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Arizona State University

2022 Greenhouse Gas Emissions Inventory for Goverment Operations

A comprehensive report prepared for

City of Phoenix

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sustainabilitysolutions.asu.edu

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Note: The data and calculations presented in this report may not be exact due to rounding errors within the GHG emissions template.

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Acronyms

AR	IPCC Assessment Report (Numbered 2 through 5)
ASU	Arizona State University
AZNM	Arizona and New Mexico eGRID Subregion
B20	A biodiesel blend consisting of 20% biodiesel and 80% diesel fuel
CARB	California Air Resources Board
CCAR	California Climate Action Registry
CH_4	Methane
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent Emissions
eGRID	EPA's Emissions and General Resource Integrated Database
EIA	U.S. Energy Information Administration
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
FTE	Full-time equivalent
GGE	Gasoline Gallon Equivalent
GHG	Greenhouse Gas
GAC	Granular Activated Carbon
GWP	Global Warming Potential
ICLEI	International Council for Local Environmental Initiatives
IPCC	Intergovernmental Panel on Climate Change
JPA	Joint Powers Authority
LED	Light Emitting Diode
LEED	Leadership in Energy and Environmental Design
LGOP	Local Government Operations Protocol
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MT	Metric Tons
MWh	megawatt-hour
NAU	Northern Arizona University
NERC	North American Electric Reliability Corporation
N_2O	Nitrous Oxide
REC	Renewable Energy Credit
T&D	Transmission & Distribution
TRP	Trip Reduction Program
UNFCCC	United Nations Framework Convention on Climate Change
WWT	Wastewater Treatment
WWTP	Wastewater Treatment Plant

Executive Summary

The *City of Phoenix 2022 Greenhouse Gas Emissions Inventory for Government Operations* is the fifth update to the City of Phoenix (the City) government operations GHG emissions inventory. The initial GHG inventory of government operations covered calendar year 2005 and was published in 2009. This report provided both a baseline GHG inventory and technical support for the *City of Phoenix 2009 Climate Action Plan for Government Operations*. The climate action plan projected that GHG emissions from the City's government operations would increase by 14% over 2005 level if no actions were taken. As a result, the Phoenix City Council, in December 2008, adopted a mandate to reduce GHG emissions from government operations to 5% below the 2005 GHG emissions levels by 2015.

In 2013, the City conducted a GHG emissions inventory for calendar year 2012 to track progress toward the 2015 GHG emissions reduction goal. The *City of Phoenix 2012 Greenhouse Gas Emissions Inventory for Government Operations* found that GHG emissions from government operations had decreased 7.2%, exceeding the City's 2015 goal. Shortly thereafter, the Phoenix City Council adopted a new goal to reduce government operations GHG emissions to 15% below 2005 levels by 2015. The *City of Phoenix 2015 Greenhouse Gas Emissions Inventory for Government Operations* found that government operations GHG emissions were reduced by 15.6%, thus meeting the updated 2015 GHG emissions goal. In 2017, the City updated its government operations GHG emissions reduction goal to 40% below 2005 levels by 2025. The *City of Phoenix 2022 Greenhouse Gas Emissions Inventory for Government Operations* provides data-driven progress tracking towards the 2025 goal.

Findings

The major findings of the *City of Phoenix 2022 Greenhouse Gas Emissions Inventory for Government Operations* are listed below.

- 2022 government operations GHG emissions were 96,201 MT CO_2e (16%) below 2018 levels and 206,314 MT CO_2e (29%) below 2005 levels.
- A further reduction in the GHG intensity of government operations is needed between 2022 and 2025 to meet given stated GHG emissions reduction goals – 40% below 2005 levels by 2025.
- Based on 2022 activity and emissions factor data, one pathway to achieving the 2025 goal is to expand the purchase and registration of renewable

energy credits (RECs). Subsequently, the City would need to set up a verification system to enable the incorporation of purchased RECs into government operations GHG inventory. Further shifting away from fossil fuels in the vehicle fleet and exploring landfill gas to energy are other pathways for reducing GHG emissions.

- Between 2018 and 2022, the GHG intensity of the regional electricity grid fell by 24%. Over the same period, GHG emissions from purchased electricity fell by 27% (79,584 MT CO_2e).
- Buildings and Facilities GHG emissions from purchased electricity fell 29,849 MT CO_2e (21%) between 2018 and 2022 despite a 4% increase in electricity purchases. The observed emissions decrease was driven by the GHG intensity of the regional electricity grid decreasing by 25%.
- GHG emissions Traffic Signals and Streetlights decreased 30,672 MT CO_2e (66%) from 2005 and 20,581 MT CO_2e (57%) from 2018 due to a combination of transitioning to LED lighting equipment and the GHG intensity of electricity from the regional electricity grid decreasing by 25%.
- Water Services GHG emissions from purchased electricity decreased 29,154 MT CO_2e (24%) between 2018 and 2022 while electricity purchases remained stable (<1% increase) over the same period. The observed reduction in GHG emissions was driven by the GHG intensity of the regional electricity grid decreasing by 25%.
- GHG emissions from the City's vehicle fleet decreased 12,408 MT CO_2e (9%) since 2018. Decreased vehicle fleet emissions is attributed to Public Transit's transition to B20 biodiesel from diesel.
- GHG emissions from landfills increased 5,699 MT CO_2e (5%) between 2018 and 2022.
- GHG emissions from wastewater treatment (WWT) decreased 17% (2,060 MT CO_2e) between 2018 and 2022 and were 19% higher than 2005 (1,564 MT CO_2e). The increase in emissions since 2005 is due to population growth and expanded operations. However, since 2018, WWT GHG emissions have decreased due to the capture and reuse of methane biogas at the 91st Avenue WWTP despite population growth.
- The 27th Avenue Compost Facility emitted 7,585 MT CO_2e in 2022, a 7% decrease below 2018 levels. GHG emissions reductions were directly related to a 7% reduction in material processed between 2018 and 2022. The goal for this facility is not to reduce emissions because composting is expected to reduce overall GHG emissions over its lifetime through green-organic waste processing and reducing trips to the SR-85 landfill for

disposal, which are captured in Vehicle emission reductions and total 5,691 MT CO_2e.

Since 2015 Phoenix has implemented, or is in the process of implementing, several projects in order to meet the emissions reduction goal. These projects include:

- Construction of the 27th Avenue Compost Facility.
- LED conversion of Traffic Lights and Streetlights that was completed in 2019.
- Continued expansion of the Valley Metro light rail system.
- Construction of PHX SkyTrain.
- Phasing out diesel fuel consumption by Public Transit and transitioning to less GHG intensive fuels.

The City has achieved significant GHG emissions reductions despite growing by approximately 300,000 people since 2005 (Figure ES-1). Accordingly, the per capita GHG intensity of the City's government operations have fallen 41% from 0.52 to 0.31 MT CO_2e per resident between 2005 and 2022.

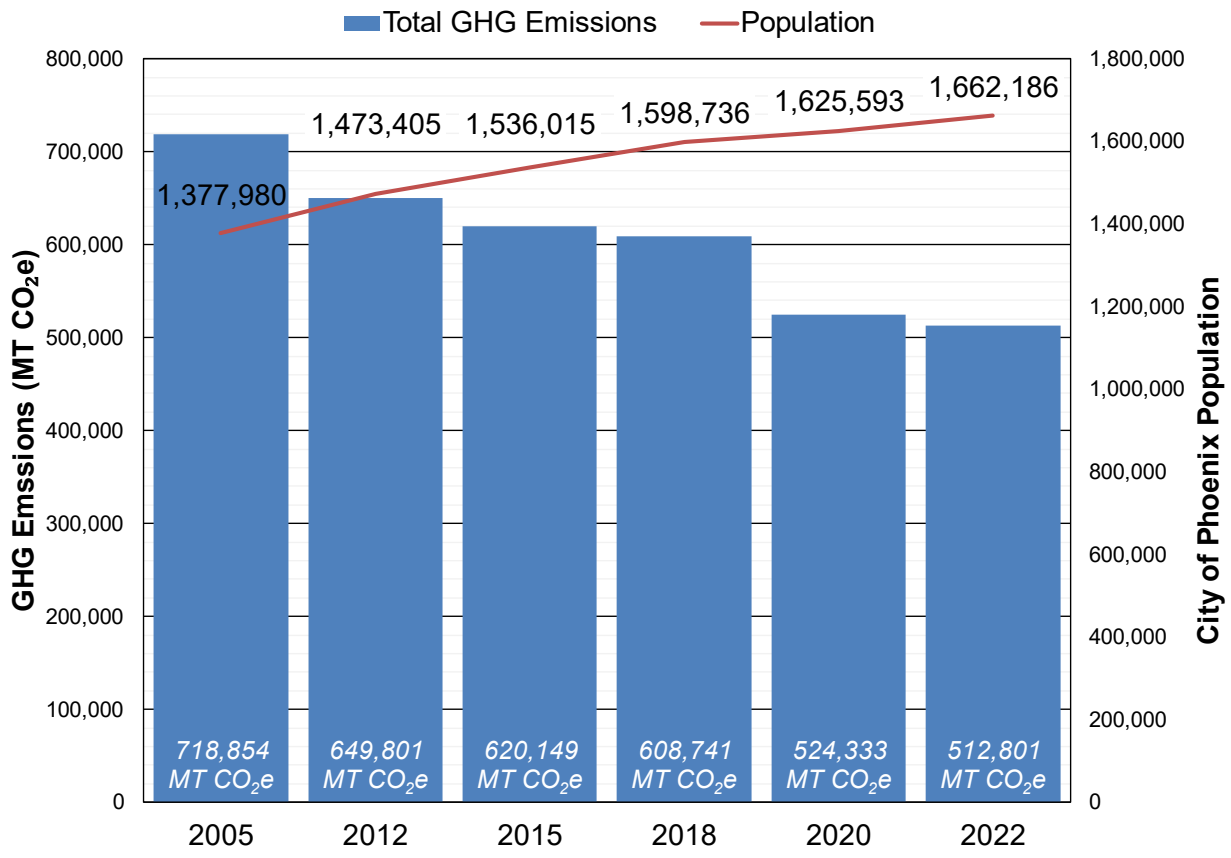


Figure ES-1. City of Phoenix Government Operations GHG Emissions and Population by Inventory Year.

1 Introduction

In December 2008, the Phoenix City Council adopted a goal to reduce GHG emissions from government operations to 5% below reported 2005 levels by 2015. To achieve this goal, the City of Phoenix (City) established a baseline GHG emissions level for City operations and developed *The City of Phoenix 2009 Climate Action Plan for Government Operations*. The report forecasted a 14% increase in GHG emissions by 2015 if Phoenix maintained a business-as-usual approach and did not take efforts to curb GHG emissions.

In 2013, the City commissioned Arizona State University's Rob and Melani Walton Sustainability Solutions Service to conduct a local government operations GHG emissions inventory for 2012 to track progress toward the 2015 goal. The 2012 government operations GHG emissions inventory found that the City had already reduced GHG emissions by 7.2%, meeting the 5% reduction goal. As a result, Phoenix City Council adopted a new goal to reduce government operations GHG emissions 15% below 2005 levels by 2015. The 2015 government operations GHG emissions inventory found that the City achieved its 15% GHG emissions reduction goal. In 2017, the City updated its government operations GHG emissions reduction goal to 40% below 2005 levels by 2025.

The *City of Phoenix 2022 Greenhouse Gas Emissions Inventory for Government Operations* summarizes the City's progress toward reducing GHG emissions from government operations 40% below 2005 levels by 2025.

The report structure is as follows:

- Section 2 provides an overview of the major findings of the GHG emissions inventory of government operations.
- Section 3 describes the GHG emissions inventory boundary along with methodological background and updates for the GHG Emissions reports.
- Section 4 summarizes results by reporting sector: Buildings and Facilities, City Vehicle Fleet, Water Distribution and Wastewater Treatment Processes, Solid Waste, and Employee Commute.
- Section 5 provides internal and external benchmarks for Phoenix operations.

2 Major Findings

In 2022, GHG emissions from City government operations were 512,801 MT CO_2e, which is 29% below 2005 levels and 16% below 2018 levels (Figure 1).

