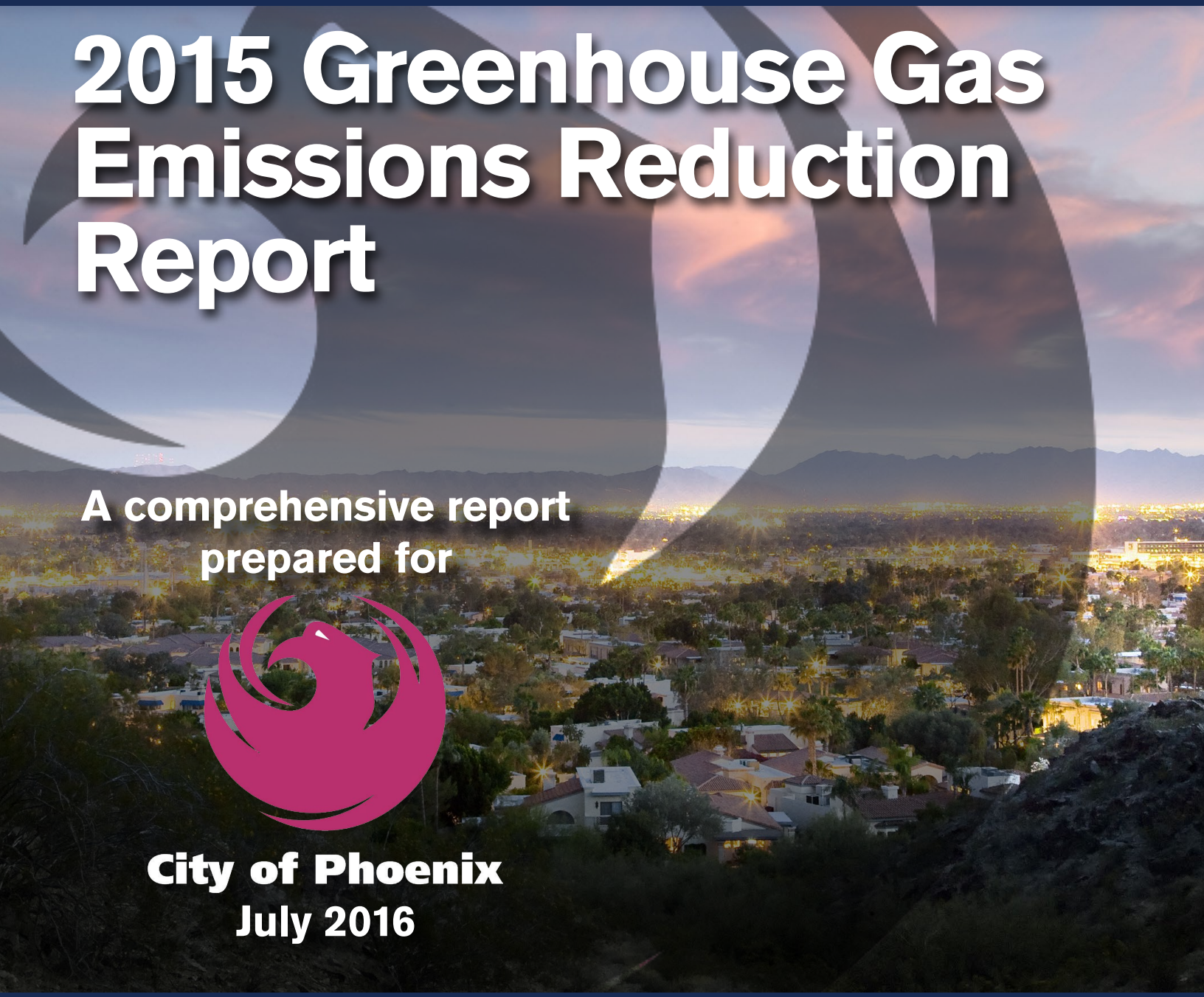
Walton Sustainability Solutions Initiatives

ARIZONA STATE UNIVERSITY

2015 Greenhouse Gas Emissions Reduction Report



A comprehensive report prepared for

City of Phoenix

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Global Sustainability Solutions Services

sustainabilitysolutions.asu.edu

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In addition, we wish to acknowledge the numerous city departments' staff for supplying the 2015 emissions-related data needed to update the 2005 report originally produced by ICLEI – Local Governments for Sustainability.

Finally, we would like to thank city of Phoenix employees, residents and business owners, who are on the ground supporting the city's efforts and who are working toward reducing their own greenhouse gas emissions. It may seem like we have a long way to go, but as this report proves—we can make a difference.

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

AZNM	Arizona and New Mexico eGRID Subregion
ASU	Arizona State University
CAP	Climate Action Plan
CARB	California Air Resources Board
CCAR	California Climate Action Registry
CEQ	President's Council on Environmental Quality
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
EN	Energy Efficiency and Solar power
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
FTE	Full-time-equivalent
GHG	Greenhouse Gas
GAC	Granulated Activated Carbon
ICLEI	International Council for Local Environmental Initiatives
IGCC	International Green Construction Codes
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	Liquid Natural Gas
LPG	Liquefied Petroleum Gas
MT	Metric Tons
NERC	North American Electric Reliability Corporation
N_2O	Nitrous Oxide
SW	Solid Waste
T&D	Transmission & Distribution
TN	Total Nitrogen
TR	Transportation
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 2015 Greenhouse Gas Emissions Inventory for Government Operations is an update to the city of Phoenix 2005 Greenhouse Gas Emissions Inventory for Government Operations. The 2005 report was published in 2009 and provided both the baseline greenhouse gas (GHG) emissions inventory and technical support for the city of Phoenix 2009 Climate Action Plan for Government Operations (CAP). The 2005 report projected that city of Phoenix (Phoenix) GHG emissions would increase by 14% if the city did not take appropriate action. As a result, the Phoenix City Council, in December 2009, adopted a mandate to reduce GHG emissions from city operations to 5% below the 2005 level by 2015. The city of Phoenix 2012 Greenhouse Gas Emissions Inventory for Government Operations indicated the city had surpassed its reduction goal with a 7.2% reduction; therefore, the Phoenix City Council adopted a new goal to reduce GHG emissions to 15% below 2005 levels by 2015.

Completion of *The city of Phoenix 2015 Greenhouse Gas Emissions Inventory for Government Operations* shows that **Phoenix has met its goal and reduced GHG emissions by 15.6% between 2005 and 2015**.

The 2015 report provides information on Phoenix's progress in meeting its emissions reduction goals. The major findings of the 2015 report are:

- While developing the 2015 GHG inventory, the reported 2005 GHG emissions were updated from 618,682 MT CO_2e to **696,709 MT CO_2e** based on revised accounting for GHG emissions.
- In 2015, overall emissions from Phoenix municipal operations totaled **588,153 MT CO_2e**.
- Phoenix has surpassed its 2015 goal for emissions reduction, as overall emissions from Phoenix municipal operations between 2005 and 2015 fell **108,556 MT CO_2e**, equivalent to a reduction of **15.6%**.
- The largest reduction in GHG emissions was in Fugitive and Process emissions, which came from increasing the efficiency of Phoenix landfill gas collection systems. Between 2005 and 2015, emissions fell from 119,291 to 70,924 MT CO_2e, preventing 48,367 MT CO_2e from being released into the atmosphere.
- The second largest reduction was in Water Services emissions, which included emissions from on-site electricity and natural gas consumption as well as emissions from Water Distribution and Wastewater Treatment. This resulted in an overall emissions reduction of 27,999 MT CO_2e, due to onsite solar power generation.

- The third largest reduction in GHG emissions was in the Buildings and Facilities sector. Overall emissions from electricity use in buildings went down by 17,281 MT CO_2e due to an increase in onsite solar power generation and a decrease of the regional eGRID factor.
- City Vehicle Fleet emissions decreased Phoenix fleet emissions by 12,855 MT CO_2e, or 9.5%. This is due to the fuel profile being transitioned from LNG and diesel to less carbon-intensive CNG and B20 fuels respectively.
- A significant reduction in GHG emissions was also seen in traffic signals emissions, which fell by 32.2%, or 2,488 MT CO_2e, due to their conversion to LED traffic signals.
- GHG emissions from streetlights fell by 1,063 MT CO_2e despite an 11% increase in the number of streetlights due to the conversion of high pressure sodium streetlights to LED streetlights.
- Stationary emissions from natural gas combustion increased by 3,815 MT CO_2e or 60%. This is due to an increase in natural gas usage by the convention center, public safety, and public works, which have constructed expanded and additional facilities and may also suggest higher economic activity.
- Employee Commute increased by 2.7% or 838 MT CO_2e, due to the increase of inventory data on hydrogen, bus, and light rail commuter methods.
- Granulated Activated Carbon (GAC) Hauling and Regeneration is a new emission sector in the 2015 inventory and emitted 588 MT CO_2e.

Phoenix has implemented, or is in the process of implementing, several projects in order to meet and surpass its original emissions reduction goal, and offset future GHG emissions anticipated from population growth. These projects include:

- The completion of the 91st Ave biogas to transport gas project,
- The State Route 85 (SR-85) and Skunk Creek Landfill biogas projects that are currently in progress,
- The LED streetlights project, and
- Conversion of additional fleet vehicles to alternative fuels, such as the transition to biodiesel.

Through these measures, and by actively working to reduce GHG emissions from local governmental operations, Phoenix has avoided the emission of 206,095 MT CO_2e. This reduction is the difference between projected business-as-usual and actual, measured 2015 GHG emissions.

1 Introduction

In December 2008, the Phoenix City Council adopted a goal to reduce greenhouse gas (GHG) emissions[1] from city operations to 5% below the originally reported 2005 levels of 618,682 metric tons (MT) CO_2e by 2015.[2] After completing the 2012 GHG inventory, which found that the city of Phoenix (Phoenix) had already met the 5% reduction goal, Phoenix City Council updated the goal to a reduction of 15% below the reported 2005 levels by 2015. It is important to note that in the development of both the 2012 GHG emissions inventory, the reported 2005 GHG emissions were increased from 618,682 to 678,150 MT CO_2e, based on the addition of previously unaccounted emission sources and improved methodology for emissions accounting and calculation. In this 2015 inventory, 2005 emissions were further refined to 696,709 based on the revision of global warming potential (GWP) factors by the IPCC*. These changes allow for a more accurate comparison between 2005 and 2015 emissions and a more sound baseline moving forward.

The effort began with an inventory of Phoenix's 2005 emissions from municipal operations, which established a baseline and provided technical support for *The city of Phoenix 2009 Climate Action Plan for Government Operations*. The report also forecasted a 14% increase in GHG emissions, to 794,248 MT CO_2e[3] by 2015 if Phoenix maintained a business-as-usual approach and did not take efforts to curb GHG emissions. In response, the Phoenix Climate Action Plan identified 10 measures to decrease emissions in energy use, transportation, and solid waste. To assess the impact of these mitigation measures to date, Phoenix commissioned Arizona State University's (ASU) Global Sustainability Solutions Services to update the inventory and track progress to the 2015 GHG emissions goal.

This report provides an updated inventory of 2015 emissions from municipal operations in six sectors – Buildings and Facilities, City Vehicle Fleet, Wastewater Treatment, Solid Waste, Employee Commute, and Granulated Activated Carbon Hauling and Regeneration. These sectors are categorized into three scopes to capture direct

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[1] Hereafter referred to as *emissions.*

[2] Metric Tons (MT) CO_2e: Carbon dioxide equivalent metric tons. This is consistent with the established international standard for comparison of the global warming potential of different greenhouse gases relative to CO_2. A metric ton is equivalent to 2,204 pounds.

[3] Projected 2015 GHG emissions based on revised 2005 totals presented in this report and not previously reported 2005 GHG emission totals. The IPCC, the primary authority on climate change science, has updated the GWP values several times over the years, each adjustment the result of advances in scientific understanding.

emissions (Scope 1) and indirect emissions (Scopes 2 and 3)[4]. The update provides a direct comparison to the 2005 inventory as well as a revised baseline for future inventories. Tracking emissions over time will allow Phoenix to evaluate the effectiveness of its emissions reduction policies and programs. Furthermore, the inventory provides a platform for Phoenix to develop best practices for reducing its carbon footprint.

