/a
Palo Alto Landfill Waste	30,732	5,519	4,721	5,029	5,297	1.3%
Total	**55,057**	**6,531**	**6,660**	**6,522**	**6,857**	**1.7%**

1.f. Wastewater Treatment

As shown in Table 5, in 2022 the RWQCP wastewater-related emissions accounted for 0.6 percent of total 2022 GHG emissions in Palo Alto – a 100.7 percent increase from 2021 and a 70.2 percent decrease from 1990. RWQCP GHG emissions originate from electricity, natural gas (methane), and landfill gas usage required to treat the wastewater, as well as GHGs that are emitted from the wastewater itself either during treatment or after (effluent). The nitrogen within wastewater is subject to transformation to nitrous oxide at varying stages in the treatment process as well as after it has been discharged to a receiving water (effluent). These emissions are included in the RWQCP totals.

The significant increase in indirect GHG emissions from wastewater effluent between 2021 and 2022 is primarily driven by increased nitrogen content in wastewater effluent (an 86 percent increase). Because the 2021 nitrogen content level is well below the lowest data point during the COVID pandemic, it can be concluded that the 2021 activity data was the result of a measurement error and the 2022 activity data is representative of current conditions despite the comparative increase.[20] Accounting for less than one percent of all GHG emissions in the 2022 citywide inventory, however, the effect on total GHG emissions is insignificant. Still, GHG emissions from wastewater are significantly lower than 1990 levels.

As shown in Figure 4, the RWQCP operations achieved significant GHG reductions in 2019 when the facility's sewage sludge incinerators were replaced with the more environmentally friendly Sludge Dewatering and Truck Loadout Facility. Previously, the RWQCP incinerators were the City's largest facility related GHG source. The updated biosolids treatment process has and will continue to reduce climate-warming GHG emissions by approximately 15,000 MT of CO_2e per

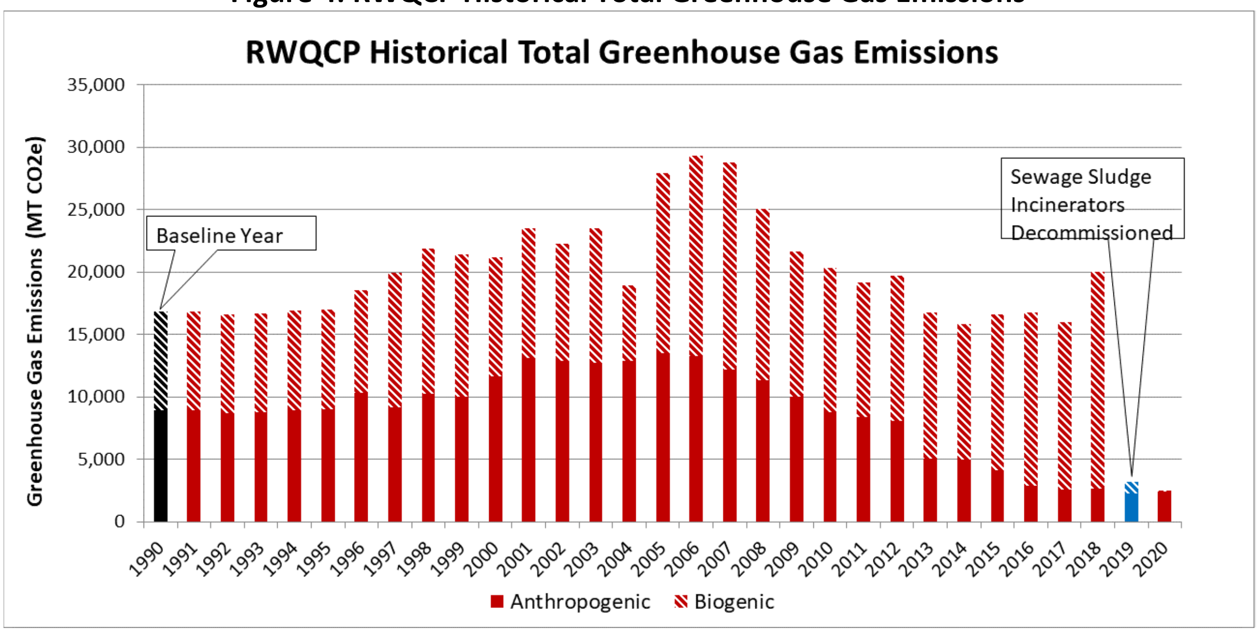
[19] Not included because the landfill was closed

[20] The 2021 nitrogen content level was reported as 1,205 kilograms (kg) of nitrogen (N) per day. The lowest data point during the COVID pandemic was 1,950 kg N per day. The 2022 activity data was reported as 2,240 kg N per day.

year when compared to the emissions from incineration. This approximates the carbon dioxide emissions of 3,000 passenger cars. The dewatered sludge is used as agricultural soil supplements.