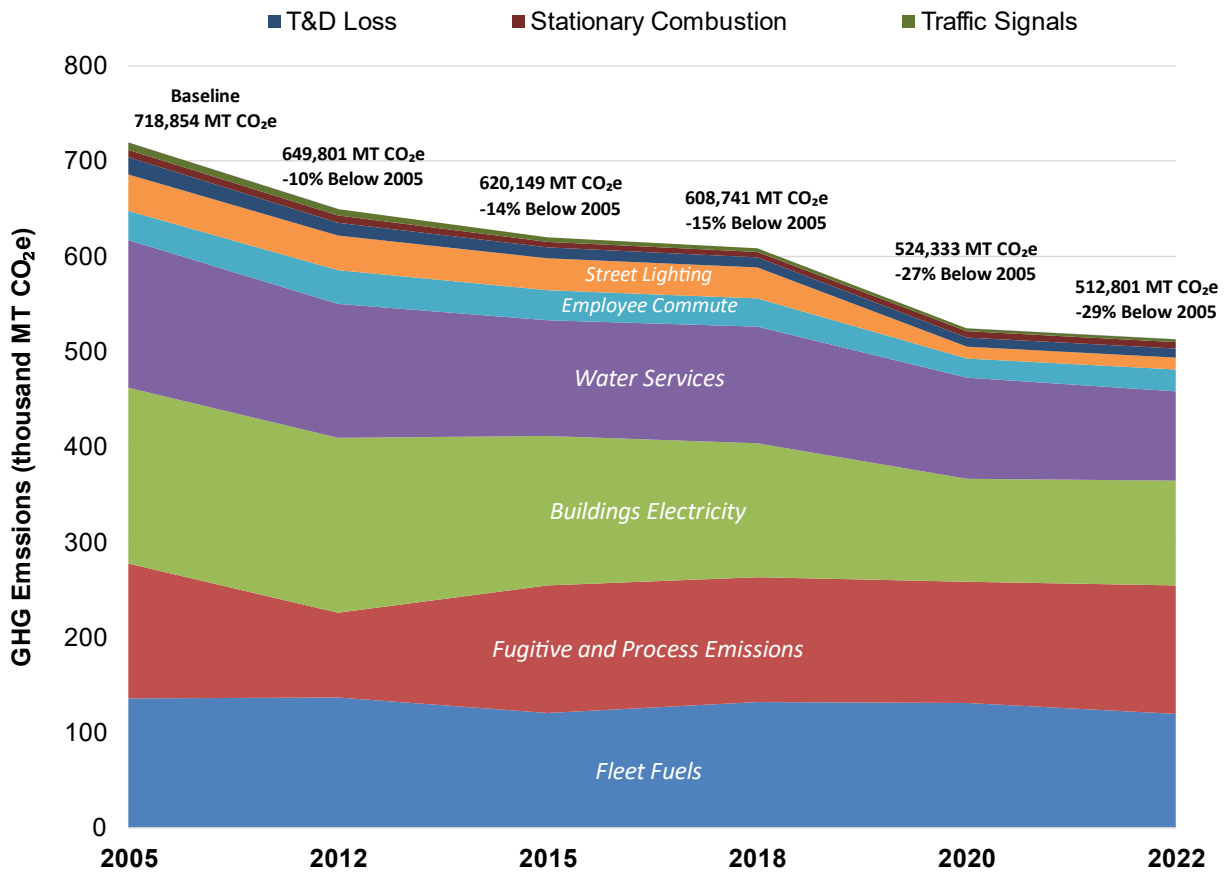


Figure 1. City of Phoenix GHG Emissions by Sector and Inventory Year

The City reduced GHG emissions through a combination of internal and external drivers. Internal drivers include energy efficiency upgrades, the incorporation of alternative fuels into the vehicle fleet fuel portfolio, and upgrades to landfill gas capture systems. External drivers include a decrease in the EPA's Emissions & Generation Resource Integrated Database (eGRID) regional emissions factor, which is a measure of the GHG intensity of electricity produced and consumed[1]. Between 2005 and 2022, the GHG intensity of the Arizona-New Mexico (AZNM) subregion fell by approximately 41%, from 1,316 lb. CO_2e emitted per MWh of electricity generated (lb. CO_2e/MWh) to 779 lb. CO_2e/MWh. The

[1] The Emissions & Generation Resource Integrated Database (eGRID), developed by the EPA in collaboration with the Energy Information Administration (EIA), the North American Electric Reliability Corporation (NERC), and the Federal Energy Regulatory Commission (FERC), is a comprehensive source of data on the environmental characteristics of almost all electric power generated in the United States. Detailed information can be found at http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html.

closure of the Navajo Generation Station in 2019, operated by Salt River Project substantially reduced the GHG intensity of electricity in the Arizona-New Mexico subregion.

As shown in Table 1, between 2005 and 2022, GHG emissions from City government operations decreased across every subsector. Further between 2018 and 2022, GHG emissions decreased across every subsector except for Scope 1 stationary combustion of 1.5% (89 MT CO_2e) and Scope 3 emissions associated with Water Services of 36% (317 MT CO_2e). While these subsectors had measured GHG emissions increases, the relative magnitude of the increases were minor compared to the overall emissions total. GHG emissions from the City fleet decreased 9% (12,408 MT CO_2e) due to the shift away from diesel to B20 biodiesel and CNG consumption by Public Transit. Scope 2 Water Services decreased 24% (29,154 MT CO_2e) despite a <1% decrease in electricity consumption due to reductions in the GHG intensity of the regional electricity. In 2022, GHG emissions from employee commuting were 22% lower than 2018 levels. Changes in commuting GHG emissions are likely due to combination of increased levels of remote work and more fuel-efficient personal vehicles. Employee commuting vehicle miles and GHG emissions from the lows observed during the 2020 inventory year.

Table 1 shows changes GHG emissions for City government operations and population between 2005 and 2022.

Table 1. GHG Emissions by Scope and Sector by Inventory Year

Scope 1 Emissions (metric tons CO_2e)	2005	2012	2015	2018	2020	2022	2005-2022 Change	2005-2022 % Change
Stationary Combustion	7,404	7,329	6,377	6,085	6,447	6,436	-968	-13%
Fleet Fuels	135,420	136,572	120,420	131,808	130,730	119,400	-16,020	-12%
Fugitive and Process Emissions	142,165	89,005	133,939	131,519	127,138	134,618	-7,547	-5%
Scope 1 Total Emissions	**284,988**	**232,906**	**260,735**	**269,412**	**264,314**	**260,453**	**-24,535**	**-9%**

Scope 2 Emissions (metric tons CO_2e)	2005	2012	2015	2018	2020	2022	2005-2022 Change	2005-2022 % Change
Buildings Electricity	184,285	183,851	156,646	140,007	108,418	110,158	-74,127	-40%
Street Lighting	38,502	36,416	33,935	32,069	12,224	12,582	-25,920	-67%
Traffic Signals	7,733	7,157	4,755	4,075	3,130	2,981	-4,751	-61%
Water Services	155,368	137,793	121,158	122,002	105,452	92,848	-62,520	-40%
Scope 2 Total Emissions	**385,888**	**365,217**	**316,494**	**298,153**	**229,225**	**218,569**	**-167,319**	**-43%**

Scope 3 Emissions (metric tons CO_2e)	2005	2012	2015	2018	2020	2022	2005-2022 Change	2005-2022 % Change
Employee Commute	30,272	35,042	31,350	29,518	20,257	23,053	-7,219	-24%
Transmission and Distribution Loss	17,705	13,640	10,810	10,777	9,592	9,528	-8,178	-46%
Water Services	0	2,996	760	881	946	1,198	1,198	-
Scope 3 Total Emissions	**47,977**	**51,679**	**42,920**	**41,176**	**30,795**	**33,779**	**-14,198**	**-30%**

Total Emissions (metric tons CO_2e)	2005	2012	2015	2018	2020	2022	2005-2022 Change	2005-2022 % Change
Total Scope 1 and 2 Emissions	670,876	598,123	577,230	567,565	493,538	479,022	-192,116	-29%
Total Scope 1, 2, & 3 Emissions	**718,854**	**649,801**	**620,149**	**608,741**	**524,333**	**512,801**	**-206,314**	**-29%**
City of Phoenix Population	**1,377,980**	**1,473,405**	**1,536,015**	**1,598,736**	**1,625,593**	**1,662,186**	**284,206**	**21%**

2.1 Revisions

During the GHG inventory process, where necessary, updates and revisions are made to input data and methods used to calculate GHG emissions from previous years. This process may cause differences between previously reported emissions totals and emissions totals in this report. These revisions are detailed below for transparency.

2005:

- Updated the input data for estimating tailpipe CH_4 and N_2O from gasoline and diesel with the latest available data from the EPA.

2012:

- Data for the population treated by the 91st Avenue WWTP were updated and revised upwards.
- City of Phoenix population numbers were updated to match the Water Services Department population estimates instead of utilized Census estimates.
- Updated the input data for estimating tailpipe CH_4 and N_2O from gasoline and diesel with the latest available data from the EPA.

2015:

- Data for the population treated by the 91st Avenue WWTP were updated and revised upwards.
- City of Phoenix population numbers were updated to match the Water Services Department population estimates instead of utilized Census estimates.
- Updated the input data for estimating tailpipe CH_4 and N_2O from gasoline and diesel with the latest available data from the EPA.

2018:

- Data for the population treated by the 91st Avenue WWTP were updated and revised upwards.
- City of Phoenix population numbers were updated to match the Water Services Department population estimates instead of utilized Census estimates.
- Updated the input data for estimating tailpipe CH_4 and N_2O from gasoline and diesel with the latest available data from the EPA.

2020:

- Data for the population treated by the 91st Avenue WWTP were updated and revised upwards.
- Totals for diesel and B20 biodiesel consumption were updated. The 2020 inventory overestimated diesel consumption and did not accurately capture the Public Transit transition from diesel to B20 biodiesel.
- City of Phoenix population numbers were updated to match the Water Services Department population estimates instead of utilized Census estimates.
- Updated the input data for estimating tailpipe CH_4 and N_2O from gasoline and diesel with the latest available data from the EPA.

3 Methodology

3.1 Local Government Operations Protocol

Phoenix's 2005 baseline emissions inventory was based on the Local Government Operations Protocol (LGOP), developed by the International Council for Local Environmental Initiatives (ICLEI – now officially called 'ICLEI- Local Governments for Sustainability'), the California Climate Action Registry (CCAR), the California Air Resources Board (CARB), and The Climate Registry (The Registry). The LGOP serves as a national standard for quantifying and reporting emissions associated with government operations. To ensure consistency, the ASU and NAU team has used the 2010 version (Version 1.1) of the protocol for the previous GHG emissions inventories.

The LGOP provides a methodology for the calculation of GHG emissions from numerous sources and for the development of a comprehensive inventory report. Activity data are collected from a GHG emissions source and multiplied by an emission factor (e.g., metric tons CO_2 emitted per kWh) to calculate the total emissions. Where activity data are not available, they are modeled. The LGOP provides emission factors for most calculation methodologies used in the report. Measured or calculated emissions are then converted to carbon dioxide equivalent emissions (CO_2e) using the IPCC AR5 GWP factors[2] shown in Appendix A.

3.2 Scope Classifications and Sectors

GHG emissions from government operations are categorized as Scope 1, 2, or 3 emissions. Scope categories indicate whether GHG emissions are direct or indirect in order to improve transparency and to inform different types of climate policies and goals. The Scope categories are illustrated in Figure 2.

- Scope 1: Direct emissions from City owned or controlled operations.
- Scope 2: Indirect emissions associated with the consumption of purchased or acquired electricity, steam, heating or cooling that occur at sources not owned or controlled by the City.
- Scope 3 (optional under the protocol for cities to include in their inventories): All other indirect emissions not covered in Scope 2, such as transport-related activities in vehicles not operated by Phoenix (e.g., employee commuting and business travel) and other outsourced activities. This report includes employee commuting

[2] Greenhouse Gas Protocol, 2016. Global Warming Potential Values. URL: https://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf

and outsourced granular activated carbon (GAC) hauling and regeneration activity as Scope 3 emissions.

This report is organized into five sectors to make it more compatible for policy making and project management teams.

- Buildings and Facilities
- City Vehicle Fleet
- Water Distribution and Wastewater Treatment
- Solid Waste
- Employee Commute

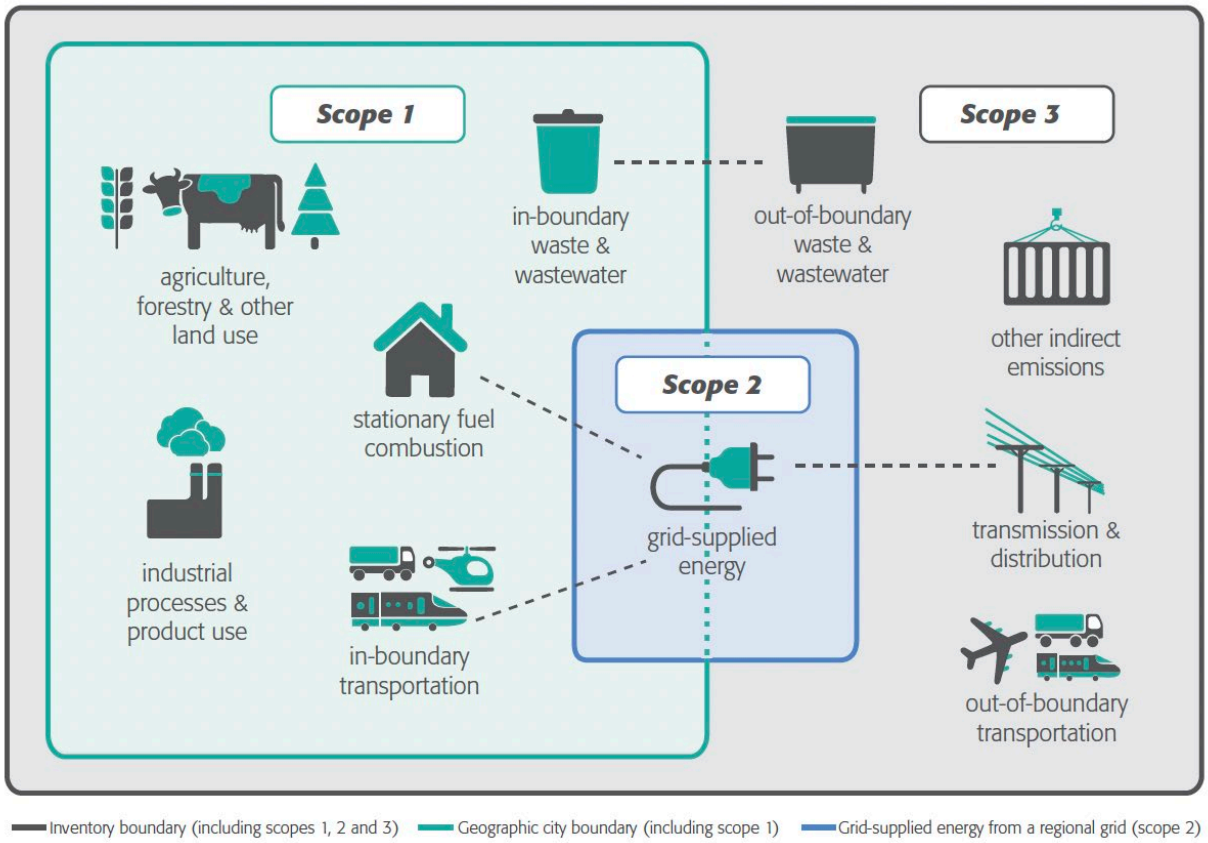


Figure 2. Overview of LGOP Scopes and Emissions Sources[3]

[3] Image Source: *Global Protocol for Community-Scale Greenhouse Gas Inventories: An Accounting and Reporting Standard for Cities Version 1.1*. URL: https://ghgprotocol.org/sites/default/files/standards/GPC_Full_MASTER_RW_v7.pdf

3.3 City of Phoenix Government Operations Boundary

The LGOP provides two approaches for defining the boundaries of what to include in the government operations GHG inventory: the first approach is *operational control* and includes those operations in which the local government has the authority to introduce and implement operating policies; the second is *financial control* and includes those operations that are fully consolidated in financial accounts. More detail on both approaches can be found in the LGOP Version 1.1[4].

