Attachment E: Palo Alto's 2021 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 75 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 is 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.

Staff did not complete a consumption based GHG inventory as there is no State guidance yet, though staff believes this inventory type is valuable. The California Air Resources Board (CARB) has been tasked with developing an implementation framework and accounting to track consumption-based emissions over time.[3] 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.

In 2014, World Resources Institute, C40 Cities Climate Leadership Group (C40) and ICLEI – Local Governments for Sustainability (ICLEI)[4] partnered to create a global standard protocol for generation-based GHG inventories. The official GHG Protocol standard for Cities[5] provides a

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[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] 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.

[4] Formerly the International Council for Local Environmental Initiatives, renamed in 2003 to ICLEI – Local Governments for Sustainability.

[5] The GPC is the official protocol specified by the Global Covenant of Mayors and defines what emissions must be reported and how.

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[6], which provides more detailed methodology specific to the U.S. AECOM utilized the GPC Protocol when developing our 2021 GHG inventory. It seeks to:

- Help cities develop a comprehensive and robust 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
- 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 inventory was completed for 2005 and then extrapolated for 1990 (the baseline year). Beginning in 2010, new community GHG inventories were completed annually, enabling Palo Alto to track progress over time.

The 2021 Palo Alto GHG inventory, completed by AECOM, uses the approach and methods provided by the GPC. Inventory calculations were performed using the ClearPath[7] tool, a software platform designed for creating generation-based GHG inventories. The City's GHG inventory conforms to the GPC Basic protocol for a generation-based inventory.

The GPC Basic protocol describes three emissions scopes for community emissions:

- **Scope 1:** GHG emissions from sources located within the city boundary, such as stationary fuel consumption.
- **Scope 2:** GHG emissions occurring because of 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[8]. Under the Basic reporting level as defined by the GPC protocol, the inventory requirements

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[6] U.S. Community Protocol; https://icleiusa.org/us-community-protocol/
[7] ClearPath tool; https://icleiusa.org/clearpath/
[8] GPC Protocol; https://ghgprotocol.org/sites/default/files/standards/GHGP_GPC_0.pdf

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.

1.b. Palo Alto's 2021 GHG Emissions
In 2021, Palo Alto emitted an estimated 359,312 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 53.9 percent decrease in total community emissions, despite a population increase of 19.5 percent during that same time period. This equates to 5.4 metric tons of carbon dioxide equivalent (MT CO2e) per Palo Alto resident in 2021 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 that 53.9 percent reduction to-date, 44.2 percent came from achieving carbon neutrality for the City's electricity portfolio, 28.6 percent from declines in transportation emissions, 13.9 percent from reduction in natural gas (methane[10]) consumption, 11.5 percent from declines in solid waste emissions, and 1.7 percent from declines in wastewater-related emissions. In comparison to 2020, that is a 6.7 percent decrease in total community emissions.

For the emissions sources in 2021, 51.7 percent are from on-road transportation, 37.8 percent are from natural gas (methane) use, and the remainder are from other sources. A comparison of 1990, 2019, 2020, and 2021 GHG emissions is shown in

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[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 2021 GHG Emissions by Sector**

and Table 1. The full comparison between the inventories can be found in Attachment B 1990 vs. 2021 Greenhouse Gas Emissions by Sector and Subsector. Additional existing emissions sources that were missing from the 1990 GHG inventory were included in the 2021 GHG inventory to comply with the GPC Basic protocol (Airport Emissions, Off-road Vehicles, Caltrain Commuter Rail, Composting, and Palo Alto Landfill Gas Flaring).