Section 1 is an overview of the major findings of the 2015 GHG Emissions Inventory Update. Section 2 describes the methodology for the 2015 GHG Emissions Inventory Update, including the Local Government Operations Protocol for emissions accounting, the organizational boundaries, emissions scope definitions, and methodological revisions between the 2005 and 2015 GHG inventories. Section 3 is a summary of inventory results. Section 4 breaks down the results by reporting sector including Buildings and Facilities, City Vehicle Fleet, Water Distribution and Wastewater Treatment Processes, Solid Waste, Employee Commute, and Granulated Activated Carbon Hauling and Regeneration for water treatment. Section 5 provides internal and external benchmarks for Phoenix operations. Finally, Section 6 details biogenic emissions, which are non-fossil CO_2 emissions that are not included in Phoenix's total emissions.

1.1 Major Findings

The revised baseline total emissions for 2005 are 696,709 MT CO_2e, up from the originally published 618,682 MT CO_2e (Table 1). Based on this revised 2005 GHG emissions total, emissions from Phoenix government operations in 2015 fell by 15.6% to 588,153 MT CO_2e. With this decrease, Phoenix has surpassed its 15% GHG emissions reduction goal. The reductions can be attributed to a combination of internal and external measures.

Internal measures include city policies, city-led solar power projects, energy efficiency upgrades, the incorporation of alternative fuels into the City Vehicle Fleet fuel portfolio, and upgrades to landfill gas capture systems.

External measures include a decrease in the EPA's Emissions & Generation Resource Integrated Database (eGRID) regional factor[5]. The eGRID database inventories the

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[4] Scope classifications are explained in more depth in the methodology section.
[5] 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

environmental attributes of electric power generation and its effect on air emissions for every power plant in the United States. Phoenix is in the Arizona and New Mexico (AZNM) subregion. The carbon intensity of the AZNM subregion fell by 12%, translating into an eGRID emissions factor reduction from 1,317 lb. CO_2e/MWH in 2005 to 1,158 lb. CO_2e/MWH in 2015, due primarily to Arizona's and New Mexico's solar power portfolios. Additional external factors include changing IPCC GWP emissions factors between 2005 and 2015. The 2005 GHG emissions inventory utilized IPCC AR2 GWP emissions factors when it was first completed in 2009, while the 2015 GHG emissions inventory utilized IPCC AR4 emissions factors for 2015 GHG emission calculations; AR4 was then also applied to update 2005 GHG emissions inventory results for this current 2015 inventory update. This practice of updating the AR4 emissions factors is consistent with the procedures found in the EPA U.S. Greenhouse Gas Inventory Report[6], where IPCC AR4 was used for calculating emissions from 1990 to 2014.

Phoenix has reduced its emissions in almost every category except stationary combustion and employee commuting, and also in GAC hauling and regeneration, which did not exist in 2005. Phoenix's overall reduction is largely due to the decrease in landfill gas, fleet, and city facilities emissions. The generation of solar power helped to decrease emissions at city buildings and facilities. The switch to LED traffic signals also reduced the emissions from purchased utilities. Fugitive emissions were significantly reduced at two landfills with enhanced methane capture systems. Phoenix's 2015 GHG Emissions Inventory Update results are compared to 2005 in Table 1 below.

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information can be found at http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html.

[6] US EPA, 2016. U.S. Greenhouse Gas Inventory Report: 1990—2014. URL: https://www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html

Table 1. 2005 and 2015 GHG Emissions Scope and Sector Comparison

Scope 1	2005 (original)	2005 (revised)	2015	2005-2015 Change	% Change
Stationary Combustion	7,425	7,398	10,796	3,398	45.9%
Fleet Fuels	122,141	135,486	122,630	-12,855	-9.5%
Fugitive and Process Emissions	92,133	119,291	70,924	-48,367	-40.5%
Scope 1 Total Emissions	**221,699**	**262,175**	**204,350**	**-57,825**	**-22.1%**
Scope 2	**2005 (original)**	**2005 (revised)**	**2015**	**2005-2015 Change**	**% Change**
Buildings Electricity	176,426	184,361	167,080	-17,281	-9.4%
Street Lighting	36,828	38,518	37,455	-1,063	-2.8%
Traffic Signals	7,396	7,736	5,248	-2,488	-32.2%
Water Services	148,611	155,432	126,993	-28,439	-18.3%
Scope 2 Total Emissions	**369,261**	**386,046**	**336,776**	**-49,270**	**-12.8%**
Scope 3	**2005 (original)**	**2005 (revised)**	**2015**	**2005-2015 Change**	**% Change**
Employee Commute	27,722	30,672	31,510	838	2.7%
Transmission and Distribution Loss	0	17,816	14,928	-2,888	-16.2%
Granulated Activated Carbon Hauling and Regeneration	0	0	588	588	N/A
Scope 3 Total Emissions	**27,722**	**48,488**	**47,026**	**-1,461**	**-3.0%**
GHG Inventory	**2005 (original)**	**2005 (revised)**	**2015**	**2005-2015 Change**	**% Change**
Total Scope 1 and 2 Emissions	590,960	648,221	541,126	-107,095	-16.5%
Total Scope 1, 2, & 3 Emissions	**618,682**	**696,709**	**588,153**	**-108,556**	**-15.6%**

2 Methodology

2.1 Local Government Operations Protocol

In order for cities to quantify emissions in a meaningful way, a standardized approach is critical. It allows individual cities to compare year-to-year results as well as their practices and procedures to other municipalities across the country. 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 for this update, ASU used the 2010 version (Version 1.1) of the protocol for both 2015 and the revised 2005 emissions inventories.

This protocol provides a methodology for the calculations of emissions from numerous sources for the development of a comprehensive inventory report. Emissions are measured directly from sources such as landfill monitoring systems or through calculation-based methodologies. In the latter case, activity data is collected and multiplied by an emission factor (e.g., CO_2 emitted/kWh) to calculate the total emissions. 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 AR4 GWP factors[7] shown in Appendix B.

2.2 2015 vs. 2005 Methodology

The 2015 GHG emissions inventory methodology generally follows that of the 2005 inventory. However, some technical improvements have been made to more accurately quantify emissions. In 2010, ICLEI and partners released the latest LGOP Version 1.1. This update included several changes to figures, methods, and other factors. Details can be found on the ICLEI website. In addition to the LGOP update, the 2015 GHG emissions inventory changed emission factors from 2005. The 2005 GHG emissions inventory utilized IPCC AR2 GWP emissions factors, while the 2015 GHG emissions inventory utilized IPCC AR4 GWP emissions factors for both 2005 and 2015 GHG emission calculations. This update follows the procedures found in the EPA U.S. Greenhouse Gas Inventory Report, which complies with UNFCCC reporting guidelines for national inventories, requiring the use of GWP values from AR4 for national GHG

[7] US EPA, 2016. U.S. Greenhouse Gas Inventory Report: 1990—2014. URL: https://www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html

emissions inventories[8]. The following additional changes to methodology were made to correct, amend, or update the 2005 data and more accurately reflect 2015 emissions:

- Estes Landfill was added to both inventories;
- Employee commuting emissions at sites with less than 50 employees added to both the 2005 and 2015 inventories;
- In 2005, wastewater treatment emissions were estimated using population-based data. In 2015, site-specific data were used where applicable;
- In 2005, transmissions and distribution (T&D) loss in the electric grid was not included. The 2015 update includes T&D loss in the electricity grid as Scope 3 emissions for both 2005 and 2015;
- The 2015 model calculated biogenic CO_2 emissions from the flaring of methane gas at landfill and wastewater treatment plants, non-fossil biofuel emissions, and the combustion of biogas at the 91st Avenue Wastewater Treatment Plant on-site for boilers. Biogenic CO_2 emissions were not calculated in the original 2005 inventory, but have been included in the revised 2005 inventory herein;
- In 2005, the city of Phoenix did not have any solar power, while 2015 has electricity production data from solar installations.

2.2.1 Landfill-Specific versus EPA Reporting Characteristics for Solid Waste Landfills

In 2009, EPA published a rule requiring point sources that emit more than 25,000 MT CO_2e per year to report emissions as part of the Greenhouse Gas Reporting Program (GHGRP).[9] As of 2010, the city of Phoenix began reporting emissions to the GHGRP – these emissions are publically-available with the Facility Level Information on GreenHouse gases Tool (FLIGHT), a nationwide database on large, point-source GHG emitters. Under this program, the city of Phoenix has reported landfill emissions using national average characteristics, which uses an assumed landfill gas collection efficiency of 75% for closed landfills in the region, based on an area with intermediate soil cover; an assumed collection efficiency of ~67% for open landfills with daily cover; and an assumed standard rate of 10% of the CH_4 generated that is oxidized near the

[8] 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.
[9] US EPA, 2013. Greenhouse Gas Reporting Program Overview Factsheet. URL: https://www.epa.gov/sites/production/files/2014-09/documents/ghgrp-overview-factsheet.pdf.

surface of the landfill.[10] These assumptions vary greatly from the landfill-specific metrics used internally by the city of Phoenix, in which the collection efficiencies are projected at each facility. Both EPA and city of Phoenix reporting characteristics were used to study the GHG emissions for solid waste in the city of Phoenix (Table 2 and 3). However, due to the especially dry climate in Phoenix, and the advanced technologies being implemented at specific landfills (such as SR-85 having horizontal in addition to traditional vertical wells, surface monitoring, flare data, and landfill cover maintenance), site specific collection efficiency characteristics were used for final reporting purposes. Table 4 shows the difference in CO_2e emissions based on the reporting characteristics used for Solid Waste.

Table 2: Landfill-Specific Characteristics Developed by City of Phoenix

Landfill	2005 Landfill-Specific Characteristics			2015 Landfill Specific-Characteristics		
	Destruction Efficiency	Collection Efficiency	Oxidation Rate	Destruction Efficiency	Collection Efficiency	Oxidation Rate
Skunk Creek Landfill	99%	50%	10%	98%	85%	25%
27th Ave Landfill	97%	85%	10%	98%	85%	25%
Del Rio Landfill	89%	50%	10%	89%	50%	10%
Deer Valley Landfill	92%	75%	10%	92%	75%	10%
19th Avenue Landfill	98%	85%	10%	98%	85%	10%
Estes Landfill	0%	0%	0%	0%	0%	0%
SR-85 Landfill	0%	0%	0%	98%	90%	25%

[10] Amini, Hamid and Reinhart, Debra, 2012. Evaluating Landfill Gas Collection Efficiency Uncertainty. Presentation at the 15th Annual LMOP Conference and Project Expo. January 17-19, 2012.

Table 3: EPA National Average Landfill Characteristics

Landfill	2005 National Average Landfill Characteristics			2015 National Average Landfill Characteristics		
	Destruction Efficiency	Collection Efficiency	Oxidation Rate	Destruction Efficiency	Collection Efficiency	Oxidation Rate
Skunk Creek Landfill	97.9%	75%	25%	98%	75%	25%
27th Ave Landfill	98%	75%	25%	98%	75%	25%
Del Rio Landfill	89%	50%	10%	89%	50%	10%
Deer Valley Landfill	92%	75%	10%	92%	75%	10%
19th Avenue Landfill	98%	75%	10%	98%	75%	10%
Estes Landfill	0%	0%	0%	0%	0%	0%
SR-85 Landfill	0%	0%	0%	98%	69%	25%

Table 4: Comparison of Solid Waste Emissions by Reporting Method

Landfill	Calculated Emissions Using Landfill-Specific Characteristics (MT CO_2e)			Calculated Emissions Using National Average Characteristics (MT CO_2e)		
	2005	2015	Change	2005	2015	Change
Skunk Creek Landfill	60,156	17,321	-42,835	17,981	30,609	12,268
27th Ave Landfill	25,425	8,265	-17,160	36,943	14,648	-22,295
Del Rio Landfill	4,377	6,238	1,861	4,368	6,238	1,870
Deer Valley Landfill	3,031	2,358	-673	3,031	2,352	-679
19th Avenue Landfill	3,908	3,097	-811	6,848	5,541	-1,307
Estes Landfill	13,500	11,055	-2,445	13,500	11,055	-2,445
SR-85 Landfill	0	12,839	12,839	0	45,139	45,139
Totals	110,397	61,173	-49,224	82,671	115,582	32,911

2.2.2 Estimating Tailpipe Emissions of CH_4 and N_2O

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 2015 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. The data-reporting format change avoided the need to track vehicle mileage for use of the per mile CH_4 and N_2O emissions factors used in the 2005 emissions.