This inventory uses the *operational control* approach as it most accurately represents GHG emissions sources within the City's control. The boundaries of the City operations GHG inventory follow the same guidelines as the 2005 baseline inventory. However, Scope 3 GHG emissions – emissions resulting from granular activated carbon (GAC) hauling and regeneration and electricity transmissions and distribution (T&D) loss – and biogenic emissions were added into the 2012 inventory, and have been included in each inventory since. The 27th Avenue Compost Facility was added to the municipal operations GHG emissions inventory in 2018 as a new facility. A detailed description of considerations of the City's operational control boundary is located in Appendix B.

3.4 Inventory Changes Since 2005

The 2022 GHG emissions inventory methodology generally follows that of the previous government operations GHG emissions inventories. With each emissions inventory, technical improvements are made to more accurately quantify emissions. In 2010, ICLEI and partners released the latest LGOP Version 1.1. The 2010 update included several changes to figures, methods, and other factors. Additionally, the 2005 and 2012 GHG emissions inventory utilized Intergovernmental Panel on Climate Change (IPCC) AR2 Global Warming Potential (GWP) emissions factors; the 2015 GHG emissions inventory utilized IPCC AR4 GWP emissions factors; the 2018 and 2020 GHG emissions inventory utilizes IPCC AR5 GWP; and the 2022 GHG emissions inventory utilizes IPCC AR6 GWP. This procedure of updating GWP factors, found in the EPA U.S. Greenhouse Gas Inventory Report, complies with the United Nations Framework Convention on Climate Change (UNFCCC) reporting guidelines for national inventories, requiring the use of the latest GWPs for national GHG emissions inventories[5].

[4] ICLEI USA, 2020. Greenhouse Gas Protocols. URL: https://icleiusa.org/ghg-protocols/
[5] UNFCCC Secretariat, 2014. Report of the Conference of the Parties on its nineteenth session, held in Warsaw from 11 to 23 November 2013. Decision 24/CP.19, paragraph 2. URL: http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf.

Estimating Tailpipe Emissions of Methane and Nitrous Oxide

The methodology used to estimate tailpipe methane (CH_4) and nitrous oxide (N_2O) emissions changed between the 2005 and 2015 GHG emissions inventories. In 2005, the Clean Air-Cool Planet's GHG modeling software was used to estimate fleet emissions of CH_4 and N_2O. The 2022 inventory uses the Climate Registry's simple estimation method for tailpipe CH_4 and N_2O emissions based upon fuel carbon dioxide content, providing a standard estimation of these emissions across fuel and vehicle types. Using this method, CH_4 and N_2O emissions factors were developed for the previous inventories using the EPA *Inventory of U.S. Greenhouse Gas Emissions and Sinks*[6]. This method avoids the need to track vehicle mileage.

Wastewater Treatment Methane and Nitrous Oxide Emissions

Wastewater treatment CH_4 and N_2O emissions for 2005 were obtained from the *City of Phoenix 2015 Greenhouse Gas Emissions Inventory for Government Operations.* Please refer to that report for an explanation for the backcasting methodology to estimate 2005 emissions levels. For the 2022 GHG inventory, population data for the 91st Ave WWTP were updated for the 2012, 2015, 2018, 2020, and 2022 inventory years. Population data were not updated for 2005 as these data were not made available. The updated population data, which increased the population served by the 91st Ave WWTP, increased GHG emissions wastewater treatment nitrous oxide emissions.

Alternative Fuel Estimates for Employee Commuting

Employee commuting data is based on an annual survey conducted by the Maricopa County Trip Reduction Program (TRP) regarding commuting throughout the work week. Alternative fuel combustion data were obtained Energy Information Administration (EIA) *Annual Energy Outlook* to estimate alternative fuel employee commuting. It was assumed that national alternative fuel combustion levels provided a proxy for alternative fuel combustion patterns for City employees[7].

Estimating Compost Emissions

In 2017, the City began operating the 27th Avenue Compost Facility. While another compost operation is located near the 27th Avenue Compost Facility, this is a private sector facility that is neither owned nor operated by the City. GHG emissions from composting were calculated according to EPA methodology for estimating national-level

[6] U.S. EPA (2019). Inventory of U.S. Greenhouse Gas Emissions and Sinks. URL: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks 2.
[7] U.S. Energy Information Administration (2013). Annual Energy Outlook. URL: https://www.eia.gov/outlooks/aeo/

emissions from composting in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019*[8].

Estimating Aviation GHG Emissions

The 2018 levels Jet Fuel A and Aviation Gasoline consumption for Police Department Aircraft were assumed for 2020 because the data was unavailable. Jet Fuel A and Aviation Gasoline consumption data were available for the 2022 GHG inventory.

[8] U.S. EPA. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017. URL: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2017

4 Results

4.1 Summary

Overall Findings

GHG emissions from City of Phoenix government operations have decreased 29% below 2005 levels.

Total GHG Emissions Sector*

- Buildings and Facilities** — 137,041 MT CO_2e
- City Vehicle Fleet — 119,400 MT CO_2e
- Employee Commute — 23,053 MT CO_2e
- Solid Waste — 124,614 MT CO_2e
- Water Services — 108,692 MT CO_2e

*Above GHG emissions represent all emissions within a sector across all emissions scopes and includes Transmission and Distribution Loss in the regional electricity grid.
** Excludes Water Services electricity and natural gas use.

2005 to 2022: What has Changed?

The 2022 GHG emissions inventory of City operations provides additional data in support of the City's efforts to reduce GHG emissions (Figure 3). Numerous projects and activities undertaken by the City since 2005 have significantly reduced the GHG intensity of City operations. Projects and activities, and how they have affected the government operations GHG emissions, are listed below.

- The installation of advanced methane capture systems at landfills reduced fugitive methane emissions from City landfills.
- Transitioning City Fleet to B20 and CNG from diesel has reduced the GHG intensity of Public Works activities.
- Public Transit has transitioned diesel consumption to B20 and increased use of CNG, reducing GHG intensity, while fuel consumption has increased since 2015 in order to meet service level needs, including T2050 goals.
- Energy efficiency upgrades to buildings and facilities, streetlights, traffic signals, water treatment and distribution, and wastewater treatment.

- The 27th Avenue Compost Facility, while adding to the city emissions, diverts material from the SR-85 landfill and produces an environmentally beneficial, salable product, and is expected to reduce overall GHG emissions over its lifetime through green-organic waste processing and reducing trips to the SR-85 landfill for disposal.

Beyond projects and activities undertaken by the City, the GHG intensity of the regional electricity grid – the Arizona-New Mexico (AZNM) eGRID subregion – has fallen 41% since 2005 and 24% since 2018. The 2019 retirement of the Navajo Generation Station and an increase in renewable energy generation reduced the GHG intensity of the regional electricity grid. The planned retirement of additional regional coal power plants over the next decade will further reduce the GHG intensity of the regional electricity grid.

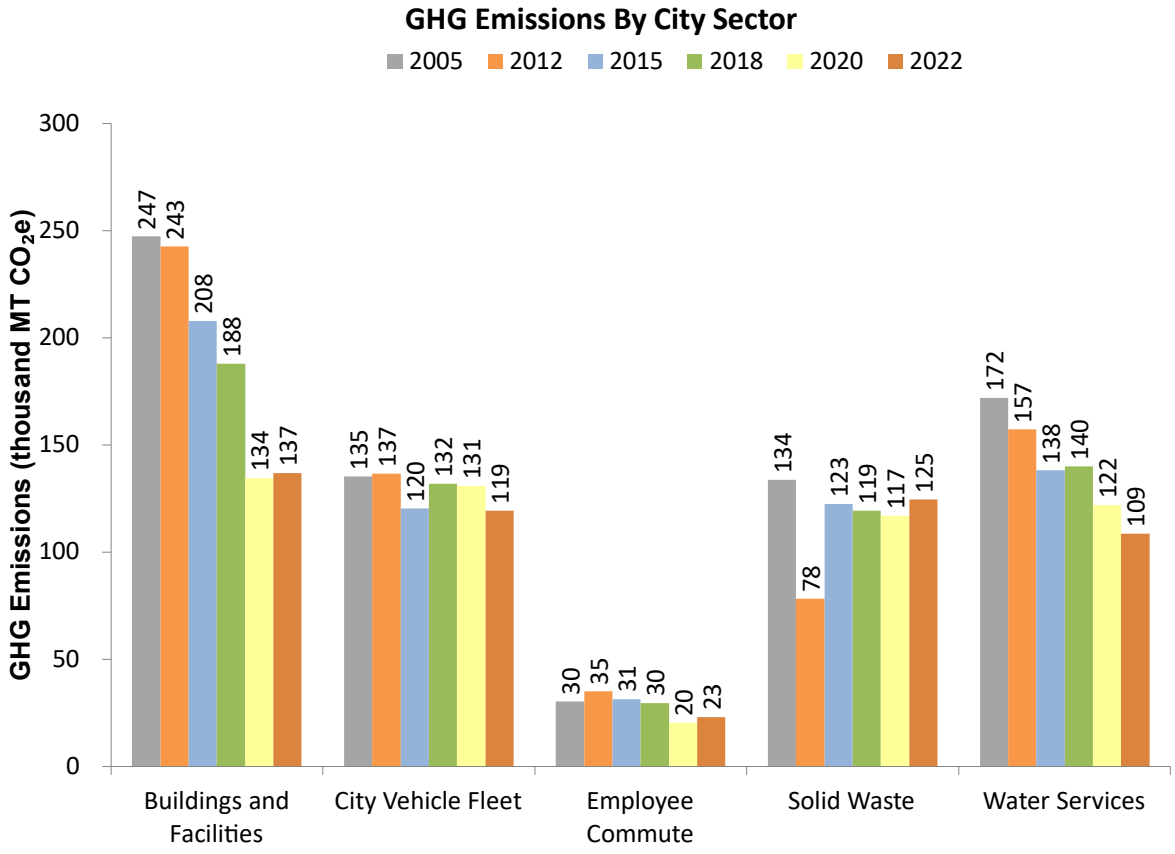


Figure 3. GHG Emissions by City Sector

Since 2005, reductions in GHG emissions from City government operations have been uncoupled from population growth and driven by changes to the regional electricity grid. Between 2005 and 2022, the City's population grew from 1,377,980 to 1,662,186

residents[9]. Despite this 22% increase in population, GHG emissions from operations decreased by 29% over the same period. If the GHG intensity of the regional electricity grid had remained at 2005 levels GHG emissions would have decreased by only 7% by 2022. City-led and regional measures that reduced the GHG intensity of consumed electricity or enhanced the energy efficiency of operations have enabled the City to decrease GHG emissions while growing significantly. As regional electricity utilities work toward net zero GHG emissions goals for 2050, electricity dependent GHG emissions will continue to decrease. However, measures to GHG emissions from the City's fleet and solid waste operations are required to meet long-term GHG emissions reductions goals.

Emissions Sources and Distribution

City government operations GHG emissions are largely attributed to four sources: Scope 1 emissions (direct) from Fugitive and Process Emissions and Fleet Fuels and Scope 2 emissions (indirect, purchased electricity) from Buildings and Water Services. Figure 4 details total GHG emissions by Scope and Subsector.