Figure 1: 1990 vs 2021 GHG Emissions by Sector

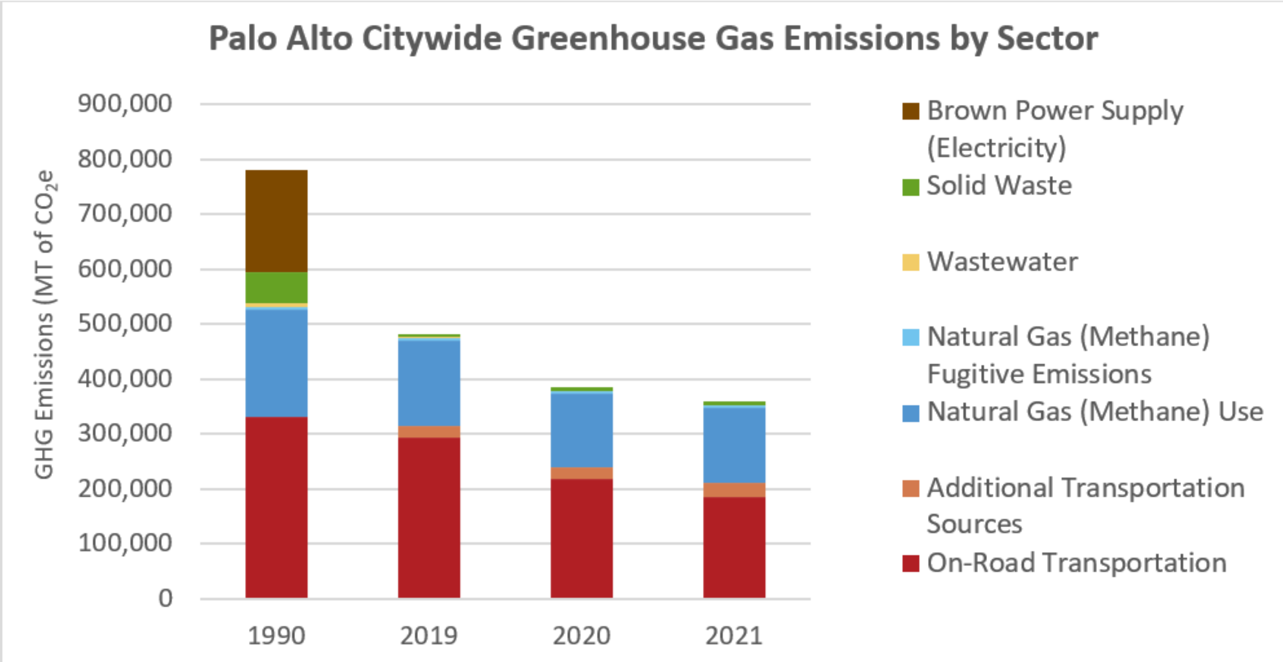
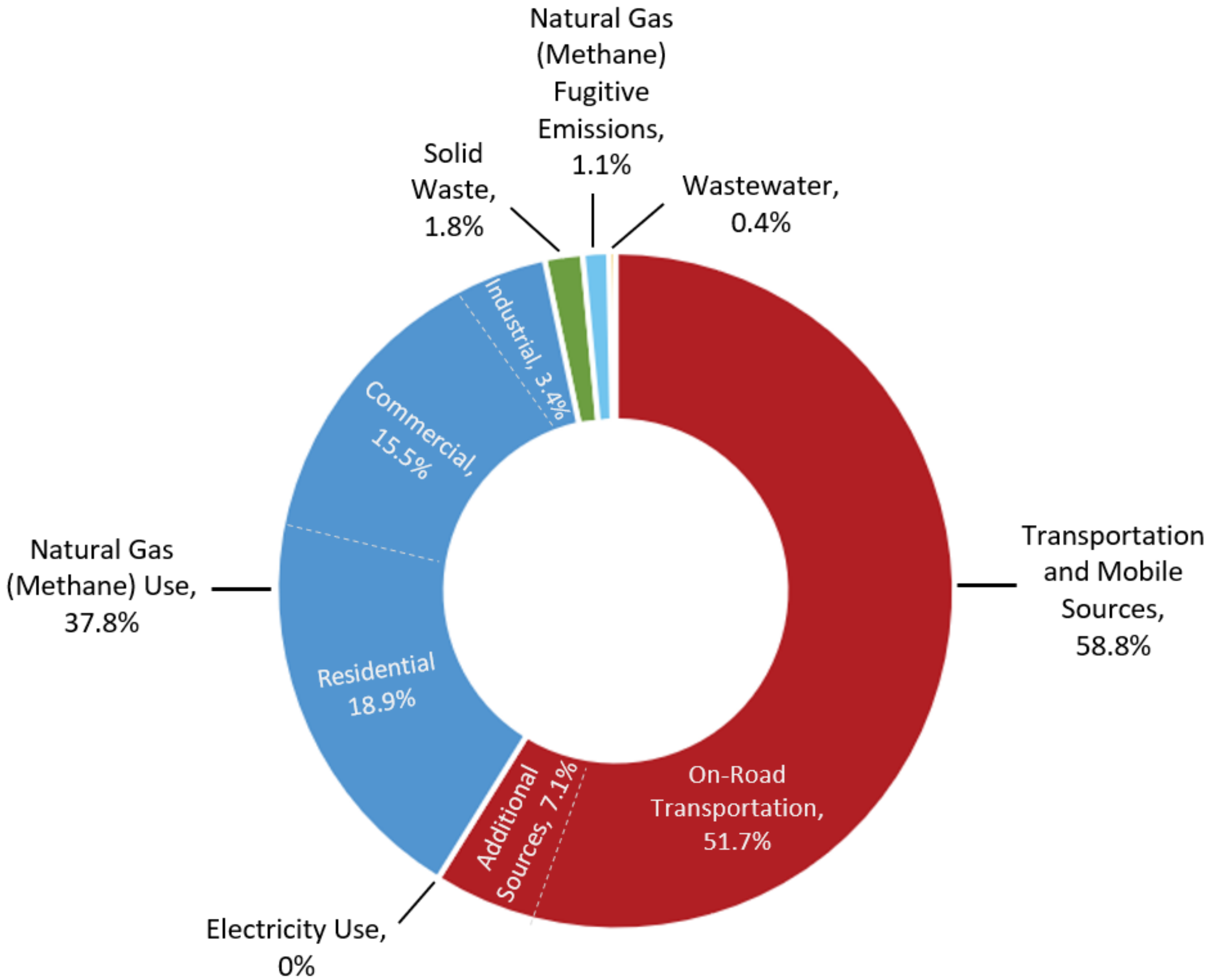