3Table 5: 1990 vs 2022 Wastewater-Related Emissions by Subsector						
Subsector	**1990 GHG emissions (MT CO_2e)**	**2019 GHG emissions (MT CO_2e)**	**2020 GHG emissions (MT CO_2e)**	**2021 GHG emissions (MT CO_2e)**	**2022 GHG emissions (MT CO_2e)**	**Percent of Total 2022 Emissions (%)**
Wastewater Biosolid Treatment[21]	n/a	812	0	0	0	0%
Wastewater Treatment and Effluent	8,504	1,385	1,388	1,262	2,532	0.6%
Total	**8,504**	**2,197**	**1,388**	**1,262**	**2,532**	**0.6%**

Figure 4: RWQCP Historical Total Greenhouse Gas Emissions



[21] Includes biosolid composting, anaerobic digestion, and incineration

1990 vs. 2022 Citywide Greenhouse Gas Emissions by Sector and Subsector							
Sector and Subsector	**1990 GHG emissions (MT CO_2e)[22]**	**2019 GHG emissions (MT CO_2e)**	**2020 GHG emissions (MT CO_2e)**	**2021 GHG emissions (MT CO_2e)**	**2022 GHG emissions (MT CO_2e)**	**% Change in 2022 from 1990**	**Percent of Total 2022 Emissions**
Total Transportation & Mobile Sources	**331,840**	**315,081**	**238,523**	**211,403**	**251,063**	**-24.3%**	**61.2%**
- On-Road Transportation	331,840	293,413	217,279	185,925	221,923	-33.1%	54.1%
- Airport Emissions	Not Included	2,192	1,664	2,641	1,837	n/a	0.4%
- Off-road Vehicles	Not Included	14,634	15,029	18,961	20,191	n/a	4.9%
- Caltrain Commuter Rail	Not Included	4,842	4,552	3,876	7,112	n/a	1.7%
Total Natural Gas (Methane) Use	**194,000**	**153,509**	**134,365**	**135,697**	**144,996**	**-25.3%**	**35.4%**
- Commercial Energy	Not calculated	66,987	53,515	55,676	62,667	n/a	15.3%
- Industrial Energy	Not calculated	14,373	11,961	12,176	12,677	n/a	3.1%
- Residential Energy	Not calculated	72,149	68,889	67,846	69,652	n/a	17.0%
Natural Gas (Methane) Fugitive Emissions	**4,718**	**5,009**	**4,384**	**4,427**	**4,709**	**-0.2%**	**1.1%**
Total Wastewater-Related Emissions	**8,504**	**2,197**	**1,388**	**1,262**	**2,532**	**-70.2%**	**0.6%**
- Wastewater Biosolid Treatment[23]	n/a	812	0	0	0	n/a	0%
- Wastewater Treatment and Effluent	8,504	1,385	1,388	1,262	2,532	-70.2%	0.6%
Total Solid Waste	**55,057**	**6,531**	**6,660**	**6,522**	**6,857**	**-87.5%**	**1.7%**
- Composting	Not Included	731	1,623	1,256	1,327	n/a	0.3%
- Palo Alto Landfill Gas Flaring[24]	Not Included	281	316	237	233	n/a	0.1%
- Palo Alto Landfill Gas Fugitive	24,325	n/a[25]	n/a	n/a	n/a	n/a	n/a
- Palo Alto Landfill Waste	30,732	5,519	4,721	5,029	5,297	-82.8%	1.3%
Brown Power Supply (Electricity)	**186,000**	**n/a**	**n/a**	**n/a**	**n/a**	**-100.0%**	**n/a**
Total GHG Emissions (MT CO_2e)	**780,119**	**482,237**	**385,320**	**359,312**	**410,157**	**-47.4%**	**100%**

[22] Source: 2016 S/CAP Framework and 2016 Earth Day Report
[23] Includes biosolid composting, anaerobic digestion, and incineration
[24] 2016 Earth Day Report labeled these emissions as biogenic
[25] Not included because the landfill was closed