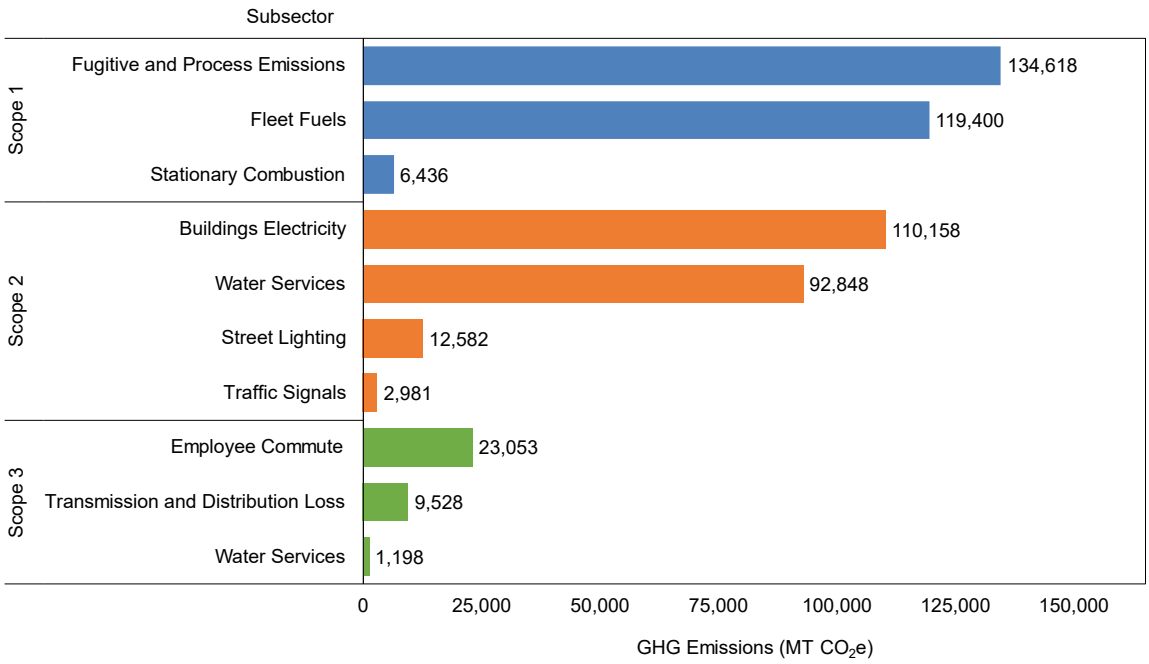


Figure 4. Total Emissions by Scope and Subsector

Scope 1 and Scope 2 GHG emissions account for 93% of GHG emissions from City government operations. Scope 1 emissions account for 51% of City government

[9] Population totals are estimated from City of Phoenix Water Services Department data on wastewater treatment populations.

operations GHG emissions (Figure 5). Of Scope 1 emissions, Fleet Fuels and Fugitive and Process Emissions represents 26% and 23% of total GHG emissions, respectively. Scope 2 GHG emissions from Buildings Electricity and Water Services each account for approximately 21% and 18% of total GHG emissions, respectively. Combined, these four sectors comprise 89% of GHG emissions from City government operations. As the regional electricity grid becomes less GHG-intensive, and if City REC purchases are incorporated into the GHG inventory, Scope 2 GHG emissions will comprise a smaller proportion of the City government operations GHG emissions inventory.

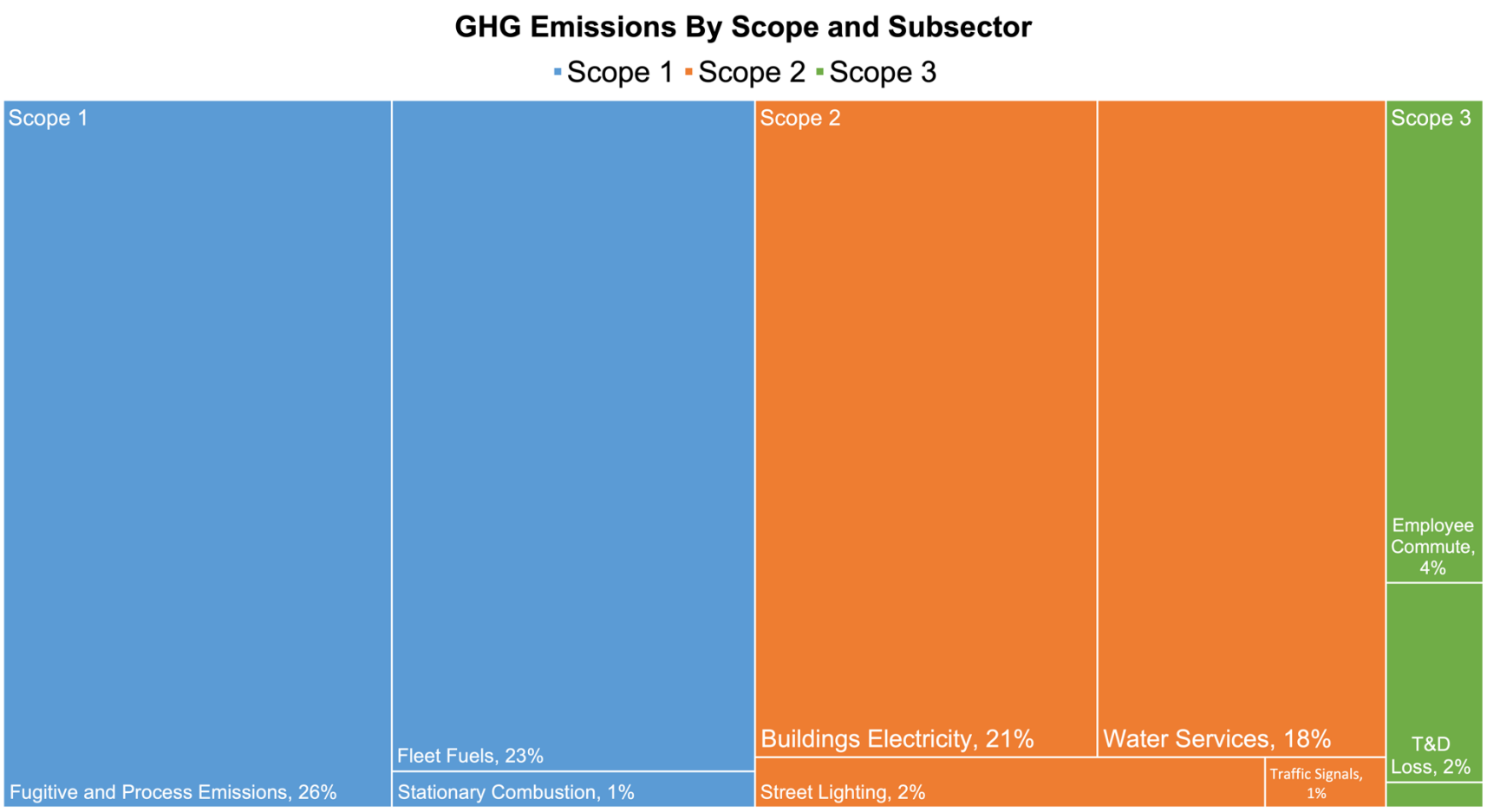


Figure 5. Percent of Total Emissions by Scope and Subsector

GHG Emissions Reductions Since 2005

Every GHG emissions subsectors has decreased emissions since 2005 (Figure 6).

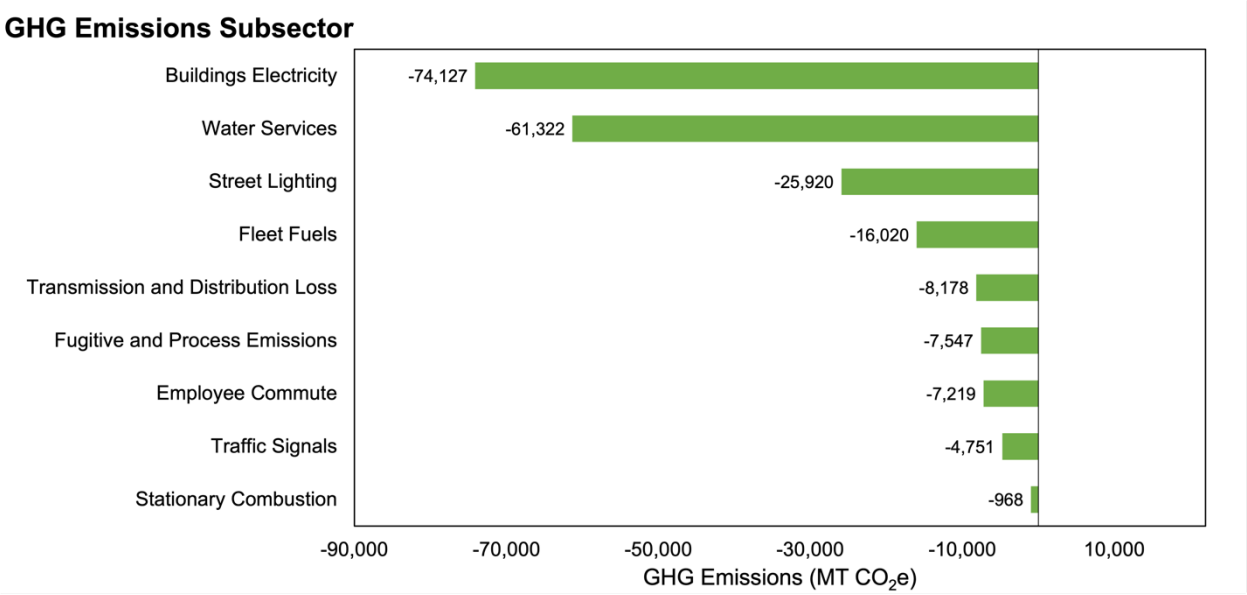


Figure 6. Emissions Changes Between 2005 and 2022.

Street Lighting (67%), Traffic Signals (61%), Buildings Electricity (40%), and Water Services (39%) subsectors and have had the largest observed decreases in GHG emissions between 2005 and 2022. The observed GHG emissions reductions in these subsectors were driven by two major factors. First, the regional electricity grid became less GHG intensive. A less GHG intensive regional electricity grid has led to the reduction of 167,319 MT CO_2e below 2005 levels. Second, energy efficiency projects have reduced electricity and natural gas consumption, but exact emissions reductions are difficult to quantify.

Additional factors that contribute to the observed GHG emissions reduction include:

- Completely transitioning from diesel to B20 biodiesel fuel in Public Transit vehicles.
- Capturing generated biogas at the 91st Avenue Wastewater Treatment Plant.
- A change in commuting patterns (increased teleworking) compared to previous inventory years.

5 Findings by Sector

5.1 Buildings and Facilities

Building and Facilities Findings

*Total Emissions: 225,005 MT CO_2e**
44% of government operations emissions
20% decrease from 2005 levels

Emissions Sources

- Building Electricity Consumption
- Building Natural Gas Consumption
- Streetlights Electricity Consumption
- Traffic Signals Electricity Consumption
- Water Services Electricity and Natural Gas Consumption*

City Action Highlights

- To date, the City has installed:
  - 94,865 LED Street Lights
  - 63,090 LED Signal Indicators
  - 9,308 LED Pedestrian Indicators

*Water Services electricity and natural gas consumption are included because this section describes trends for all electricity and natural gas consumption.

2005 to 2022: What has Changed?

- Between 2005 and 2022, the GHG emissions intensity of the AZNM subregion of the U.S. electricity grid fell by 41%.
- City electricity consumption fell by 6% between 2018 and 2020 but rebounded by 11% between 2020 and 2022. Increased electricity consumption by Aviation and the Convention Center drove the observed rebound between 2020 and 2022.

Emissions Sources and Distribution

GHG emissions in the Buildings and Facilities sector occur directly from the combustion of natural gas purchased from a natural gas utility and indirectly from the purchase of electricity.