2.2.3 Site-specific CH_4 Emissions from Wastewater Treatment

The 2005 CH_4 emissions values from Wastewater Treatment used in this report vary from the previously reported values. In 2005, CH_4 emissions from the 23rd Avenue and 91st Avenue Wastewater Treatment Plants (WWTP) were modeled on LGOP population-based estimation methods. Data provided for the 2015 inventory contained CH_4 production, flaring, and on-site use data for both 2005 and 2015 at the 91st Avenue WWTP. 2005 data was revised using this site-specific data for consistency. Additionally, in the previous 2005 emissions model, flaring emissions were not separated into 91st Avenue and 23rd Avenue components. These are separated into two emissions sources in the 2015 Inventory update.

2.2.4 Backcasting N_2O Emissions from Wastewater Treatment

Effluent N_2O emissions are based on the total nitrogen (TN) content of the effluent and estimated either via population-based methods or site-specific data. The two methods were tested for 2015 population and site-specific data. When comparing the results, there was an order of magnitude reduction in N_2O emissions from population-based calculations to site-specific effluent data. Using population-based emissions estimation methodologies for 2005 and site-specific emissions estimation methodologies for 2015 would create an order of magnitude reduction in emissions that is an artifact of the methodology. Therefore, the 2005 effluent N_2O emissions in this inventory have been backcasted from 2015 site-specific data using the ratio between Phoenix's population in 2015 and 2005 as a scaling factor. The backcasting approach was used because there was incomplete data to calculate 2005 emissions from site-specific data.

2.2.5 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 employees' means of commuting throughout the week. While the survey asks employees if they use an alternative fuel vehicle, the type of fuel is not specified. Alternative fuel vehicle ownership data for Arizona were obtained from the federal Energy Information Administration (EIA) to estimate alternative fuel employee commuting. It was assumed that statewide alternative fuel sales data provided a proxy for alternative fuel vehicle ownership patterns for city of Phoenix employees.[11]

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[11] U.S. Energy Information Administration (2013). Renewable & Alternative Fuels. Alternative fuel vehicle data. URL: http://www.eia.gov/renewable/afv/users.cfm

2.3 Organizational Boundaries

Given the variety of governmental structures, the LGOP provides two emissions reporting approaches for defining the boundaries of what to include in the 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.

2.4 City of Phoenix Boundary Guidelines

Phoenix uses the operational control approach as it most accurately represents emission sources within the city's control. The boundaries of the 2015 inventory follow the same guidelines as the 2005 baseline inventory. However, it expanded upon the 2005 inventory by tabulating emissions from T&D loss in the electricity grid, calculating biogenic emissions—emissions from non-fossil carbon sources—resulting from municipal operations, and including the additional considerations outlined below.

T&D loss can account for up to 25% of generated electricity, demonstrating the added benefit of developing on-site solar power projects. Including T&D loss in an inventory is a GHG accounting standard endorsed by the President's Council on Environmental Quality (CEQ) and complies with the ICLEI LGOP. Furthermore, electricity use by municipal operations typically is one of the largest municipal emissions sources—accounting for 55% of the city's emissions. Therefore, accounting for T&D loss creates a richer picture of the GHG impact of municipal electricity consumption.

Biogenic 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.

Other considerations included the 91st Avenue WWTP emissions and if they 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 Phoenix 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 will be re-evaluated in the future if other partners in the facility develop their own GHG emissions inventories and wish to include their share of the emissions from this facility.

Phoenix 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. However, Phoenix 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.

Finally, Phoenix could choose not to report Employee Commute and Granulated Activated Carbon 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 GAC hauling and regeneration as Scope 3 emissions despite the fact that these operations are outsourced as the city holds financial control; considers it an area over which it has influence; and data for this activity is relatively easy to obtain and evaluate. Both sludge and solid waste hauling were included as Scope 1 emissions as those contracts are considered more integral to city operations and control.

2.5 Scope Classifications and Sectors

In accordance with the LGOP, emission sources from city operations are categorized into Scope 1, 2, or 3 emissions. The scope indicates if emissions are direct or indirect emissions in order to improve transparency and to provide utility for different types of climate policies and goals. The Scope categories are illustrated in Figure 1.

- Scope 1: All direct emissions from operational sources owned or controlled by Phoenix.
- 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 Phoenix.
- 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 outsourced activities. This report includes employee commuting and outsourced GAC Hauling and Regeneration activity.

In addition to categorizing emissions by scope, the inventory is organized into six sectors to make it more relevant to Phoenix policy making and project management.

- Buildings and Facilities
- City Vehicle Fleet
- Water Distribution and Wastewater Treatment
- Solid Waste
- Employee Commute
- Granulated Activated Carbon Hauling and Regeneration

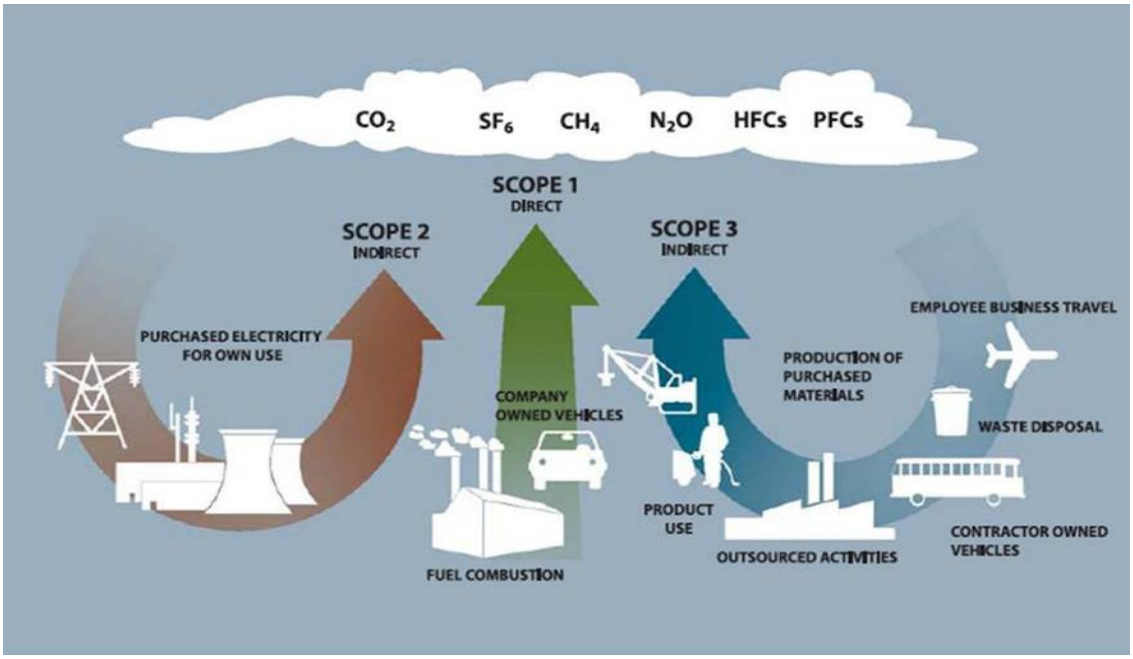

Figure 1: Overview of LGOP Scopes and Emissions Sources.

Source: The city of Phoenix 2005 GHG Emissions Inventory for Government Operations (2009). Adopted from World Resources Institute GHG Protocol Corporate Accounting and Reporting Standard (Revised Edition), Chapter 4, 2004.

3 Results

3.1 Summary

3.1.1 2005 vs. 2015: What Changed Overall?

Between the 2005 baseline and the 2015 update, several changes to the city of Phoenix impacted emissions. These include:

- Installation of advanced methane capture systems at city landfills;
- Biodiesel and ethanol alternative fuel programs;
- Energy efficient streetlight, traffic signal, water distribution, and wastewater treatment upgrades;
- City solar power installations;
- Increase in bus ridership and electric vehicle ownership by city employees; and
- The transition from liquefied natural (LNG) to compressed natural gas (CNG) in transit buses and the transition from B20 to CNG in refuse trucks.

Between 2005 and 2015, the city's population increased from 1,461,575 to 1,537,058 residents, while the number of full-time equivalent (FTE) employees remained relatively constant from 14,667 in 2005 to 14,664 in 2015.

2015 Overall Findings

15.6% decrease

0.6% beyond Phoenix's 2005 Goal!

Emissions Sources

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

City Action Highlights

- Installation of advanced methane capture systems at city landfills
- Biodiesel and ethanol alternative fuel programs; Biodiesel required in solid waste haul trucks and
- Energy efficient streetlight, traffic signal, water distribution, and wastewater treatment upgrades
- City solar power projects
- Increase in bus ridership and electric vehicle ownership by city employees
- Transition from LNG to CNG in city buses and from B20 to CNG in refuse trucks.

Finally, the AZNM regional eGRID factor decreased by 12%. The reduced carbon intensity of the AZNM, from 1,317 lb. CO_2/MWh in 2005 to 1,158 lb. CO_2/MWh in 2015, is a result of the adoption and implementation of solar power portfolios in both Arizona and New Mexico.

3.1.2 Emissions Sources and Distribution

Emissions in Phoenix are largely attributed to three sectors: Buildings and Facilities (electricity and natural gas), City Vehicle Fleet fuel combustion, and Water Services. Figure 2 provides an overview of the relative magnitude of CO_2e emissions by source and scope.

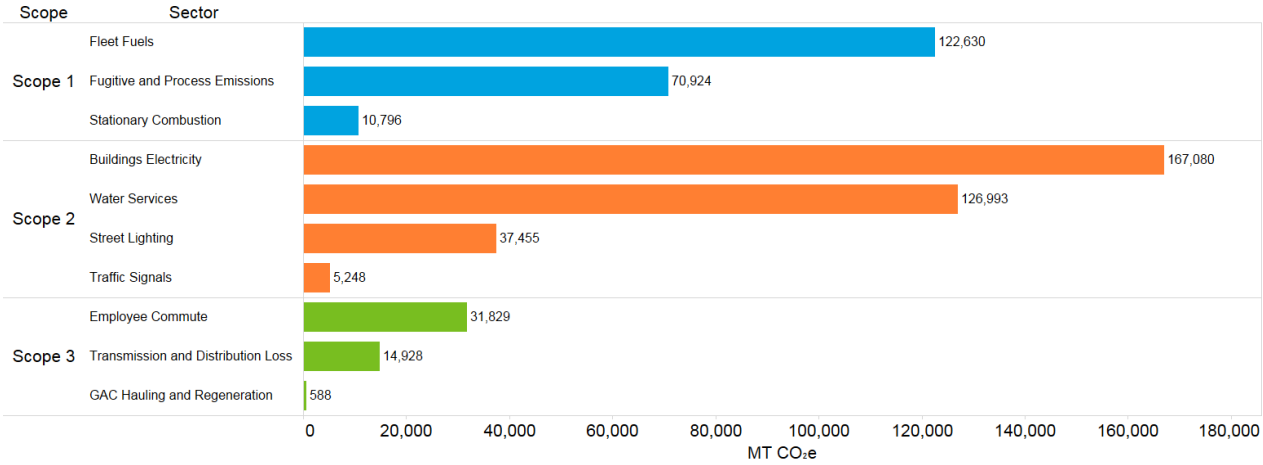

Figure 2: 2015 Emissions by Scope and Sector

As illustrated in Table 5, purchased electricity (Scope 2 emissions) accounts for approximately 57% of operational GHG emissions from city of Phoenix – GHG emissions from buildings electricity and Water Services electricity consumption represents 30% and 22% of City GHG emissions, respectively. Scope 1 GHG emissions from City fleet fuels accounts for 21%.