Table 1: 1990 vs 2021 GHG Emissions by Sector

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)	Percent Change in 2021 from 1990
On-Road Transportation	331,840	293,413	217,279	185,925	-44.0%
Additional Transportation Sources		21,668	21,244	25,478	n/a
Natural Gas (Methane) Use	194,000	153,509	134,365	135,697	-30.1%
Natural Gas (Methane) Fugitive Emissions	4,718	5,009	4,384	4,427	-6.2%
Wastewater-Related Emissions	8,504	2,197	1,388	1,262	-85.2%
Solid Waste	55,057	6,531	6,660	6,522	-88.2%
Brown Power Supply (Electricity)	186,000				- 100%
Total GHG Emissions (MT CO_2e)	**780,119**	**482,237**	**385,320**	**359,312**	**-53.9%**

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: 2021 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.

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 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 2021, transportation and mobile sources accounted for 58.8 percent of total GHG emissions in Palo Alto, a 11.4 percent decrease from 2020. 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, one-half of daily vehicular trips with an origin within Palo Alto city limits and a destination outside of Palo Alto city limits (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 (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 (e.g. back-pack leaf blower, based on service population), and transportation refrigeration units (based on service population).
- Caltrain Commuter Rail – This includes emissions from Caltrain travel within Palo Alto.

Table 2: 2021 Transportation and Mobile Sources

Subsector	2019 GHG emissions (MT CO_2e)	2020 GHG emissions (MT CO_2e)	2021 GHG emissions (MT CO_2e)	Percent of Total 2021 Emissions (%)
On-Road Transportation	293,413	217,279	185,925	51.7%
Airport Emissions	2,192	1,664	2,641	0.7%
Off-road Vehicles	14,634	15,029	18,961	5.3%
Caltrain Commuter Rail	4,842	4,552	3,876	1.1%
Total Transportation & Mobile Sources	**315,081**	**238,523**	**211,403**	**58.8%**

Estimating vehicles miles traveled (VMT) is a complicated process and is one of the few emissions sources that the City does not estimate annually. Forecasts of on-road transportation emissions are typically based on outputs from a travel forecasting model, other accounting-type method (sketch models), or Big Data (vehicle navigation data from built-in GPS and location-based services data from cell phones). Previously, Fehr & Peers provided VMT estimates for 2019, 2030, and 2040, with AECOM using the VMT estimates for 2019 to estimate the VMT for

2020. The VTA model used to calculate Palo Alto's 2019 annual VMT is only updated every few years and has not yet been updated to better reflect changes in VMT due to the pandemic. For 2021, AECOM used the VMT estimates from the Google Environmental Insights Explorer.