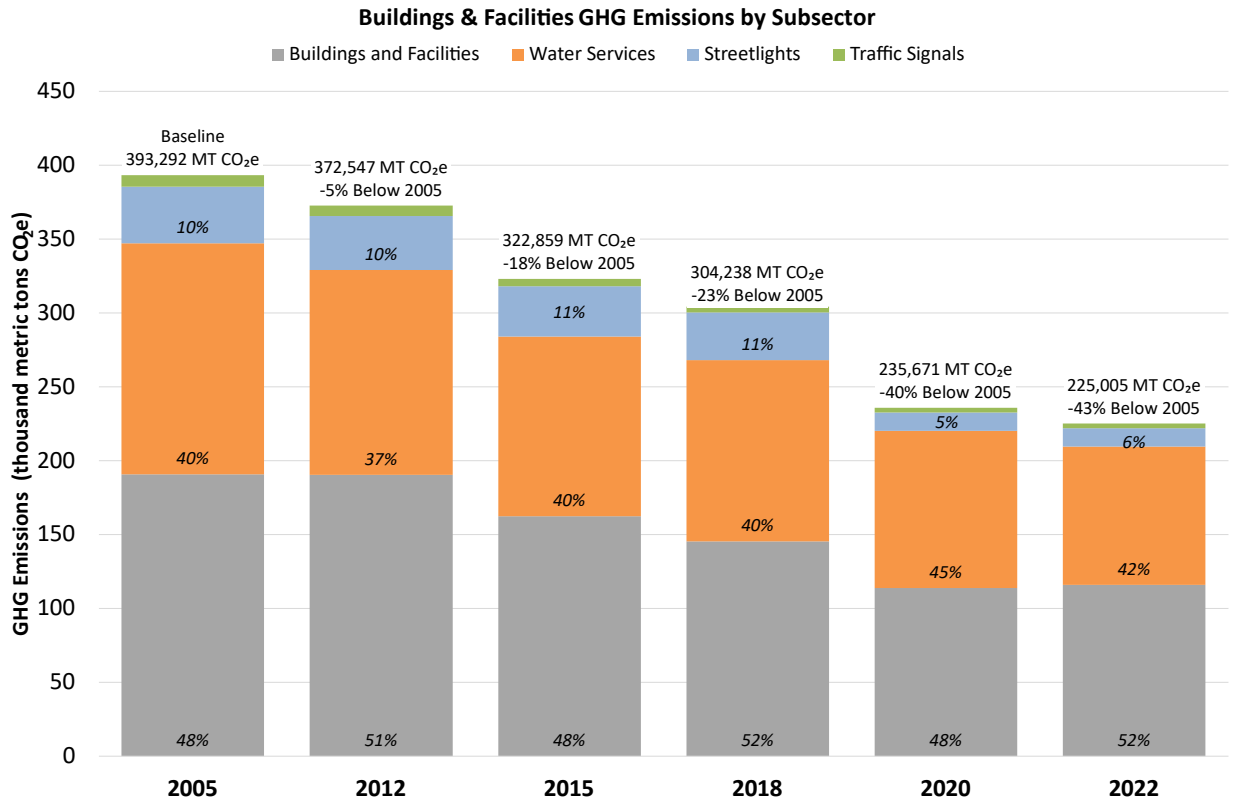


Figure 7. Buildings and Facilities GHG Emissions by Inventory Year

GHG emissions from natural gas combustion fell by 13% between 2005 and 2022 but increased 6% between 2018 and 2022 largely due to increased natural gas usage at the Convention Center. Additionally, GHG purchased electricity emissions decreased 43% below 2005 levels and 27% below 2018 levels. The steep decline in Buildings and Facilities GHG emissions is primarily due to a significant reduction in the GHG intensity of the regional electricity grid.

Streetlights electricity consumption peaked in 2015 at 71,316,538 kWh and has since fallen 50% to 35,591,984 kWh. In 2022, Traffic Signals electricity consumption was 35% lower than reported consumption in 2005 and 4% lower than 2018. The decrease in electricity consumption has occurred over a period during which the City has invested heavily in LED retrofits of Streetlights and Traffics Signals. Energy efficiency upgrades, along with a less GHG intensive electricity grid, have reduced GHG emissions from traffic signals and streetlights by 66% below 2005 levels.

The City owns RECs and has registered some of its REC purchases. A list of City owned and registered RECs is located in Appendix C. The data in Appendix C is for informational purposes only. Currently, RECs are not incorporated into the City's government

operations GHG inventory and, therefore, do not affect inventoried GHG emissions. Formalizing and approving a process to incorporate owned and registered RECs into future GHG emissions accounting would allow the City to utilize these assets in future GHG inventories.

GHG Metrics: Buildings and Facilities

Table 2 provides a list of key GHG metrics for City buildings and facilities. The indicator below provide high-level information about the GHG intensity of City of operations.

Table 2. Buildings and Facilities Emissions Indicators

Indicator	2005	2012	2015	2018	2020	2022
Building Space (sq. ft.)	25,948,884	30,624,893	12,599,324	11,495,864	13,735,753	13,093,814
Building Space GHG Emissions Intensity (kg CO_2e per sq. ft)	7.35	6.22	12.89	12.64	9.91	10.07
Per Capita GHG Emissions Intensity (kg CO_2e per resident)	138.4	129.3	105.7	90.9	70.1	69.6
Electricity GHG Emissions per CDD (kg CO_2e per CDD)	39.1	36.3	30.9	28.3	19.3	19.6
FTE GHG Emissions Intensity (kg CO_2e per FTE)	13.00	12.64	11.08	9.94	9.79	9.78

5.2 City Vehicle Fleet

City Vehicle Fleet Findings

Total Emissions: 119,400 MT CO_2e
24% of government operations emissions
12% decrease from 2005 levels

Emissions Sources

- Gasoline
- Diesel
- B20 Biodiesel
- Compressed Natural Gas (CNG)
- Liquefied Natural Gas (LNG)
- Liquefied Petroleum Gas (LPG)
- Ethanol
- Aviation gasoline (Police Department Aircraft)
- Jet Fuel A (Police Department Aircraft)

City Action Highlights

- Biodiesel alternative fuel program
- Ethanol alternative fuel program
- Adoption of CNG in Public Transit

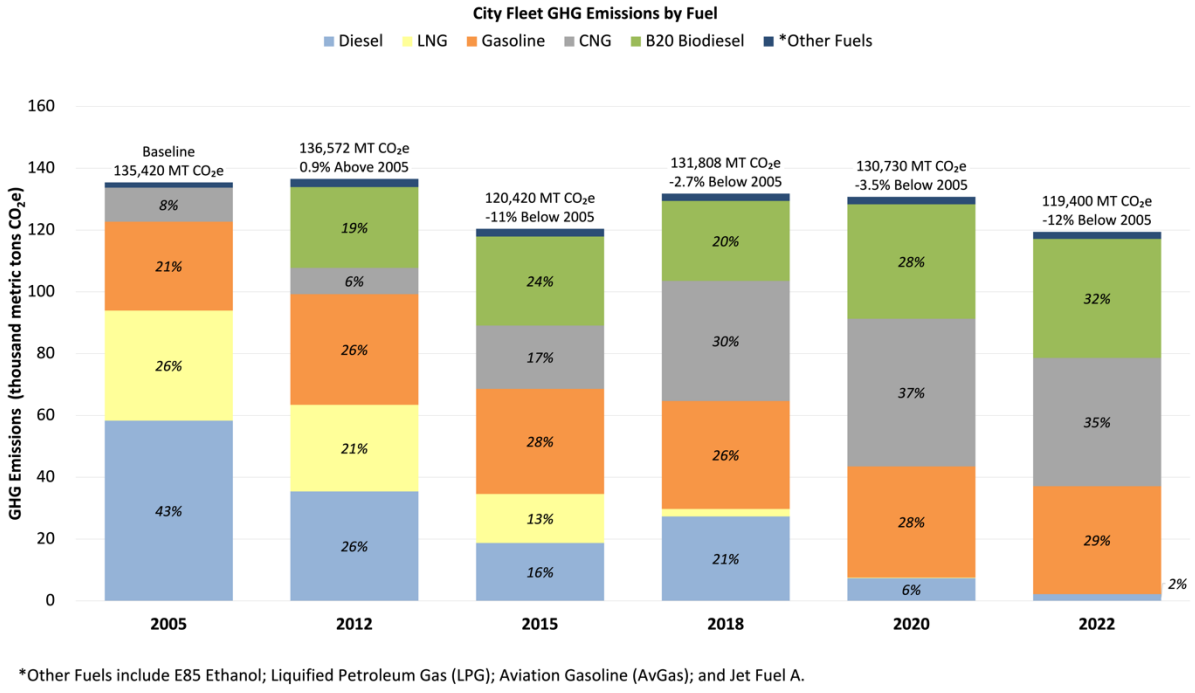
2005 to 2022: What has Changed?

- The size of Public Works fleet peaked in 2015 with 7,389 vehicles and has since decreased to 7,340 vehicles.
- Public Works and Aviation have converted the majority of the diesel vehicle fleet to B20 and CNG. However, Ultra Low Sulfur diesel fuel continues to be used in specific situations, such as emergency generators and fueling sites with low throughput.
- The PHX SkyTrain, completed in 2022, will transform how fuel is consumed to move people around Phoenix Sky Harbor International Airport by shifting away from CNG-powered buses to electric-powered automated people mover.
- GHG emissions from B20 and CNG have increased since 2018 due to added service miles as part of the City's Transportation 2050 (T2050) Plan

to increase local bus frequency, build out the existing city bus network, increase service hours of bus operations, and introduce new bus routes.

Emissions Sources and Distribution

CNG, gasoline, B20 vehicles were the largest source Vehicle Fleet GHG emissions in 2022. CNG and B20 consumption has increased as diesel consumption has decreased; 2022 diesel consumption was 59% of the 2005 levels. Since 2015, diesel consumption has increased 25% due to an increase in public transit service miles to meet T2050 goals. GHG emissions from gasoline and E85 has remained largely flat since 2012. Jet Fuel A and Aviation Gasoline GHG emissions are a small percentage of Vehicle Fleet emissions but have also increased compared to previous GHG inventory years. Figure 8 shows Vehicle Fleet GHG emissions by fuel type. Only the fossil fuel component of biofuel GHG emissions – 80% of each gallon of B20 and 15% of each gallon of E85 ethanol – is counted towards the GHG emissions.



*Other Fuels include E85 Ethanol; Liquified Petroleum Gas (LPG); Aviation Gasoline (AvGas); and Jet Fuel A.

Figure 8. Vehicle Fleet Emissions by Fuel by Inventory Year

Table 3 shows fuel consumption levels by fuel type and inventory year. The major changes to the levels of CNG, B20, and LNG fuel consumption is driven by Public Transit

vehicle fleet and service levels. The City began replacing LNG buses with more efficient CNG buses in 2013; all LNG buses are retired.

Table 3. City Fleet Fuel Consumption by Year

Fuel Type	Unit	2005	2012	2015	2018	2020	2022
Gasoline	gallon	3,172,441	3,976,124	3,813,990	3,936,224	4,064,327	3,951,270
Diesel	gallon	5,453,484	3,324,829	1,777,341	2,579,301	691,361	205,219
B20	gallon	0	3,034,345	3,394,710	3,027,969	4,309,358	4,494,994
Compressed Natural Gas (CNG)	GGE*	1,744,813	1,349,993	3,239,129	6,151,022	7,555,353	6,568,467
Liquefied Natural Gas (LNG)	gallon	7,917,008	6,222,272	3,528,633	543,296	38,866	0
E85 Ethanol	gallon	0	287,438	340,753	311,460	335,145	255,756
Liquified Petroleum Gas (LPG)^	gallon	14,392	0	0	0	0	0
Aviation Gasoline (AvGas)^	gallon	2,401	5,975	4,961	4,875	4,875	505
Jet Fuel A^	gallon	163,160	222,283	202,119	192,739	192,739	196,934

* GGE – Gasoline Gallon Equivalent
^ Jet Fuel A and Aviation Gas consumption levels were carried over from 2018 to 2020 due to a lack of available data.

GHG Metrics: Vehicle Fleet

Emissions per vehicle maintained by Public Works fell from approximately 9.2 to 6.1 MT CO_2e per vehicle, despite an increase to the number of vehicles (Table 4). The data shown in Table 4 are for Public Works vehicles only.

Table 4. City Fleet Indicators Change

Indicator	2005	2012	2015	2018	2020	2022
Number of Vehicles	6,090	7,387	7,389	7,340	7,340	7,400
MT CO_2e per Vehicle	9.4	7.3	6.7	6.8	6.6	6.1

5.3 Water Services

Water Services Findings

Total Emissions: 94,225 MT CO_2e
19% of government operations emissions
37% decrease from 2005 levels

Emissions Sources

- Water distribution stationary & process emissions
- 23rd Avenue and 91st Avenue wastewater treatment plants
- Granular activated carbon (GAC) hauling and regeneration
- Electricity and natural gas use

City Action Highlights

- The onsite capture of biogas at the 91St Avenue Wastewater Treatment plant has reduced GHG emissions from wastewater treatment.

2005 to 2022: What has Changed?

- The Cave Creek Water Reclamation Plant (WRP) was taken offline in January 2010 due to wastewater flows being half the plant capacity. However, due recent growth, the Cave Creek WRP is being rehabilitated and is planned to reopen in 2026.
- In January 2007, the Lake Pleasant Water Treatment Plant (WTP) came online.
- The Verde WTP was closed in December 2011. The Verde WTP has since been demolished and the area restored to natural conditions.
- In 2022, the Water Services department treated 98.7 billion gallons of water and 46.3 billion gallons of wastewater. The volume of water treated has increased 4% since 2005.
- The emissions from the hauling and regeneration of granular activated carbon (GAC) for water treatment did not occur in 2005 but have been included in the GHG inventory since 2012.

Emissions Sources and Distribution

Between 2005 and 2022, Water Services GHG emissions have decreased approximately 37% (Figure 9). The majority of Water Services GHG emissions occur from electricity consumption, and these emissions have decreased along with the GHG intensity of regional electricity grid. Most wastewater treatment GHG emissions – CH_4 flaring and N_2O wastewater discharge – are population-driven. Projected population increases over the next decade will likely increase these GHG emissions unless further mitigation efforts are undertaken. However, the capture and reuse of CH4 generated during wastewater treatment (biogas) has the potential to substantially reduce GHG emission from methane flaring.