Table 5: 2015 Emissions by Scope and Sector (MT CO_2e)

Sector	Scope 1	Scope 2	Scope 3
Stationary Combustion	10,796		
Fleet Fuels	122,630		
Fugitive and Process Emissions	70,924		
Buildings Electricity		167,080	
Street Lighting		37,455	
Traffic Signals		5,248	
Water Services		126,993	
Employee Commute			31,510
Transmission and Distribution			14,928
GAC Hauling and Regeneration			588
Total	204,350	336,776	47,026

3.1.3 City Action Highlights

Phoenix exceeded its 2015 goal of reducing emissions by15% by reducing total emissions by 15.6%. Total emissions fell from the revised 697,132 MT CO_2e in 2005, to 588,153 MT CO_2e in 2015. Emissions have decreased from 2005 levels in Scope 1 and 2, and in a number of areas with the exception of stationary combustion, which increased from 7,398 MT CO_2e to 10,796 MT CO_2e and employee commute, which increased from 30,672 MT CO_2e to 31,510 MT CO_2e. The increase in stationary combustion resulted from increase in natural gas usage in the departments of public safety, public works, streets, and the convention center. Also, emissions from GAC Hauling & Regeneration increased, which did not exist in 2005. These highlights are illustrated in Figure 3.

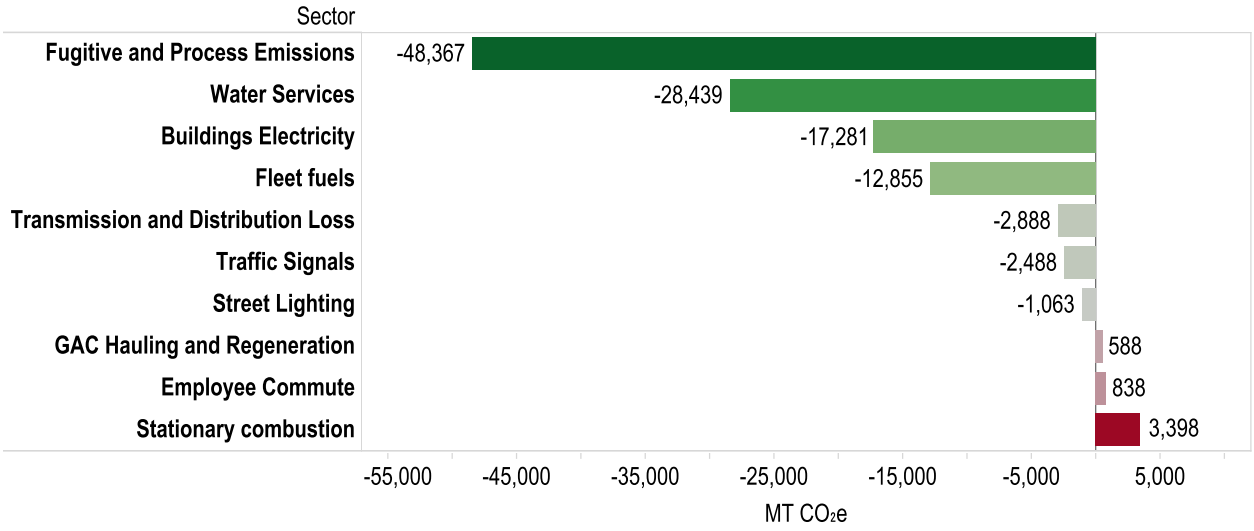

Figure 3: Emissions Changes between 2005 and 2015.

The overall reduction is primarily due to the increased efficiency in the capture rates of fugitive emissions at Phoenix Solid Waste landfills; solar power generation by Water Services and Aviation departments; and the change from diesel fuel to CNG and B20 in fleet fuels and from LNG to CNG in transit buses. GAC Hauling and Regeneration is part of the Water Services sector, but has been reported separately as a Scope 3 emission since emissions are a result of indirect activities. Buildings Electricity also had a significant decrease between reporting years primarily due to the development of solar power; without solar power development, emissions from Buildings Electricity would have increased. T&D loss (Scope 3) is a new inventory item to the 2005 and 2015 inventories and is also shown separately.

Decreased energy consumption and solar power development in Water Services also played a major role in decreasing municipal emissions. A citywide total of 23,895,183 kWh of solar power was generated onsite, with the largest being in Water Services and

Aviation, producing 12,821,727 kWh and 8,393,344 kWh, respectively. In total, solar power offset 4.3% of the energy used in 2015.

Additionally, Phoenix implemented successful biodiesel and CNG programs, which have replaced over 3.5 million gallons of diesel fuel with alternative fuels that emit less GHGs per gallon. Contracted waste haulers are now required to use B20 while Transit is making the transition away from LNG to CNG. The city has also been replacing both its traffic signals and high-pressure sodium streetlights with energy efficient LED lights.

4 Findings by Sector for 2015

4.1 Buildings and Facilities

4.1.1 2005 vs. 2015: What Changed?

The Aviation Department took operational control of the Rental Car Center. This occurred during 2005 and therefore, only partial year emissions for the 2005 inventory were captured.

Traffic sign conversion to LED lights was completed.

In addition, the eGRID factor decreased by 12%.

Emissions Sources and Distribution
Overall, city buildings consumed 9% less purchased electricity due to onsite solar power generation. This reduction, along with a reduction in the eGRID factor, contributed to the 11.7% decrease in emissions from Buildings and Facilities.

However, natural gas consumption in city buildings and facilities increased 60%. The increase in natural gas consumption was most notable in the Public Safety, Public Works, Streets departments, and at the Phoenix Convention Center.

2015 Building and Facilities Findings

Total Emissions: 347,572 MT CO_2e
59.1% of municipal operations emissions
11.7% decrease from 2005 levels

Emissions Sources

- Electricity and natural gas used for city buildings
- Streetlights
- Traffic Signals
- Energy for Water Distribution and Wastewater Treatment Facilities

City Action Highlights

- 45+ energy efficient building and facility measures implemented
- Energy efficient LED lights in 100% of new traffic signals and streetlights
- Water Services installed 7.5 MW of solar power at its Lake Pleasant Water Treatment Plant
- Aviation installed 5.4 MW of solar power on the East Economy Parking Garages and the Sky Harbor Rental Car Center Facilities

Streetlights consumed 11% more purchased electricity despite only an 8% increase in the number of streetlights. However, due to the reduction in the eGRID factor and energy efficiency measures, emissions from street lighting decreased. As the transition to LED lights continues, electricity consumption for this sector is expected to decline further.

Traffic signals consumed 23% less purchased electricity in 2015 than in 2005, primarily due to the installation of new LED traffic signals and retrofitting old traffic signals. The

decrease in emissions from more energy efficient traffic signals occurred despite a 15% increase in the number of traffic signals in the city of Phoenix.

Water Services consumed 7% less purchased electricity with the inclusion of onsite solar power generation.

Overall purchased electricity emissions in the Buildings and Facilities sector decreased by 12.8%. A combination of solar power development on city facilities, and energy efficiency upgrades to city buildings and facilities account for most of the decrease (see Appendix C & D for a list of projects). A cleaner regional electricity supply also helped lower emissions from buildings and facilities. Figure 4 summarizes the percentage increase and decrease by sector for municipal operations with the addition of buildings natural gas consumption.

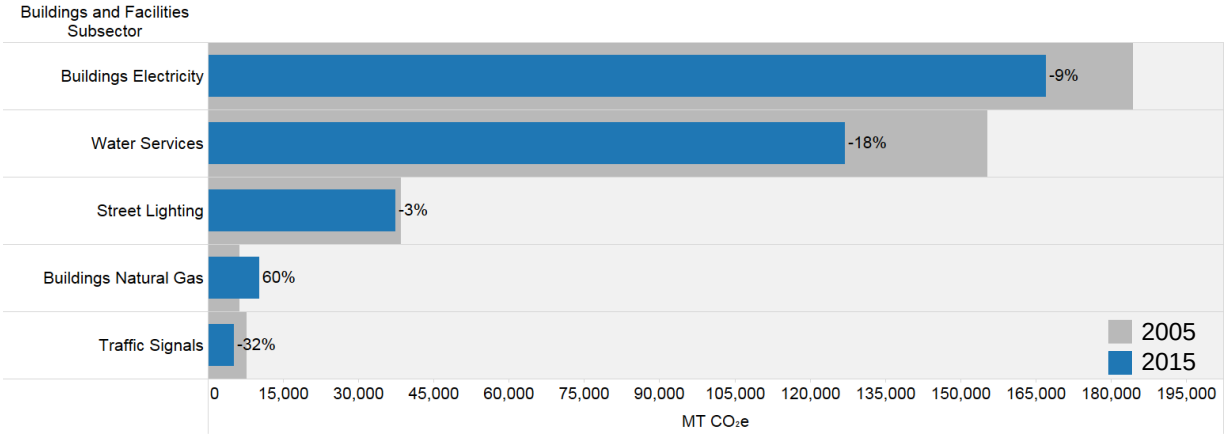

Figure 4: Buildings and Facilities Emissions Changes between 2005 and 2015

Buildings emissions result from both electricity and natural gas consumption. While measuring the emissions of electricity is relatively straight-forward, natural gas is measured by volume requiring a conversion to its heat equivalent, or therms, to calculate energy use and emissions. Table 6 provides a breakdown of energy use in the Building and Facilities sector, including onsite solar power generation, and the resulting emissions by subsector.

Table 6: 2015 Buildings and Facilities Emissions by Subsector

Subsector	Total kWh	Solar Power Generation (kWh)	Total Therms	MT CO_2e
Buildings - Electricity	329,202,339	11,073,456	--	167,080
Buildings - Natural Gas	--	--	1,919,621	10,196
Street Lighting	71,316,538	--	--	37,455
Traffic Signals	9,993,097	--	--	5,248
Water Services	254,622,318	12,821,727	112,938	127,593
Total	671,254,990	23,895,183	203,2559	347,572

Solar power generation played a significant role in the reduction of emissions for Buildings and Facilities. Between 2005 and 2015, Phoenix has continued its commitment towards its 15% solar power goals as well as reducing operational emissions, largely through the installation of solar power projects. These projects offset 3.6% of Buildings and Facilities electricity demand. Table 7 shows the breakdown of onsite solar power generation by department.

Table 7: Departmental Energy Consumption and Solar Power Generation*

Department	2005 Usage (kWh)	2015 Usage (kWh)	2015 Solar Power Generation
Aviation	146,623,742	163,282,319	8,393,344
Convention Center	20,677,290	29,785,775	125,800
Fire	12,351,668	14,499,768	58,384
Housing Services	15,671,524	10,801,435	46,707
Human Services	2,422,428	2,412,965	262,728
PRLD-Libraries	7,940,129	8,097,824	148,251
PRLD-Recreation	31,687,827	34,908,714	70,353
Public Transit	1,258,319	1,708,064	43,788
Public Works	54,102,114	38,062,376	1,924,101
Water Services	260,221,729	254,622,318	12,821,727
Totals	552,956,771	558,181,588	23,895,183

*Department with no solar power generation not included in table.

4.1.2 City Action Highlights

Energy efficiency measures were also implemented in over 45 city buildings (see Appendix A) and the Phoenix Green Building Code was adopted to facilitate energy efficient construction on new buildings. Additionally, the city installed 15.3 MW of solar power capacity between the 2005 and 2015 GHG inventories.

Phoenix increased efficiency of streetlight and traffic signals through the installation of 1,120 LED streetlights and 1,138 LED traffic signals—as a comparison, Phoenix had 25 LED traffic signals in 2005. Overall emissions from the traffic signal and street lighting sector decreased by 8% and traffic signals and streetlights emitted less per light, decreasing from 7.97 to 4.69 MT CO_2e per traffic signal and 0.46 to 0.41 MT CO_2e per streetlight, between 2005 and 2015. Table 8 outlines the GHG intensity increases and efficiency gains for select Buildings and Facilities indicators.