The Google Environmental Insights Explorer (EIE) uses aggregated data to derive local data, including distance driven by mode, then applies regional assumptions from the Climate Action for Urban Sustainability (CURB) tool — an internationally recognized third-party data source — to estimate the mix of vehicle and fuel types. This reflects actual trips from geospatial data based on continuous observation. Total distance traveled for all trips is aggregated and modeled to the entire city using aggregated location information from Google Location History and other sources. Google EIE is now GPC compliant, which is why staff opted to use the Google EIE data instead of the VTA model, which has not been updated since before the pandemic. In addition, ICLEI recommends cities use Google EIE data to estimate VMT.

On-road transportation accounts for approximately 51.7 percent of Palo Alto's total emissions, a 14.4 percent decrease from 2020. Because the 2021 GHG inventory uses Google EIE to calculate VMT and not the VTA model, it is possible that the emissions reductions in on-road transportation were because of the change in methodology and not from actual reductions in VMT. Using the VTA model, Fehr and Peers estimated VMT to be 729,969,567 total annual miles in 2020 compared to 518,286,844 total annual miles in 2021 using Google EIE. In addition, Google EIE does not use speed bin analysis[11], whereas Fehr and Peers did. However, moving forward, future GHG inventories will continue to use Google EIE to calculate VMT, so the 2022 GHG inventory will be a better comparison.

Off-road transportation accounts for approximately 5.3 percent of Palo Alto's total emissions, a 26.2 percent increase from 2020, mainly from transportation refrigeration units and light commercial (outdoor power equipment such as compressors and generators). Off-road transportation emissions were not calculated in 1990. It is important to note that most of the off-road transportation emissions are based on models at the County level that were not adjusted to reflect any pandemic-induced activity changes and do not reflect Palo Alto-specific variation.

Caltrain commuter rail emissions account for approximately 1.1 percent of Palo Alto's total emissions, a 14.9 percent decrease from 2020. Caltrain electrification is a key component of the Caltrain Modernization program[12], with Caltrain scheduled to be electrified by the end of 2023 or early 2024. Once the Caltrain Modernization program is complete, most of the Caltrain commuter rail emissions will be eliminated.

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[11] GHG emissions are commonly calculated using forecasts of VMT that are grouped according to the average speed of the traveling vehicles, which is called speed bin analysis. Slower-moving vehicles generate more pollutants, while travel speeds between 40-50 miles per hour (mph) tend to represent the most fuel-efficient operating conditions for internal combustion engines.

[12] Caltrain Modernization Program; https://calmod.org/

Airport emissions account for approximately 0.7% of Palo Alto's total emissions, a 58.7% increase from 2020. Intracity flights fuel use is estimated by the City and not reflective of actual fuel consumption.

1.d Natural Gas (Methane) Use

In 2021, natural gas (methane) emissions accounted for 37.8 percent of total 2021 GHG emissions in Palo Alto, a 1 percent increase from 2020 and a 30.1 percent decrease from 1990. As shown in Table 3, Palo Alto's total natural gas (methane) consumption in 2021 was 25,518,320 therms. Residential energy accounts for 18.9 percent of total emissions, commercial energy accounts for 15.5 percent of total emissions, and industrial energy accounts for 3.4 percent of total emissions. The pandemic drastically affected natural gas (methane) consumption. The temporary shelter-in place order, as well as changes in how and where people worked, resulted in major changes in the commercial and industrial sectors, with fewer people staying in hotels, going to restaurants, and going to retail establishments in 2020. In 2021, as the commercial and industrial sectors began to rebound, natural gas (methane) use increased 4 percent in the commercial sector and 1.8 percent in the industrial sector. Natural gas (methane) use decreased 1.5% in the residential sector.

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. However, offsets are not included in this GHG inventory.

Table 3: 2021 Natural Gas (Methane) Use

Subsector	2019 Consumption (Therms)	2020 Consumption (Therms)	2021 Consumption (Therms)	Percent of Total 2021 Emissions (%)
Residential Energy	13,565,360	12,952,262	12,756,160	18.9%
Industrial Energy	2,707,034	2,253,641	2,294,119	3.4%
Commercial Energy	12,954,768	10,061,842	10,468,041	15.5%
Total Natural Gas (Methane) Use	**28,867,162**	**25,267,739**	**25,518,320**	**37.8%**

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 2021, natural gas (methane) fugitive emissions accounted for 1.2 percent of total GHG emissions in Palo Alto, an increase of 1 percent from 2019 and a decrease of 6.2 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.