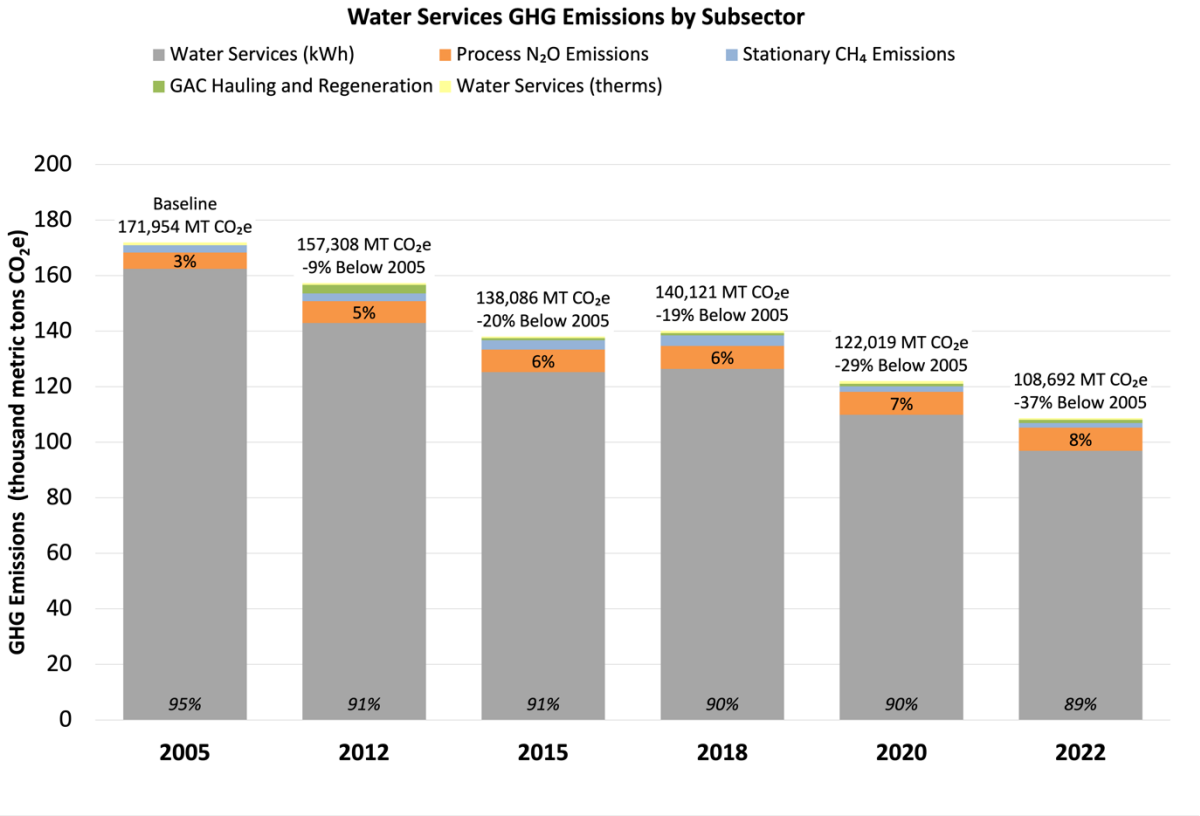


Figure 9. Water Services Emissions by Inventory Year

The changes in the GHG emissions observed at the 23rd Avenue and 91st Avenue WWTPs are due to a combination of population change as well as the changes in operation at the WWTPs, such as biogas capture. Wastewater treatment GHG are shown in Figure 10.

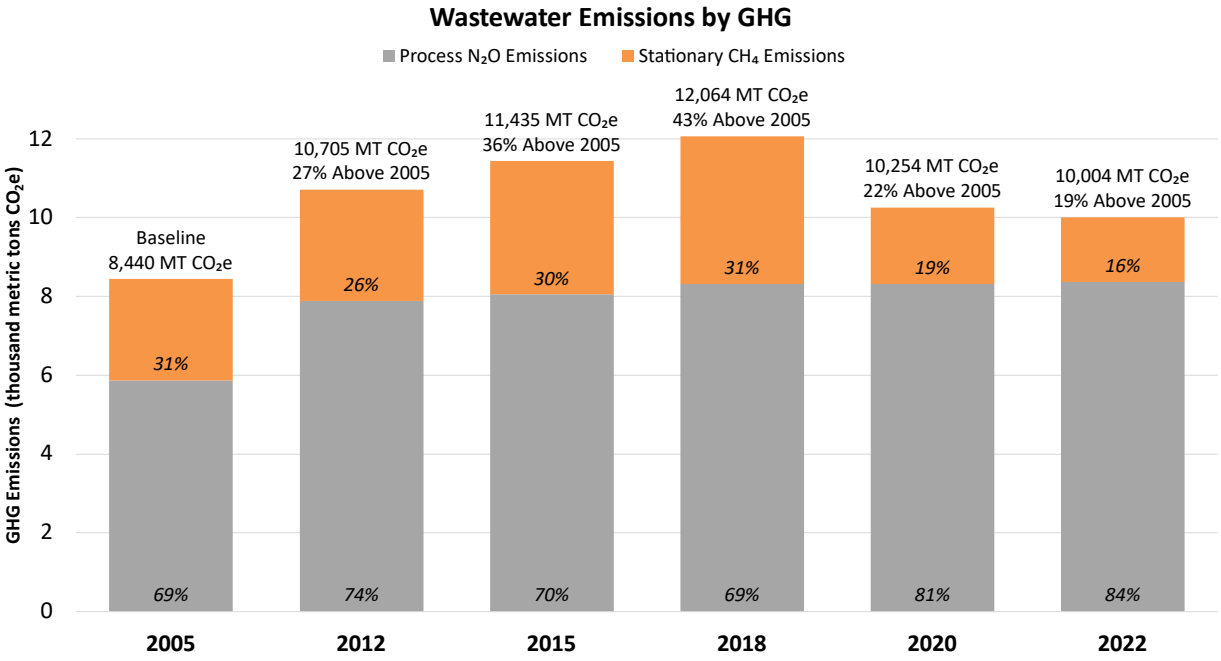


Figure 10. Wastewater Treatment GHG Emissions by Inventory Year

GHG emissions at the 23rd Avenue and 91st Avenue WWTPs are shown in Table 5. During 2022, the 91st Avenue WWTP, which is the larger of the two WWTPs, emitted roughly the same amount of GHGs as the 23rd Avenue WWTP. The 91st Avenue WWTP accepts wastewater from Glendale, Mesa, Scottsdale, and Tempe. In previous inventory years, the 91st Avenue WWTP emitted more than double the 23rd Avenue WWTP. The reduction in GHG emissions at the 91s Avenue WWTP observed in 2022 occurred because of the reuse of captured methane emissions (biogas). Currently, the City accounts for all GHG emissions at the 91st Avenue WWTP because the plant is under the City's operational control.

Table 5. 2022 GHG emissions at the 23rd Avenue and 91st Avenue WWTPs

Wastewater GHG Emissions Source		Wastewater Treatment Plant ($MT CO_2e$)		Total
		23rd Avenue	91st Avenue	
Stationary CH_4 Emissions	Incomplete Digester Gas Combustion	1,933	194	**2,126**
Process N_2O Emissions	Effluent Discharge	386	1,341	**1,726**
	Nitrification/Denitrification	5,375	5,375	**4,242**
Total		**3,322**	**3,402**	**4,693**

GHG Metrics: Water Services

Water Services indicators in Table 6 below shows that the GHG intensity of drinking water served by the City has consistently decreased since 2005.

Table 6. Water Services Emissions Indicators

Indicator	2005	2012	2015	2018	2020	2022
Gallons of Drinking Water Treated (billion gallons)	105.9	98.95	95.35	99.23	102.64	98.71
MT CO_2e per Billion Gallons Treated	1,624	1,590	1,448	1,412	1,189	1,101
Water Treatment Plants	6	5	5	5	5	5
MT CO_2e per WTP	28,659	31,462	27,617	28,024	24,404	21,738
Million Gallons of Wastewater Treated	69.5	42.2	40.3	40.8	41.1	46.3
MT CO_2e per Million Gallons Wastewater Treated	2,473	3,728	3,424	3,436	2,965	2,347

5.4 Solid Waste

Solid Waste Findings

Total Emissions: 124,614 MT CO_2e
24% of government operations emissions
7% decrease from 2005 levels

Emissions Sources

- City landfills emitted 117,029 MT CO_2e
- The 27th Avenue Compost Facility emitted 7,585 MT CO_2e

City Action Highlights

- 27th Avenue Compost Facility will help avoid future GHG emissions

2005 to 2022: What has Changed?

- In 2006, the State Route 85 (SR-85) landfill was opened and features an ongoing installation of a landfill gas collection system, which includes horizontal wells that can capture gas while waste is still being placed in the landfill.
- In 2017, the City opened the 27th Avenue Compost Facility. This facility increases the solid waste emissions, but is expected to reduce long-term GHG community emissions associated with the hauling and disposal of green & organic solid waste at the SR-85 Landfill.

Emissions Sources and Distribution

The SR-85 landfill, which opened in 2006, is the only operational landfill managed by the City. The SR-85 landfill has an active landfill gas collection system which has a 65% collection efficiency. The City also manages six closed landfills. Collection efficiencies at closed City landfills ranged from 50-85%. The Del Rio Landfill is the only City landfill that does not have a landfill gas collection system. Methane emissions are expected to increase at the SR-85 landfill as it is the only active landfill in the City, while methane emissions from the other City landfills will decrease as they are now closed (Figure 11).

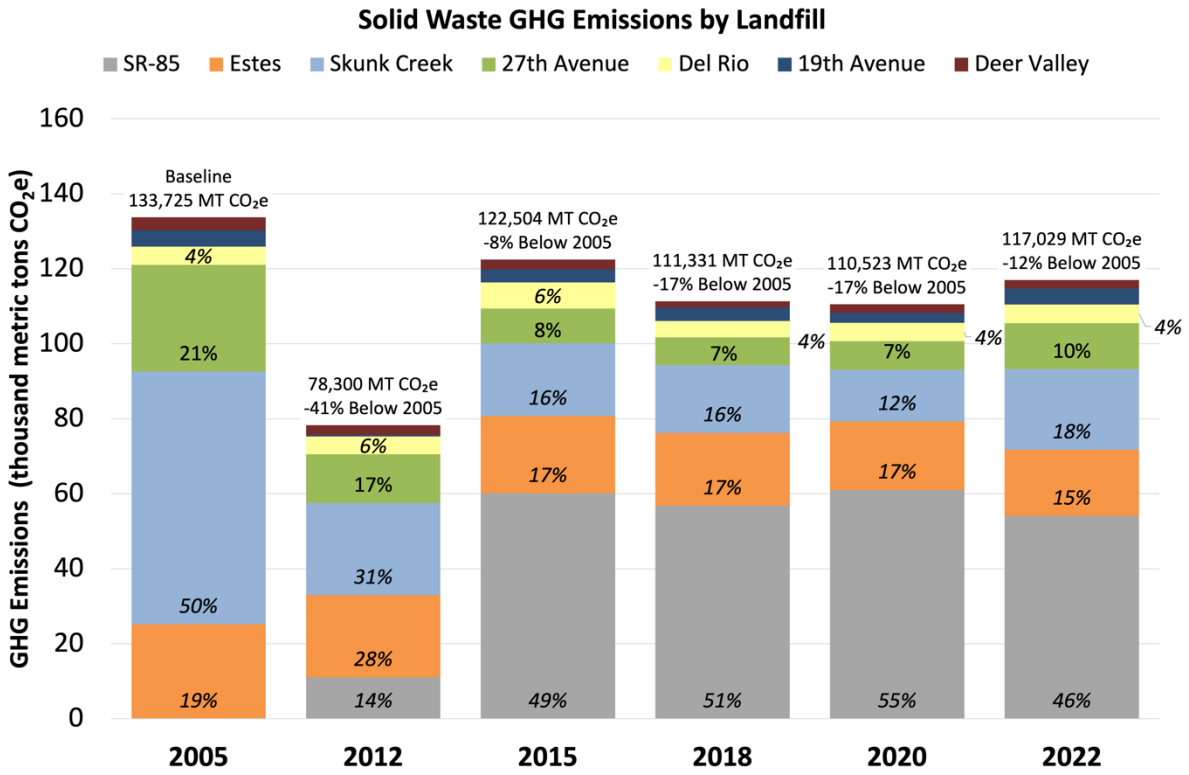


Figure 11. GHG Emissions from Phoenix Landfills by Inventory Year

Table 7 provides an overview of the amount of methane (CH_4) collected and flared, the resulting methane released after flaring, and the MT CO_2e emissions produced from the released methane at each facility.

Table 7. Solid Waste Emissions by Landfill

Facility	2005	2012	2015	2018	2020	2022
Skunk Creek	67,375	24,589	19,400	18,047	13,803	21,479
27th Avenue	28,476	13,013	9,257	7,403	7,643	12,282
Del Rio	4,902	4,760	6,986	4,367	4,859	4,942
Deer Valley	3,394	2,548	2,641	1,664	2,241	2,208
19th Avenue	4,377	429	3,468	3,598	2,676	4,345
Estes	25,200	21,896	20,636	19,432	18,284	17,702
SR-85	0	11,064	60,116	56,820	61,016	54,071
Total	**133,725**	**78,300**	**122,504**	**111,331**	**110,523**	**117,029**

Landfill GHG emissions in this report will differ from data reported to the EPA Greenhouse Gas Reporting Program. The City operations GHG emissions inventory utilizes landfill methane flaring formulas contained in the LGOP methodology, while EPA utilizes a

different methodology for both GHG emissions and estimated gas collection system capture rates. EPA specifies use of a capture rate formula which relies on cover type and area, this GHG update estimates capture rates at city landfills using operational indicators, such as status of ongoing gas well installation at SR-85, which includes horizontal wells, surface monitoring, flare data, and landfill cover maintenance.