Table 8: Buildings and Facilities Emissions Indicators and Percent of Change

Indicator	2005	2015	% Change
Building Space (sq. ft.)	N/A	12,599,324	--
Emissions per sq. ft. (kg CO_2e)	N/A	14.07	--
Employees (Full Time Equivalent)	14,667	14,664	0%
Electricity Emissions per Cooling Degree Day (CDD)	39.2	33.0	-16%
Building/Facilities Emissions per F/PTE	13	12.09	-7%
MT CO_2e Per Traffic Signal	7.97	4.69	-41%
MT CO_2e Per Street Light	0.46	0.41	-11%

4.2 City Vehicle Fleet

4.2.1 2005 vs. 2015: What Changed?

The size of city of Phoenix Public Works fleet increased from 6,090 vehicles in 2005 to 7,389 in 2015.

The majority of the diesel fleet vehicles operated by Public Works and Aviation have converted to B20 biodiesel. However, Ultra Low Sulfur diesel fuel continues to be used in specific situations, such as emergency generators and fueling sites with low throughput.

The switch to B20 biodiesel and CNG ethanol avoided approximately 21,966 MT CO_2e in vehicle fleet emissions.

Aviation reduced its fleet gasoline consumption by 27% due in large part to its significant use of E85 ethanol. Aviation also reduced its diesel and CNG use by 82% and 30%, respectively, from 2005 to 2015, due to the Phoenix Sky Train reducing inter-terminal bus usage. Transit, the only user of liquefied natural gas (LNG), will continue to reduce its use as it transitions away from LNG and to CNG in transit buses.

City Vehicle Fleet

Total Emissions: 122,630 MT CO_2e
20.8% of municipal operations emissions
9.5% decrease from 2005 levels

Emissions Sources

- Gasoline
- Compressed Natural Gas (CNG)
- Biodiesel
- Liquefied Natural Gas (LNG)
- Diesel
- 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

Table 9 shows fuel consumption in 2005 and 2015 and the percent of change based on fuel type.

Table 9: Changes in Total City Fleet Fuel Consumption

Fuel Type	2005 (MT CO_2e)	2015 (MT CO_2e)	% Change
Gasoline	28,476	34,235	20%
Diesel	56,914	18,489	-68%
B20 Biodiesel	--	28,490	--
CNG	12,314	22,835	85%
LNG	36,098	16,089	-55%
E85 Ethanol	--	496	--
LPG	85	0	--
Other	1,598	1,996	25%
Total	135,486	122,630	-9%

4.2.2 Emissions Sources and Distribution

Emissions per vehicle maintained by Public Works fell from approximately 5.3 to 4.4 MT CO_2e per vehicle, despite an increase to the number of vehicles (Table 10).

Table 10: City Fleet Indicators Change

Indicator*	2005	2015	% Change
Number of Vehicles	6,090	7389	21%
MT CO_2e per Vehicle	5.3	4.4	-17%

*Public Works Fleet only, unless otherwise indicated

Figure 5 shows the percentage of change in emissions from the Vehicle City Fleet based on the fuel type.

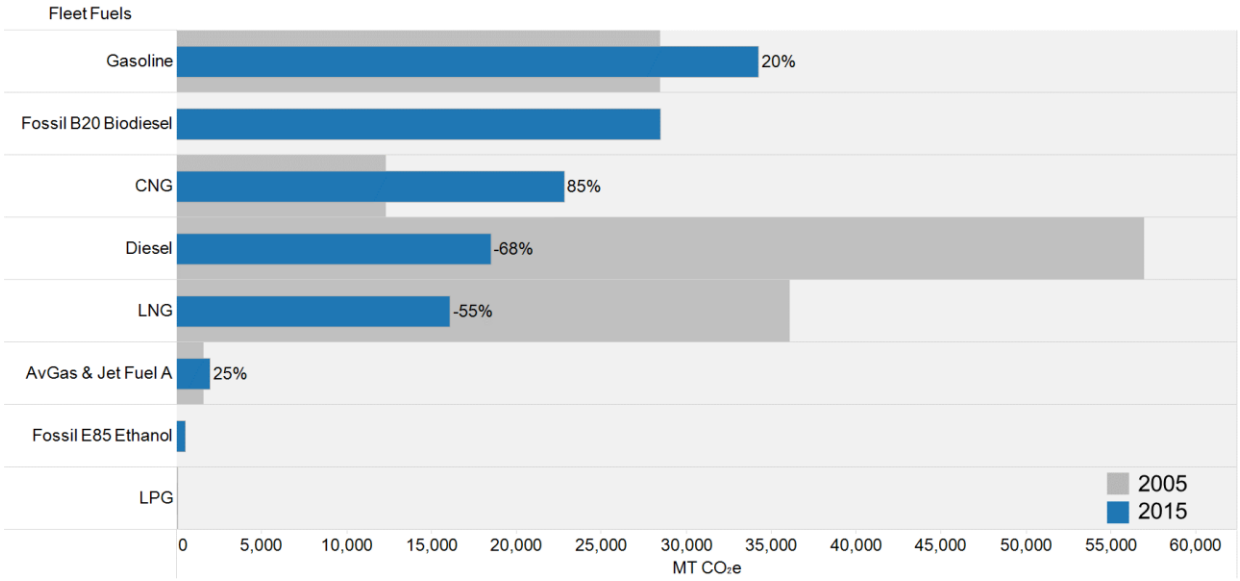

Figure 5: City Vehicle Fleet Emissions Changes between 2005 and 2015

GHG emissions from biofuels have both a fossil and biogenic emissions component. Fossil emissions, CH_4 and N_2O, result from the combustion of the gasoline fraction of the biofuel blend. Biogenic emissions result from the combustion of biomass-derived fuel. Fossil emissions add new GHG emissions to the atmosphere, whereas biogenic emissions release GHG emissions that were previously absorbed by biomass.

4.3 Water Services

4.3.1 2005 vs. 2015: What Changed?

The Cave Creek Water Reclamation Plant was taken offline in January 2010 as an efficiency measure due to wastewater flows into the plant being at only half of the plant capacity. Future wastewater flows will be reviewed to determine if there is a need to return the plant to service.

In January 2007, the Lake Pleasant Water Treatment Plant (WTP) came online. The Verde WTP was closed in December 2011 and the lease with the Salt River Pima Maricopa Indian Community for the use of the site was extended.

The volume of wastewater treated at the 27th Avenue and 91st Avenue WWTPs between 2005 and 2015 decreased by 12%.

Water Services

Total Emissions: 137,932 MT CO_2e
23.4% of municipal operations emissions
16.6% decrease from 2005 levels

Emissions Sources

- Water distribution stationary & process emissions
- 23rd Avenue and 91st Avenue wastewater treatment plants stationary & process emissions add electricity and natural gas use

City Action Highlights

- Water Service Department's Lake Pleasant solar facility generates around 10.7 million kWh annually
- Water conservation and less volumes at WTPs and WWTPs have reduced treatment energy requirements

The Water Services department finished construction of a 7.5 MW solar power facility at the Lake Pleasant WTP. The overall reduction of GHG emissions was largely due to the onsite solar power generation by Water Services.

The 2015 inventory includes emissions from the hauling and regeneration of granulated activated carbon (GAC) for water treatment that were not included in the 2005 inventory.

4.3.2 Emissions Sources and Distribution

Emissions from Water Services (water distribution and wastewater treatment) decreased by 16.6% overall between 2005 and 2015. The largest decreases were a result of onsite solar power generation. The changes in the GHG emissions from both WWTPs are due to a combination of population changes as well as the changes in operation at the WWTPs and reduced water usage from newer residential appliances. Changes in emissions for each Water Services subsector are shown in Figure 6 below.

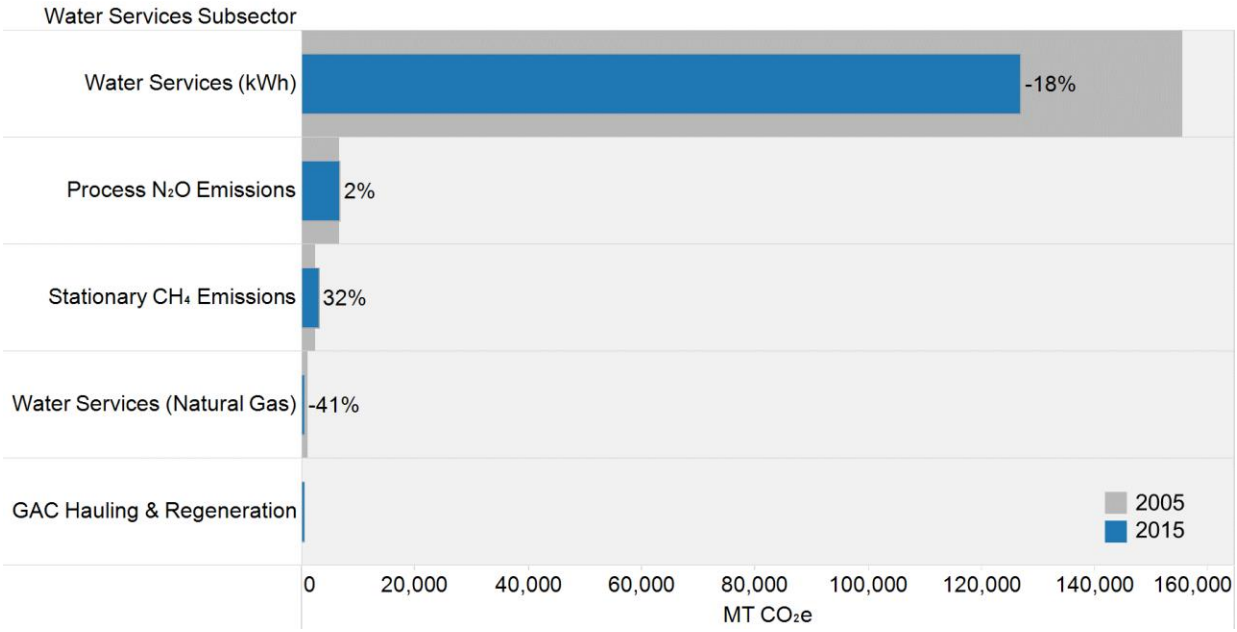

Figure 6: Water Services Emissions Changes by Subsector between 2005 to 2015.

Figure 7 shows 2005 and 2015 process emissions from Phoenix WWTPs.