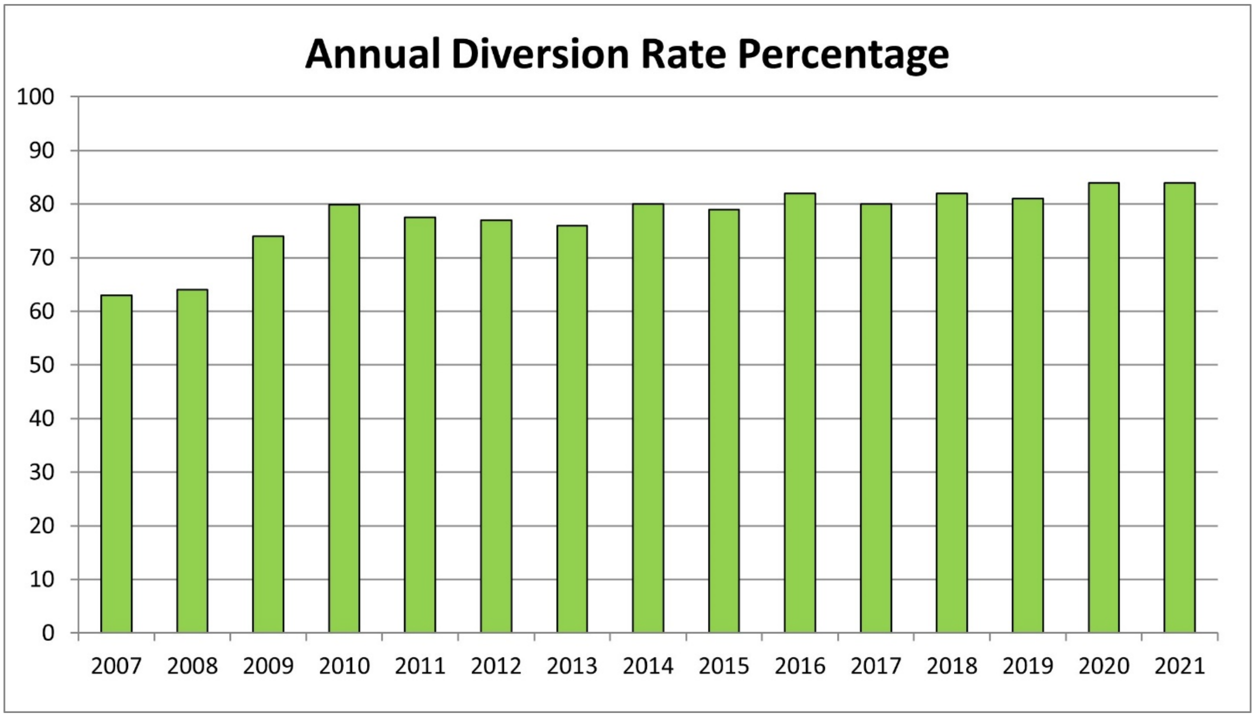
As mentioned in Section 1.a., the GPC Basic methodology includes GHG emissions attributable to activities taking place within the geographic boundary of the city. As such, the 2021 GHG inventory does not include a category of emissions that are called “upstream emissions,” which includes emissions from 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 greenhouse gas inventory.

1.e. Solid Waste

In 2021, Palo Alto's solid waste diversion rate was 84 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**: Annual Diversion Rate Percentage**, the diversion rate of 84 percent is an improvement from the 62 percent rate in 2007 but has remained relatively flat the last few years. As part of the 2016 S/CAP Framework, Council adopted a goal of 95 percent diversion of materials from landfills by 2030[13].

Figure 3: Annual Diversion Rate Percentage

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



Solid waste emissions accounted for 1.8 percent of total 2021 GHG emissions in Palo Alto, a 2 percent increase from 2020 and an 88.2 percent decrease from 1990. As shown in Table **4**, the 1990 inventory included Palo Alto Landfill Gas Fugitive emissions, whereas the 2021 inventory did not, and the 2021 inventory included composting emissions at the ZeroWaste 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 in solid waste emissions from 2020 is due largely to the increase in emissions from the closed landfills within the community.