27th Avenue Compost Facility

In 2017, the City opened the 27th Avenue Compost Facility. The facility processed 39,606 tons of compost in CY 2022, resulting in the emission of 158 MT CH_4 and 12 MT N_2O. Total GHG emissions from the compost facility were 7,585 MT CO_2e.

By composting green-organic waste at the 27th Avenue Compost Facility, the City will reduce the number of trips necessary to haul waste to the SR-85 Landfill, which in turn reduces Vehicle Fleet emissions. Over time, GHG emissions reductions from the 27th Avenue Compost Facility will be measurable compared to landfilled material.

GHG Metrics: Solid Waste

Table 8 contains high-level indicators for the City's Solid Waste GHG Solid Waste sector. These indicators include the total amount of waste deposited in City landfills for each GHG inventory year, the GHG emissions per ton of waste landfilled, and the amount of compost processed each GHG inventory year.

Table 8. GHG Emissions Indicators for Solid Waste

Indicator	2005	2012	2015	2018	2020	2022
Amount of Waste in Place (short tons)	44,030,052	50,257,923	52,405,666	54,666,679	55,451,840	56,480,962
Kg CO_2e Per Ton of Solid Waste in Landfills	3.04	1.56	2.34	2.04	1.99	2.07
Compost Processed (short tons)	—	—	—	46,768	33,213	39,606

5.5 Employee Commute

Employee Commute Findings

Total Emissions: 23,053 MT CO_2e
4% of government operations emissions
24% decrease from 2005 levels

Emissions Sources

- Gasoline
- Compressed Natural Gas (CNG)
- Hybrid Electric Vehicles
- Electric Vehicles
- Liquefied Petroleum Gas (LPG)
- Ethanol – E85

City Action Highlights

- Construction of light rail
- Employee Rideshare Program
- Development of Employee Telework Policies

2005 to 2022: What has Changed?

- City employees fill out surveys as part of the Trip Reduction Program (TRP) overseen by Maricopa County Air Quality Department. The TRP, which started in 1989, provides employers a yearly analysis of employee community statistics and behaviors.
- Employee commuting from 2005 did not include miles by bus or light rail as this data was not available. Bus and light rail commuting data were available for the rest of the previous GHG emissions inventories.
- Employee commuting using city vehicles is counted in the City Vehicle Fleet sector to avoid double counting.
- Employee commuting miles have rebounded from 2020 lows induced by the strict work-from-home policies, but still remain lower than their peak.

Emissions Sources and Distribution

Employee commuting GHG emissions occur from the fuel use for personal vehicles, vanpools, bus transit, and light rail is used to account for commuting emissions (Table 9). Alternative fuel use was estimated using annual transportation fuel usage data EIA Annual Energy Outlook. Emissions from bus commuting are reported in the Public Transit sector. Instances of employees commuting in city vehicles are counted as City Vehicle Fleet emissions. The employee commuting data show that there was an increase in hybrid-electric and plug-in electric vehicle employee commuting miles.

Table 9. Employee Commute Emissions by Fuel Type/Mode

Year	Commuting Miles	GHG Emissions (MT CO_2e)
2005	84,325,745	30,272
2012	99,937,270	35,042
2015	88,496,426	31,350
2018	87,386,610	29,518
2020	60,556,831	20,799
2022	69,483,014	23,053

*Commuting miles for 2005 were backcast from 2015 levels using employment data.
‡ The Valley Metro Light Rail did not exist in 2005.
°GHG Emissions not included in total.

City Action Highlights

The Phoenix Light Rail opened in 2008, providing city employees another opportunity to commute by public transit. The City also continued other employee commute programs, such as the rideshare program, providing carpool-parking subsidies, free bus/light rail passes for employees, emergency ride home cab vouchers, telecommuting, flex-work schedules, bicycle facilities and other incentives. However, given the structure of the current commuting data it is difficult to estimate GHG emissions from commuting alternatives. The City can encourage employees to seek alternative modes of travel to commute to work. Increasing telecommuting opportunities will decrease GHG emissions associated with employee travel.

6 City of Phoenix GHG Metrics

Table 10 details GHG Indicators for City of Phoenix government operations.

Table 10. Internal Government Operations Indicators

Government Operations Indicators	2005	2012	2015	2018	2020	2022	Unit
Population	1,377,980	1,473,405	1,536,015	1,598,736	1,625,593	1,662,186	People
Employees	14,667	12,849	14,664	14,615	14,847	14,857	Employees
Building Area	—	30,624,893	12,599,324	11,495,864	13,735,753	13,093,814	Sq. ft.
Cooling Degree Day (CDD)	4,709	5,070	5,065	4,943	5,419	5,030	CDD
Building Area GHG Intensity	—	6.22	12.89	12.64	9.91	10.02	kg CO_2e per sq. ft
Per Capita GHG Intensity	138.37	129.30	105.74	90.90	70.07	69.31	kg CO_2e per resident
CDD Electricity GHG Intensity	39.13	36.30	30.93	28.32	19.30	19.52	kg CO_2e per CDD
FTE GHG Intensity	13.00	12.64	11.08	9.94	9.79	9.78	kg CO_2e per FTE
Drinking Water Treated	105.9	98.9	95.4	99.2	102.6	98.7	billion gallons
Drinking Water GHG Intensity	1,556	1,507	1,397	1,359	1,137	908	MT CO_2e per billion gallons
Water Treatment Plants (WTP)	6	5	5	5	5	5	number
WTP GHG Intensity	27,471	31,075	27,203	27,650	23,876	23,876	MT CO_2e per WTP
Wastewater Treated	42,196	42,196	40,328	40,785	41,147	46,316	million gallons
Wastewater GHG Intensity	3.91	3.54	3.30	3.31	2.84	1.93	MT CO_2e per million gallons
Solid Waste in Place (WIP)	44,030,052	50,257,923	52,405,666	54,666,679	55,451,840	56,480,962	tons
Solid Waste GHG Intensity	3.04	1.56	2.34	2.19	2.11	2.21	kg CO_2e per Ton WIP
Fleet Size	6,090	7,387	7,389	7,340	7,340	7,400	Number of Vehicles
Fleet Vehicle GHG Intensity	9	7	7	7	7	6	MT CO_2e per Fleet Vehicle
Vehicle Miles Traveled (VMT)	52,825,683	48,022,781	—	35,990,125	—	—	VMT
VMT GHG Intensity	1	1	—	1	—	—	kg CO_2e per VMT
Gasoline Consumption	3,172,441	3,976,124	3,813,990	3,936,224	4,064,327	3,951,270	gallons
Diesel Consumption	5,453,484	3,324,829	1,777,341	2,579,301	691,361	205,219	gallons
Diesel + B20 Consumption	5,453,484	6,359,174	5,172,051	5,607,270	5,000,720	4,700,213	gallons
CNG Consumption	1,744,813	1,349,993	3,239,129	6,151,022	7,555,353	6,568,467	GGE
Commuting Gasoline Miles Traveled	80,555,678	93,917,068	83,504,307	82,130,508	57,275,929	65,100,850	miles
Commuting Gasoline Miles Per Employee	5,576	7,167	5,711	5,620	3,858	4,382	mile per FTE
% Single Occupancy Vehicle	74%	74%	76%	72.10%	67.90%	69.40%	%
Alternative Fuel Vehicle Miles	891,044	1,140,705	1,402,897	3,354,038	3,013,192	4,115,826	mile

Appendix A: Greenhouse Gas Equivalents

Table A1. IPCC AR2, AR4, and AR5 Global Warming Potential (GWP) Values

Greenhouse Gas*	AR2 GWP Values[1]	AR4 GWP Values[2]	AR5 GWP Values[3]
Carbon Dioxide (CO_2)	1	1	1
Methane (CH_4)	21	25	28
Nitrous Oxide (N_2O)	310	298	265

*Only carbon dioxide, methane and nitrous oxide were included in the 2005 and 2015 inventories

[1]GWP values used in the previous City of Phoenix 2005 and 2012 local government operations GHG emissions inventories.

[2]GWP values used in the City of Phoenix 2015 local government operations GHG emissions inventories.

[3]GWP values used in *2018, 2020, and 2022 City of Phoenix GHG Emissions from Government Operations*.

Appendix B: City of Phoenix's Government Operations Boundary

Wastewater Facilities

For the 2012 government operations GHG emissions inventory, the City considered whether the 91st Avenue wastewater treatment plant (WWTP) emissions should be part of the inventory. This plant accepts wastewater from several other cities and is operated under a formal Joint Powers Authority (JPA) agreement. Although the LGOP accounting system recommends that JPA's be excluded from the inventory, the full emissions from this facility have been included, as the City operates the facility and is listed as the responsible party on the facility's air and water permits. Inclusion of the plant's full emissions has continued in the current GHG emissions inventory of government operations.

Solid Waste Facilities

The 2022 inventory includes estimated emissions from the 27th Avenue Compost Facility. As this facility was opened in 2017, the 2018 inventory is the first inventory where city-owned compost operations are included.

Biogenic CO_2 Emissions

Biogenic CO_2 emissions are emissions from non-fossil carbon sources—such as biodiesel and ethanol in blended biofuels—and the conversion of methane to carbon dioxide resulting from methane flaring. According to LGOP, biogenic CO_2 emissions do not add carbon into the atmosphere as these sources of CO_2 are part of the natural carbon cycle and do not count toward local government operations GHG emissions total. The City can shift fossil CO_2 emissions to biogenic CO_2 emissions through the continued conversion of diesel fleet vehicles to biodiesel blends in addition to the development of biomass-based sources of electricity.

Leased Facilities

The City also reviewed options for including the facilities that are owned by Phoenix but leased to other entities. Consistent with the operational control in the protocol, the inventory would generally not include energy used at city-owned leased facilities. However, a unique circumstance occurs at Phoenix Sky Harbor International Airport. The airport could have excluded facilities that are leased to tenants (airlines, restaurants, gift shops, etc. which account for 1/3 of the terminal areas and 1/3 of common use areas) on

a proportional basis because the costs of the energy used at those airport facilities are allocated to tenants based on the size of revenue-generating area. The City chose to include emissions from the entirety of the airport-owned facilities as the airport runs the building energy systems and pays the energy bills.

Scope 3 Emissions

The City has chosen to report Employee Commute and GAC hauling and regeneration emissions because it does not maintain direct operational control and therefore is not required to report these emissions. However, because Phoenix has influence over its employees commuting habits through various rideshare incentives and telecommuting, it chose to include these emissions in the inventory as Scope 3 emissions (Scope classifications are explained below). It also chose to report emissions from outsourced GAC hauling and regeneration as Scope 3 emissions in the Water Services sector because the city holds financial control and considers it an area over which it has influence. Both sludge and solid waste hauling were included as Scope 1 emissions as those contracts are considered more integral to government operations and control.

Appendix C: Renewable Energy Credits

Table C1. Renewable Energy Credits (RECs) Owned and Registered By the city of Phoenix

RECs Owned and Registered		
Name	**2022 Value**	**Unit**
SRP Sleeve PPA - Eloy	31,585,447	kWh
Hoover Dam	7,629,000	kWh
Total	**39,214,447**	**kWh**

Appendix D: Findings by Scope

Appendix C presents City government operations GHG emissions by GHG emissions scope (Scope). GHG emissions by Scope are shown in Figures D1 and D2.