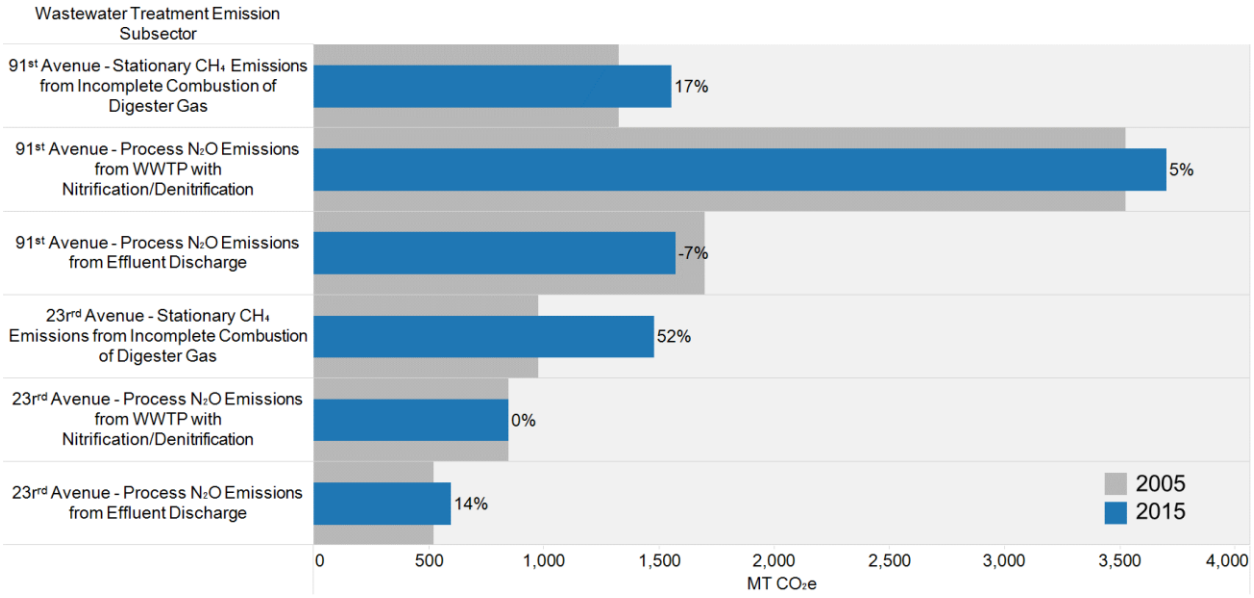

Figure 7: Wastewater Treatment Emissions Changes between 2005 and 2015

Emissions are generated from the energy used in both distribution and treatment, as well as from the regeneration of GAC used in the treatment process to remove disinfection byproducts. The wastewater treatment process itself also generates CH_4 and N_2O from incomplete combustion of digester gas, the nitrification/denitrification process, and effluent discharge. In 2015, net electricity consumption at water distribution and wastewater treatment facilities emitted a total of 126,993 MT CO_2e (Table 11). GAC hauling and regeneration is a new activity for Phoenix, so no 2005 benchmark exists. Overall, Water Services emitted 137,932 MT CO_2e from wastewater processing and treatment, GAC hauling and regeneration, electricity consumption and solar power generation, and natural gas combustion.

Table 11: 2015 Water Services Emissions by Subsector

Subsector	Total kWh	Total Therms	Total Tons CH4 Emissions	Total Tons N_2O Emissions	Total MMBTU	Total Diesel Gallons	MT CO_2e
Water Services – Electricity	254,622,318	--	--	--	--	--	126,993
Water Services – Natural Gas	--	112,938	--	--	--	--	600
Wastewater Treatment	--	--	121.3	22.5	--	--	9,751
GAC Regeneration	--	--	--	--	10,514	15,065	588
Total	254,622,318	112,938	121.3	22.5	10,514	15,065	137,932

Water Services indicators in Table 12 below shows that in 2015, less drinking water was treated and fewer GHG emissions occurred per billion gallons treated. Both gallons of wastewater treated and emissions from treating wastewater also decreased. This is in large part due to the addition of solar power and energy efficiency measures at these facilities.

Table 12: Water Services Emissions Indicators

Indicator	2005	2015	% Change
Gallons of drinking water treated (billion gallons)	109.4	106	-3%
MT CO_2e per billion gallons water treated	1,511	1,296	-14%
Million Gallons of wastewater treated	69,523	61,220	-12%
MT CO_2e per million gallons wastewater treated	2.25	2.24	-6%

4.4 Solid Waste

4.4.1 2005 vs. 2015: What Changed?

Phoenix closed Skunk Creek landfill in 2006 and improved the landfill gas collection system at the landfill to capture fugitive emissions.

Additionally, 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. This avoids fugitive methane emissions as early as possible in the landfilling process.

Solid Waste
Total Emissions: 61,173 MT CO_2e
10.4% of municipal operations emissions
44.6% decrease from 2005 levels

Emissions Sources

- Flared methane from landfill gas capture systems
- Fugitive methane from the landfill surface

City Action Highlights

- 90% efficient methane capture system at newly opened SR-85 landfill
- Increased methane capture efficiency with improvements at Skunk Creek landfill

Emissions were calculated using City of Phoenix landfill-specific (landfill-specific) and general characteristics for landfills developed by EPA. Due to the especially dry climate in Phoenix that allows for more efficient collection, the advanced technologies being implemented at certain landfill facilities such as Skunk Creek landfill for collection and SR-85 landfill-specific characteristics were used for final reporting purposes.

4.4.2 Emissions Sources and Distribution – Landfill Specific Characteristics

Fugitive CH_4 emissions from landfills were reduced by 45% due to the installation of advanced landfill gas capture systems at the Skunk Creek and SR-85 landfills. This percent reduction was the most significant of any city emissions sector.

The SR-85 landfill, which opened in 2006, is the only operational landfill managed by the city of Phoenix. It includes the ongoing landfill gas collection system mentioned previously. Estimated as 90% collection efficient, it avoids a significant amount of fugitive methane emissions. Landfill gas collection at the other city landfills is estimated to be at a level of at least 75% efficiency. Landfill gas at those sites will continue to diminish due to the natural decline of methane production over time, as the landfills are

closed and no longer receive waste. Figure 8 details the change in emissions by facility.

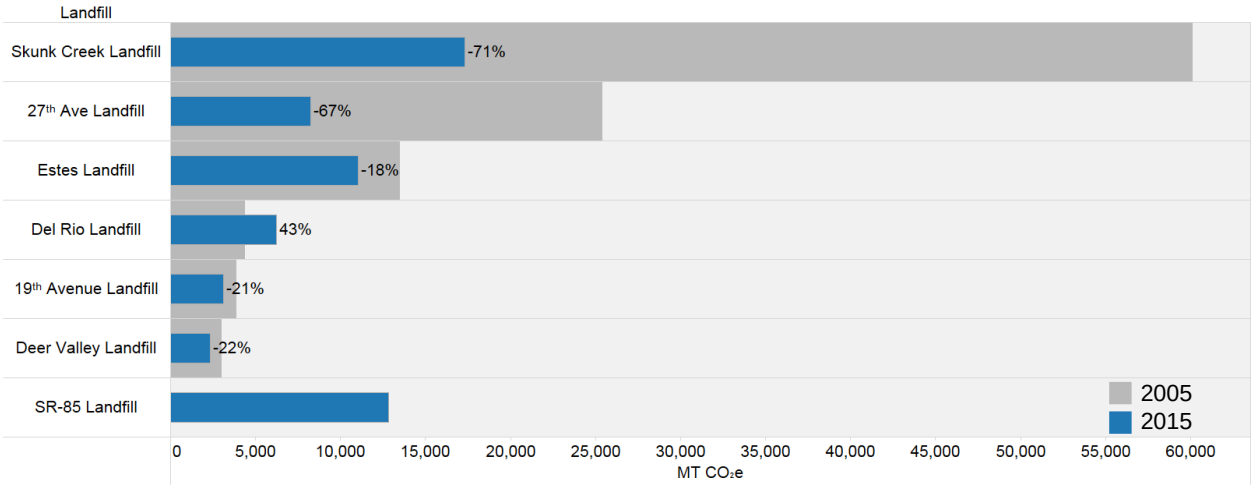

Figure 8: Phoenix Landfills Emissions Changes between 2005 and 2015

Table 13 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 13: 2015 Solid Waste Emissions by Landfill

Landfill	Tons CH_4 Collected/Flared	Tons CH_4 Released	MT CO_2e Emissions
Skunk Creek Landfill	5,315	693	17,321
27th Ave Landfill	2,553	331	8,265
Del Rio Landfill	494	250	6,238
Deer Valley Landfill	330	94	2,358
19th Avenue Landfill	815	124	3,097
Estes Landfill	442	442	11,055
SR-85 Landfill	5,522	514	12,839
Total	15,472	2,447	61,173

Table 14 (next page) depicts the amount of waste in place at Phoenix-maintained landfills and the unit emissions per short ton of waste.

Table 14: GHG Emissions Indicators for Solid Waste

Indicator	2005	2015	% Change
Amount of Waste in Place (short tons)	41,600,000	52,405,666	26%
Kg CO_2e Per Ton of Waste	2.65	1.17	-56%
Average Methane Capture	68%	83%	22%

NOTE: Landfill GHG emissions in this report will differ from data reported to the EPA for its GHG mandatory reporting. This GHG update uses formulas contained in the LGOP to calculate emissions, while EPA uses its own separate and different methodologies for both GHG emissions and estimated gas collection system capture rates. While 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.

4.5 Employee Commute

4.5.1 2005 vs. 2015: What Changed?

Employee Commute

Total Emissions: 31,510 MT CO_2e

5.4% of municipal operations emissions

2.7% increase from 2005 levels

Emissions Sources

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

City Action Highlights

- Construction of light rail
- Employee Rideshare Program

The city of Phoenix participates in the valley-wide Trip Reduction Program (TRP) overseen by Maricopa County Air Quality Department. This program allows employers to generate a yearly analysis of employee commuting from voluntary employee surveys

Miles commuted by employees increased by 5.4% from 2005 levels. Employee commuting from 2005 did not include miles by bus or light rail as this data was not available for previous GHG emissions inventories. However, both are included in 2015 data which skews the comparison. Excluding light rail and bus miles from both years would yield only a 3.1% increase in vehicle miles. For this reason, bus commuting miles have been backcast to 2005 using ratio of Phoenix employees (FTE) between 2005 and 2015. Backcasting by employment levels provides a general estimation of bus commuting by Phoenix employees. However, this method assumes an identical ridership level in 2005 and 2015. Bus commuting miles for 2005 may be overestimated due to the influence of commuting programs that incentivize bus ridership implemented after 2005.

2005 employee commuting data was updated to include Volunteer Sites (work sites with less than 50 employees), which were not included in the original report. The 2005 data was revised for those sites and estimated using the average annual commuting statistics for city employees that year. In 2015, volunteer site data was available for inclusion in the inventory.

Alternative fuel vehicle commuting miles by fuel types were estimated for 2005 and 2015 by alternative fuels sales in Maricopa County.

Lastly, employee commuting using city vehicles is not counted as employee commuting to avoid double counting. Employee commuting distance increased between 2005 and 2015, which may be a contributing factor in the 2005-2015 estimated increase in emissions.

4.5.2 Emissions Sources and Distribution

Fuel use from personal vehicles, vanpools, bus transit, and light rail is used to account for commuting emissions. Alternative fuel vehicle commuting is indicated in the TRP data, however, fuel type is not. Alternative fuel use type is estimated from statewide ownership data obtained from the EIA. 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 2015 inventory captures commuting data for all of city of Phoenix employees generated through TRP. The city's 2005 TRP survey accounted for only 69% of city employees, as it was limited to only those sites with 50 or more employees. The 2005 and 2015 data has been adjusted to account for 100% of employees for consistent and more accurate comparison with 2015 data.

Table 15 breaks down 2015 employee commuting emissions by fuel type or by mode of transportation and the resulting emissions.

Table 15: Employee Commute Emissions by Fuel Type/Mode in 2005 and 2015

Fuel Type	2005		2015	
	Commuting Miles	MT CO_2e	Commuting Miles	MT CO_2e
Gasoline	80,555,678	30,153	83,504,307	31,091
Electric	36,477	10	52,927	14
CNG	277,905	80	264,775	45
LPG	284,192	88	311,161	58
E85	12,609	2	460,061	80
Hydrogen	--	--	1,790	0
Bus*	3,158,885	338	3,158,239	184
Light Rail‡	--	--	289,157	38
Total	84,325,745	30,672	92,659,836	31,829

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

4.5.3 City Action Highlights

The Phoenix Light Rail opened in 2008, providing city employees another opportunity to commute by public transit. The city also continued its employee 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. The free bus passes for employees, specifically those working at City Hall, largely contributed to the increase in bus ridership seen in 2015.

5 Benchmarks

The 2015 inventory update lays the foundation for both internal and external benchmarking for future GHG emissions inventories. Internal benchmarks are measured in the inventory as a measure of GHG intensity, or the amount of GHG emitted for a particular output (e.g., MT CO_2e per sq. ft. of city operated building space), or GHG efficiency, which increase as city service is provided with less associated emissions (e.g., gallons of treated water per MT CO_2e emitted). Table 16 details the benchmarks and how they are measured.