In 2021, emissions from the closed landfills located within the community accounted for 1.4 percent of total waste emissions.

Table 4: 1990 vs 2021 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)	Percent of Total 2021 Emissions (%)
Composting	Not included	731	1,623	1,256	0.3%
Palo Alto Landfill Gas Flaring	Not included	281	316	237	0.1%
Palo Alto Landfill Gas Fugitive	24,325	n/a[14]	n/a	n/a	n/a

[14] Not included because the landfill was closed

Landfill Waste	30,732	5,519	4,721	5,029	1.4%
Total	**55,057**	**6,531**	**6,660**	**6,522**	**1.8%**

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.

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). SB 1383 sets several statewide goals, including:

- Reduce statewide disposal of organic waste by 50% by January 1, 2020 and 75% by 2025.
- Recover at least 20% of the currently disposed edible food for human consumption by 2025.

1.f. Wastewater Treatment

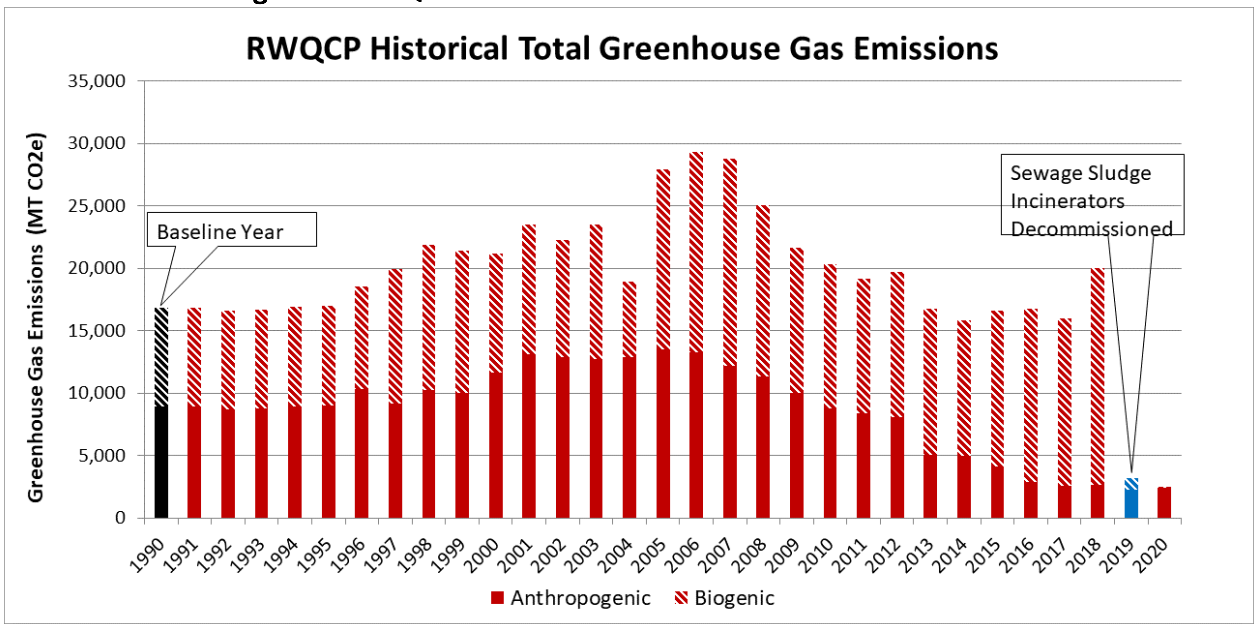
As shown in Table 5, in 2021 the City of Palo Alto Regional Water Quality Control Plant (RWQCP) wastewater-related emissions accounted for 0.4 percent of total 2021 GHG emissions in Palo Alto – a 9.1 percent decrease from 2020 and an 85.2 percent decrease from 1990. RWQCP GHG emissions originate from 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's been discharged to a receiving water (effluent). These emissions are included in the RWQCP totals. 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 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.

Table 5: 1990 vs 2021 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)	Percent of Total 2021 Emissions (%)

Wastewater Biosolid Treatment[15]	n/a	812	0	0	0%
Wastewater Treatment and Effluent	8,504	1,385	1,388	1,262	0.4%
Total	**8,504**	**2,197**	**1,388**	**1,262**	**0.4%**

Figure 4: RWQCP Historical Total Greenhouse Gas Emissions



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