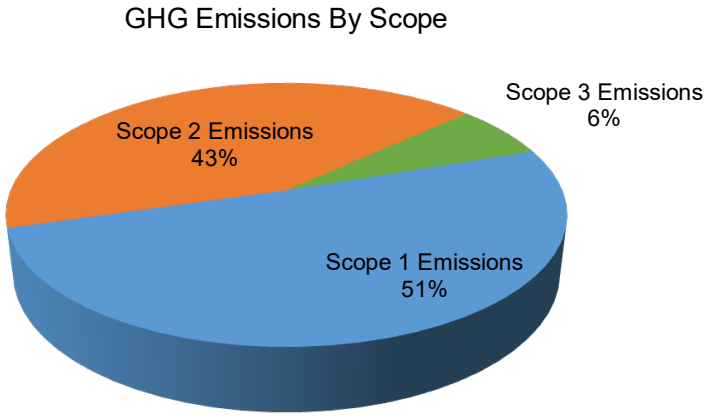


Figure D1. GHG Emissions by Scope

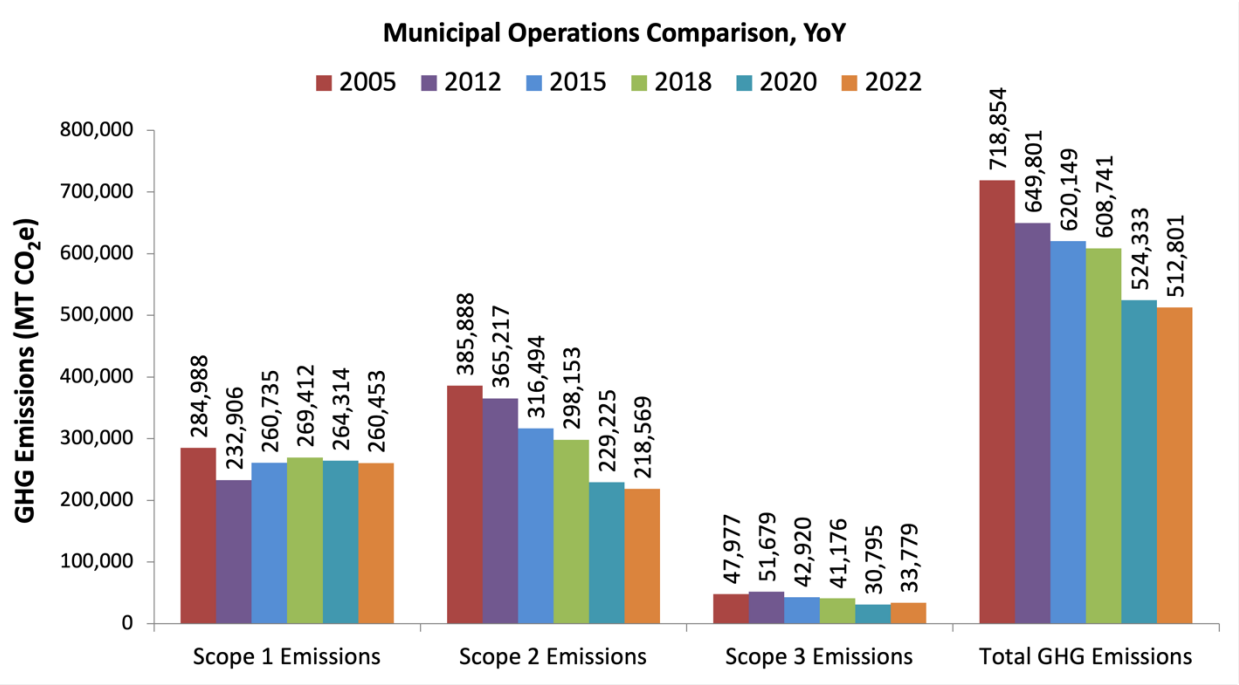


Figure D2. Government Operations GHG Emissions by Scope and Inventory Year

Scope 1

Scope 1 emissions contribute 52% of the city's total emissions accounting for 260,191 MT CO_2e. Between 2005 and 2022, Scope 1 emissions decreased 1.6%. Scope 1 is comprised of stationary combustion, fleet fuels, and fugitive and process emissions from landfills and wastewater treatment plants (Figure D3). The combustion of natural gas in buildings, and the resulting emissions, decreased 13% between 2005 and 2022, while natural gas combustion for water distribution treatment decreased 42%. The City's fugitive and process GHG emissions decreased 5% between 2005 and 2022. Fugitive methane emissions from landfills decreased by 12%. Fugitive and process emissions from wastewater treatment decreased by 36% because of the capture and reuse of flared methane at the 91st Avenue WWTP. The 27th Avenue Compost Facility was a new source of fugitive and process emissions in 2018.

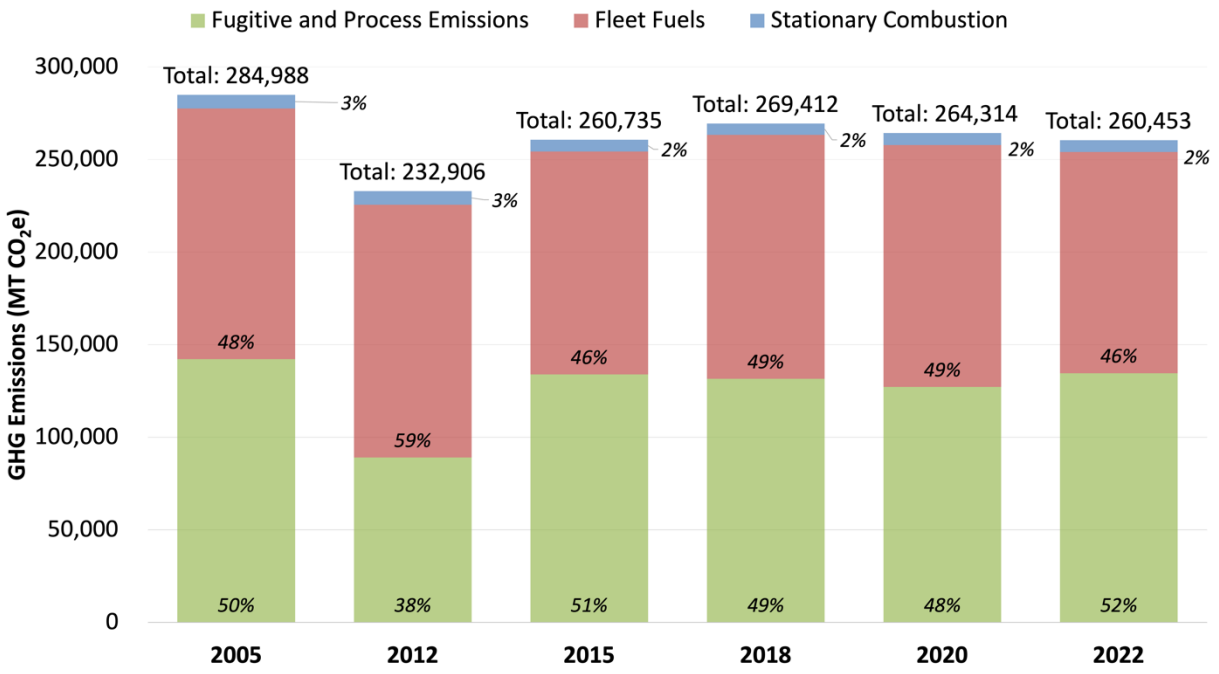


Figure D3. Scope 1 Emissions by Inventory Year

The City's fuel portfolio has changed significantly between 2005 and 2022 with the addition of B20 vehicles, CNG, and E85 flex fuel vehicles; B20 vehicles are primarily used in Public Transit. However, an increase in service miles has caused an increase in Fleet Fules (Public Transit) emissions between 2015 and 2022.

Scope 2

Scope 2 GHG emissions are indirect GHG emissions from the off-site generation of electricity used in municipal buildings, street lighting, traffic signals and wastewater treatment. Scope 2 emissions from electricity generation are calculated from billed electricity, so the benefits of on-site generation of electricity from solar enery projects are not directly accounted for and buildings may consume more electricity (both solar and grid-based generated) than what is billed (grid-based only).

Scope 2 emissions account for 43% of the City's total emissions and totaled 218,569 MT CO_2e (Figure D4) and also decreased 43% between 2005 and 2022. The significant Scope 2 GHG emissions reductions occurred over period where purchased electricity decreased only 4%. Between 2005 and 2022, the carbon intensity of purchased electricity in Arizona decreased 41% due to increased renewable energy and natural gas generation and decreased coal generation in the region electricity grid.

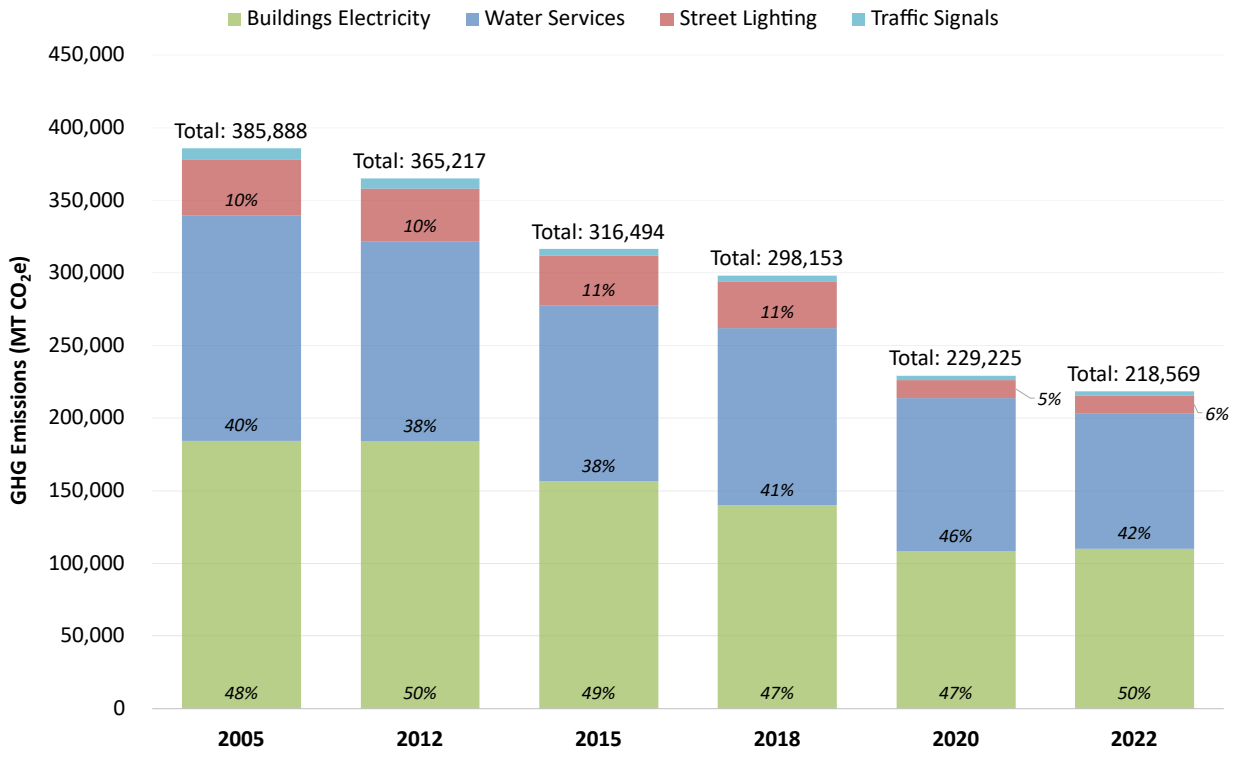


Figure D4. Scope 2 Emissions by Inventory Year

Scope 3

Scope 3 is comprised of fuel emissions from employee commute, GAC Hauling and Regeneration, and the total T&D loss in the electricity grid associated with electricity purchased by the city. Although the city does not operationally control Scope 3 emissions, the LGOP encourages the reporting of activities relevant to a city's GHG programs and goals. The City chose to report emissions from these sectors because it has some ability to impact those activities through various policies, programs, and contracts.

Scope 3 emissions account for 6% of the City's total emissions with a total of 33,779 MT CO_2e. Between 2005 and 2022, emissions from Scope 3 decreased 30%. GHG emissions from employee commuting are the largest component (68%) of Scope 3 emissions (Figure D5).

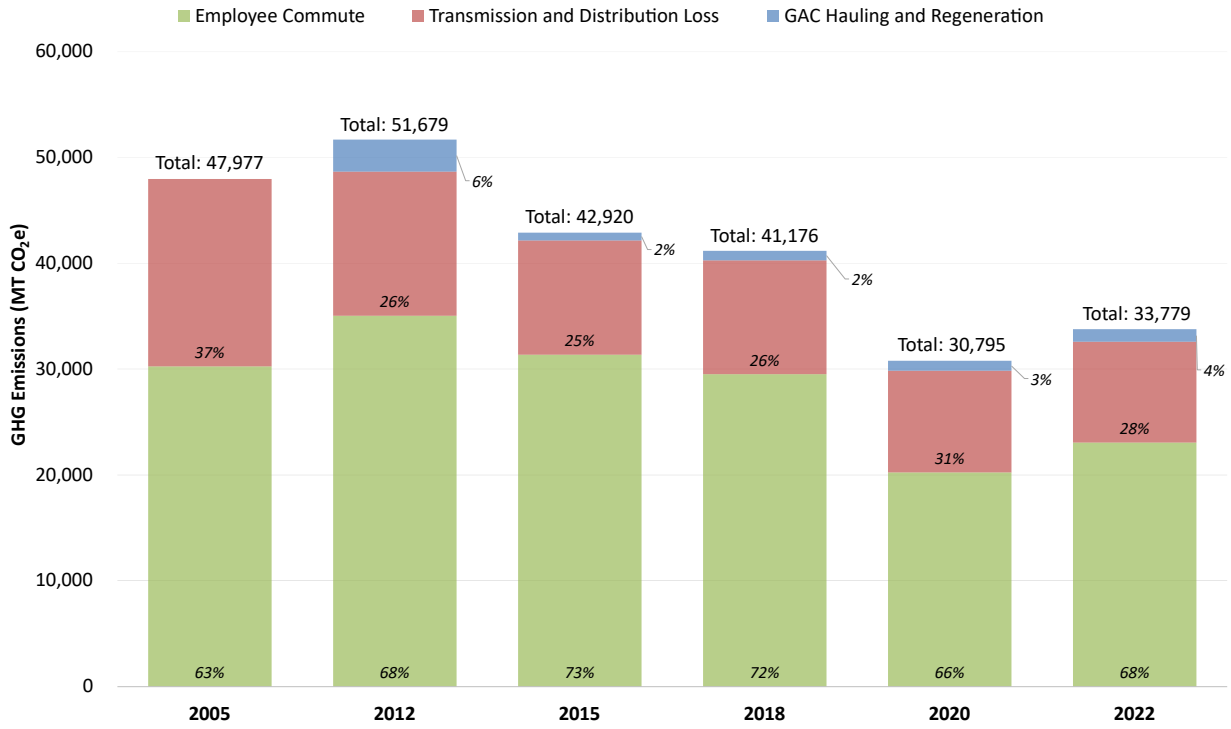


Figure D5. Scope 3 Emissions by Inventory Year