Table 16: Internal City Operations Indicators

City Operations Indicators	2005	2015	Unit
Employees	14,667	14,664	Employees
Building Area	N/A	12,599,324	Sq. ft.
Volume of Water Treated	109.4	106	Billion gallons
Volume of Wastewater Treated	69.5	61.22	Billion gallons
Waste in Place (during year)	41,600,000	50,753,766	Short tons
Annual Fleet Miles (PW Fleet only)	52,825,683	N/A	mi
Commuting Gasoline Miles Traveled	80,555,678	83,504,307	mi
Total Emissions per Employee (F/PTE)	46.05	39.35	MT CO_2e/employee
Vehicle Emissions per Employee (F/PTE)	8.98	7.75	MT CO_2/employee
Emissions per sq. ft.	N/A	45.15	kg CO_2e/sq. ft.
Cooling Degree Day GHG Intensity	36.40	37.58	MT CO_2e/CDD
Building/Facilities Emissions per F/PTE	12.6	11.4	MT CO_2e/employee
Emissions Per Traffic Signal	7.97	4.69	MT CO_2e/ Signalized Intersection
Emissions Per Street Light	0.46	0.41	MT CO_2e/ Street Light
Number of Vehicles (PW Fleet only)	6,090	7,389	Vehicles
Vehicle GHG Intensity	5.3	4.4	MT CO_2e/vehicle
Vehicle Mile GHG Efficiency (PW)	0.61	N/A	kg CO_2e/mi
Commuting Gasoline Miles Per Employee	5,492	5,711	mi/employee/year
% Single Occupancy Vehicle	73.8%	75.8%	%

External benchmarks are based on community-wide emissions, which Phoenix has yet to measure within its boundaries. Community-wide emissions would include, but would not be limited to: emissions from residential, commercial and industrial electricity usage; and emissions from commuting into and out of the city; total vehicle miles driven within the city; and private waste handling.

6 Biogenic Emissions

Biogenic emissions are produced through the combustion or decomposition of biologically-based materials rather than fossil fuels. Biogenic emissions do not count as fossil GHG emissions and are tabulated as informational items for the purposes of the 2015 inventory update. Table 17 shows biogenic emissions from city of Phoenix government operations in 2005 and 2015.

Table 17: Sources and Quantities of Biogenic Emissions (MT CO_2e)

Biogenic CO_2 Summary	2005	2015
Biogenic Landfill	66,560	79,636
Biogenic B20 Biodiesel	--	6,416
Biogenic E85 Ethanol	--	1,665
On-Site Biogas Use-91st Ave. WWTP	3,978	2,187
Flared Biogenic Wastewater CO_2 – 91st Ave. & 23rd Ave. WWTPs	58,146	39,175
Total Biogenic	128,684	129,079
% of Fossil	18%	22%

Sources of biogenic emissions come from blended biofuels, such as B20 biodiesel and E85 ethanol, municipal landfills, and wastewater treatment plants. For blended biofuels, the biofuel component of the fuel is considered biogenic while the emissions, primarily N_2O and CH_4, from the diesel or gasoline component are considered to be fossil emissions.

Appendix A: Greenhouse Gas Equivalents

Table A1: Greenhouse Gas Equivalents for the 2005 and 2015 GHG Emissions Inventories

Greenhouse Gas*	AR2 GWP Values[1]	AR4 GWP Values[2]
Carbon Dioxide (CO_2)	1	1
Methane (CH_4)	21	25
Nitrous Oxide (N_2O)	310	298
Hydrofluorocarbons (HFCs)	43-11,700	43-11,700
Perfluorocarbons (PFCs)	6,500-9,000	6,500-9,000
Sulfur Hexafluoride (SF_6)	23,900	23,900

*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.

Appendix B: Solar Projects & Partnerships

Table B1: City of Phoenix Completed and Planned Solar Projects

Solar Projects/Partnerships				
Project #	Description	Completed	kW	Projected kWh/year
1	Transit - Pecos Park & Ride (SRP Grid)	2004	100	147,000
2	N. Transfer Station Parking Lot (32 x 40w fixtures)	2006	1.3	1,955
3	North Transfer Station	2006	7	10,700
4	Phoenix Convention Center - West Bldg	2007	100	125,800
5	Camp Colley (off grid)	2007	8.5	12,335
6	North Mountain Park Visitor Ctr.	2008	3.2	4,597
7	Pecos Community Center	2009	30	43,785
8	Paradise Village Apts (Housing)	2010	2	2,845
9	Helen Drake Senior Center	2011	40	58,285
10	McCarty on Monroe (Housing/NSD)	2011	30	44,100
11	Maryvale Pool	2011	15	22,050
12	Washington Adult Center	2011	10	14,700
13	Audubon Visitor Center	2011	30	44,100
14	US Airways Parking Garage	2011	238	347,385
15	ASU DT – Cronkite School of Journalism	2011	77	112,390
16	Burton Barr Central Library	2011	150	198,000
17	Fire Training Academy	2011	10	14,595
18	Fire Station #12	2011	10	14,595
19	Fire Station #1	2011	20	29,190
20	Sunnyslope CC – Main & Gym	2011	100	147,000
21	Aviation – East Economy Parking Garages	2011	1,290	2,004,565
22	Aviation – Rental Car Center	2011	4,100	6,388,700
23	DT Transit Building	2012	30	43,785
24	Phoenix Children's Museum	2012	85	126,855
25	Water Department – Lake Pleasant WTP	2012	7,500	12,803,250
26	Metro Facilities Building	2012	90	141,750
27	Walker Building	2013	10.5	15,990
28	Washington St. Parking Garage (305 Garage)	2014	486.6	754,135
29	Adam St. Parking Garage (310 Garage)	2014	695.9	1,078,505
30	Valley Metro Light Rail- Operations Center	2015	783	1,151,010
31	SR-85, DESERT STAR (APS utility-scale)	2015	15,625	24,609,375

Appendix C: Solid Waste Findings Using EPA Characteristics

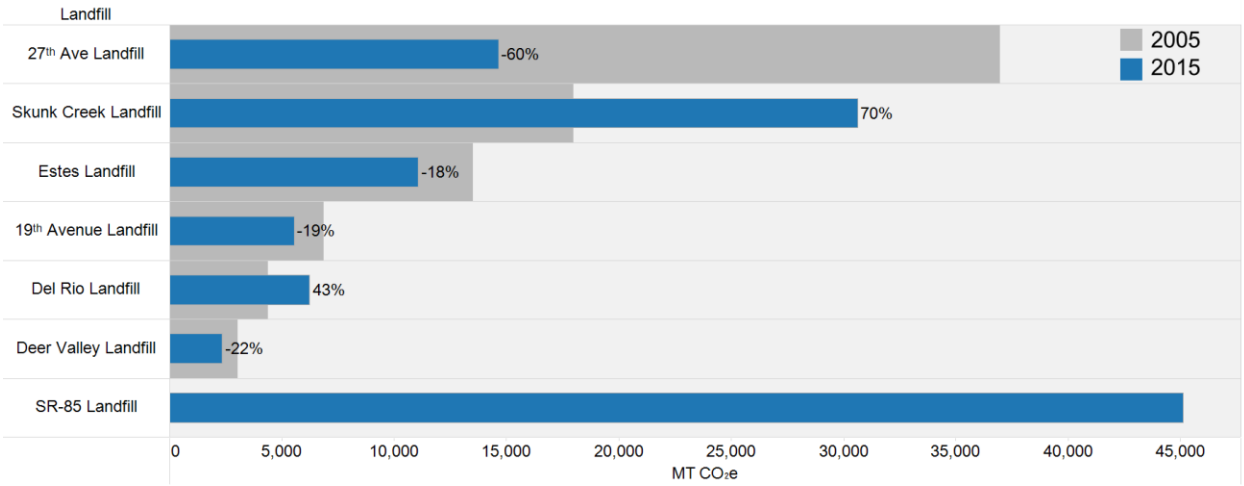

Figure C1: Changes in Emissions (in MT CO_2e) at Phoenix Landfills between 2005 and 2015; Note: SR-85 Landfill was not in operation in 2005.

Table C1: 2015 EPA Solid Waste Emissions by Landfill

Landfill	Tons CH_4 Collected/Flared	Tons CH_4 Released	MT CO_2e Emitted
Skunk Creek Landfill	6,024	1,224	30,609
27th Ave Landfill	2,893	586	14,648
Del Rio	494	250	6,238
Deer Valley	330	94	2,352
19th Avenue	924	222	5,541
Estes	442	442	11,055
SR-85	7,245	1,806	45,139
Totals	18,352	4,623	115,582

Appendix D: Findings by Scope

The following appendix presents city of Phoenix emissions broken down by scope instead of by reporting sector as in the text of the report. Overall emissions breakdowns are shown in Figures 1 and 2.

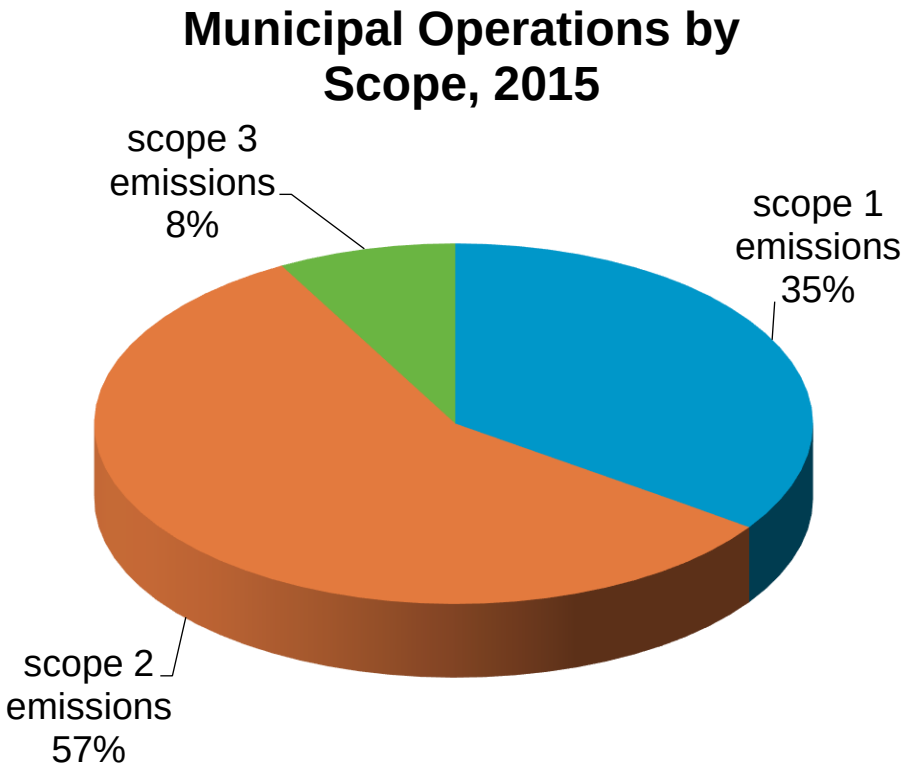

Figure D1: 2015 Emissions by Scope

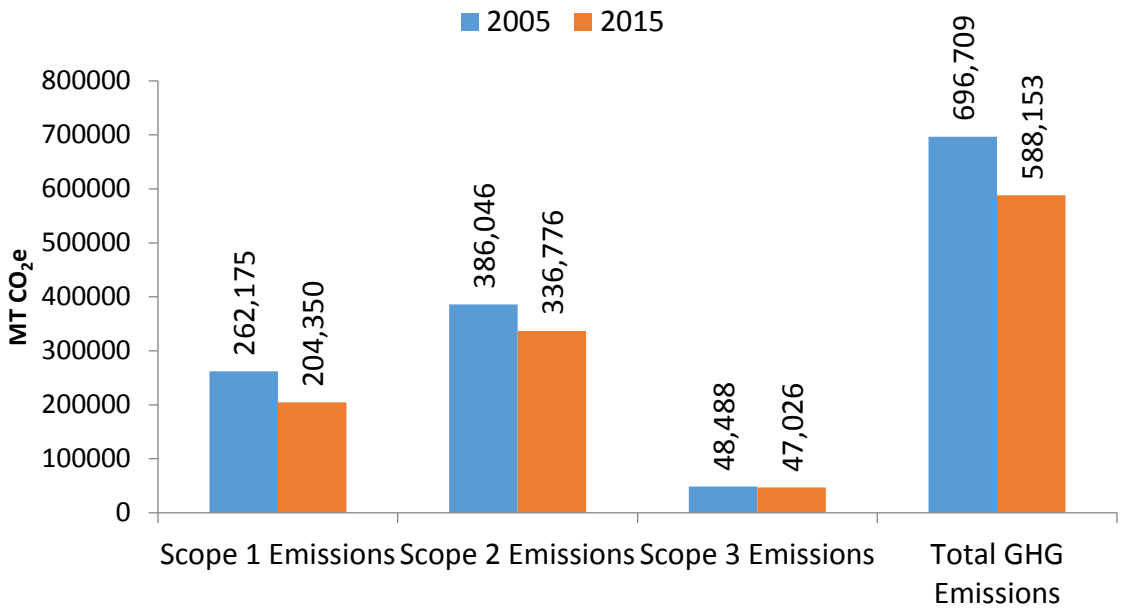

Figure D2: Municipal operations comparison, 2005 and 2015

Scope 1

Scope 1 emissions contribute 34.7% of the city's total emissions accounting for 261,175 MT CO_2e. From 2005 to 2015, Scope 1 emissions decreased 22.1%. Scope 1 is comprised of stationary combustion, fleet fuels, and fugitive and process emissions from landfills and wastewater treatment plants (Figure 4). Stationary combustion includes emissions from natural gas usage in municipal buildings, wastewater treatment, and water distribution. Fleet fuels include gasoline, diesel, B20 biodiesel, compressed natural gas (CNG), liquefied natural gas (LNG), E85 Ethanol, liquefied petroleum gas (LPG), Aviation gasoline, and jet fuel. Fugitive emissions include those released from landfill methane gas, wastewater methane emissions and wastewater nitrous oxide emissions.

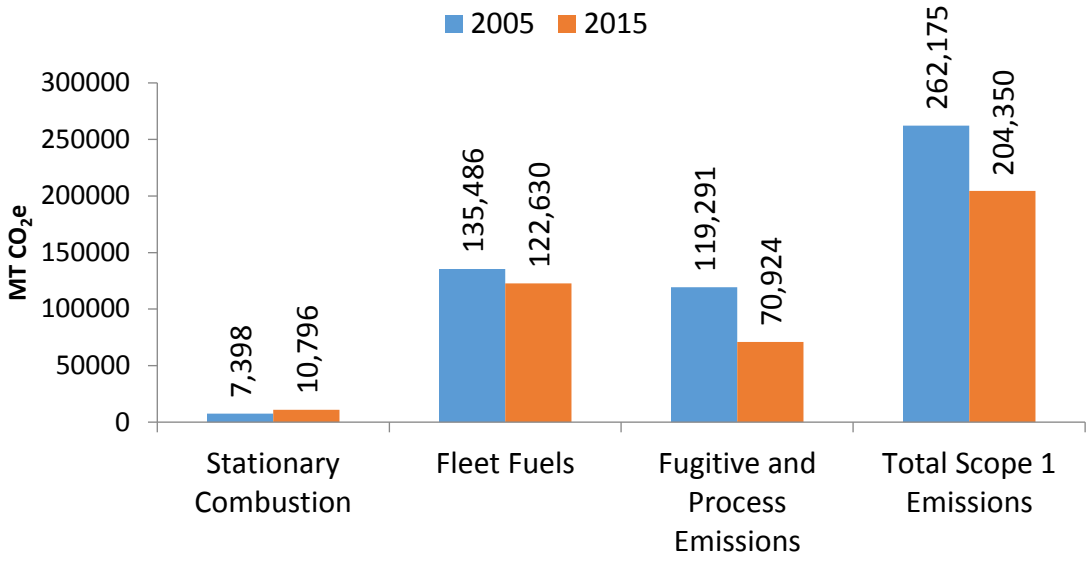

Figure D3: 2005 and 2015 Scope 1 Emissions

Stationary sources of Scope 1 emissions come from use at city buildings, use for water distribution, and use for wastewater treatment. The combustion of natural gas in buildings, and the resulting emissions, increased by 60% between 2005 and 2015, while natural gas combustion for water distribution treatment decreased by 41%.

Phoenix reduced the city's fugitive and process emissions more than any other emissions category. Fugitive methane emissions from landfills were reduced by 40.5%, due to the installation of advanced landfill gas capture systems at the Skunk Creek and the new SR-85 landfills. Fugitive and process emissions from wastewater treatment decreased slightly as city WWTPs treated less effluent in 2015 than in 2005.

The city also had significant reductions in its fleet fuels emissions. The city's fuel portfolio changed dramatically between 2005 and 2015 with the addition of B20 biodiesel vehicles and E85 flex fuel vehicles. The incorporation of biofuels into the fleet fuel portfolio helped to reduce Scope 1 emissions overal from the city's vehicle fleet by 9.5 % from 2005 to 2015. For example, converting to B20 biodiesel prevented the emission of approximately 6,944 MT CO_2e. Lower diesel consumption further reduced Scope 1 emissions along with B20 biodiesel.

Scope 2

Scope 2 emissions account for 57.3% of the city's total emissions with a total of 336,776 MT CO_2e.From 2005 to 2015, emissions from Scope 2 decreased by 12.8% (Figure 4). Scope 2 is comprised of the indirect 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).

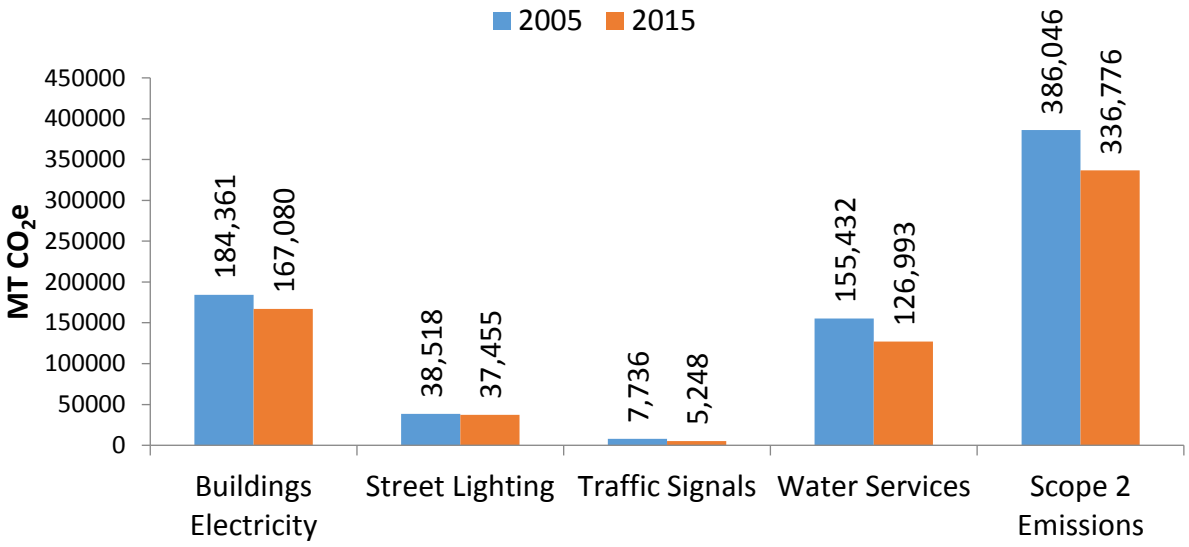

Figure D4: 2005 and 2015 Scope 2 Emissions

While Scope 2 emissions decreased between 2005 and 2015, the kilowatt-hours of electricity purchased increased by 13% overall. However, city buildings saw a 9% reduction in emissions from purchased electricity; street lighting a 3% reduction, traffic signal emitted 32% less GHGs, and water services saw an 18% reduction in MT CO_2e . Over the same period, the carbon intensity (eGRID factor) of the purchased electricity in Arizona, measured in MT CO_2e per generated kWh decreased by 12% due to the increased contribution of renewable fuel in utility/grid-base purchased electricity. Additionally, solar power generation at buildings and facilities also helped contribute to the overall decrease in Scope 2 emissions.

Scope 3

Scope 3 emissions account for 8% of the city's total emissions with a total of 47,026MT CO_2e. From 2005 to 2015, emissions from Scope 3 decreased by 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. Phoenix chose to report emissions from these sectors because Phoenix has some ability to impact those activities through various policies, programs, and contracts.

Emissions from employee commuting are the largest component (67%) of Scope 3 emissions (Figure 5). Between 2005 and 2015 total employee commuting miles increased by 4.4%. There were multiple factors that caused a change in employee commuting. First, the 2005 commuting data did not include data regarding commuting by bus. The 2015 commuting data also includes information regarding light rail commuting, which did not exist in 2005. Both bus miles and light rail miles are included in 2015 totals. The 2005 employee commute data did not include volunteer sites, which are city of Phoenix work sites that have less than 50 employees. Employee commuting to and from volunteer sites was estimated for 2005 using the average annual commuting statistics for city employees in that year. Thirdly, alternative fuel vehicle commuting miles broken out by fuel type was estimated for 2005, while 2015 usedestimates based on actual state-wide registered AFV ownership data. There was a major shift in employee commuting data towards bus ridership and personal hybrid-electric vehicle ownership from 2005 to 2015.

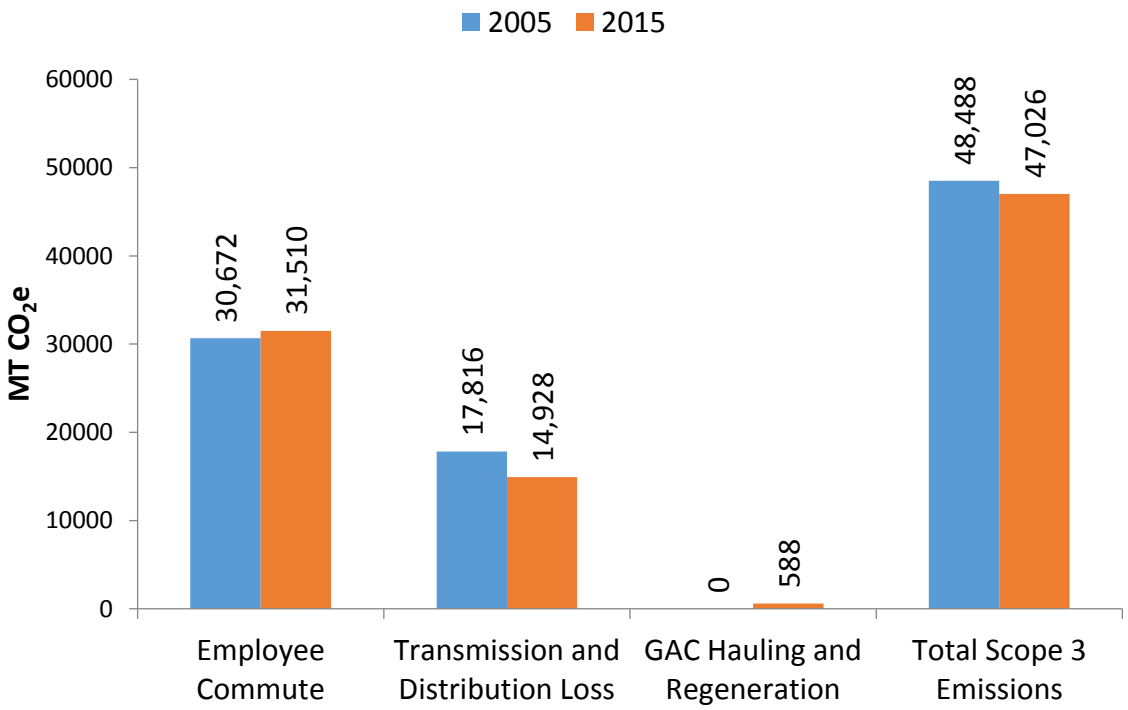

Figure D5: 2005 and 2015 Scope 3 Emissions