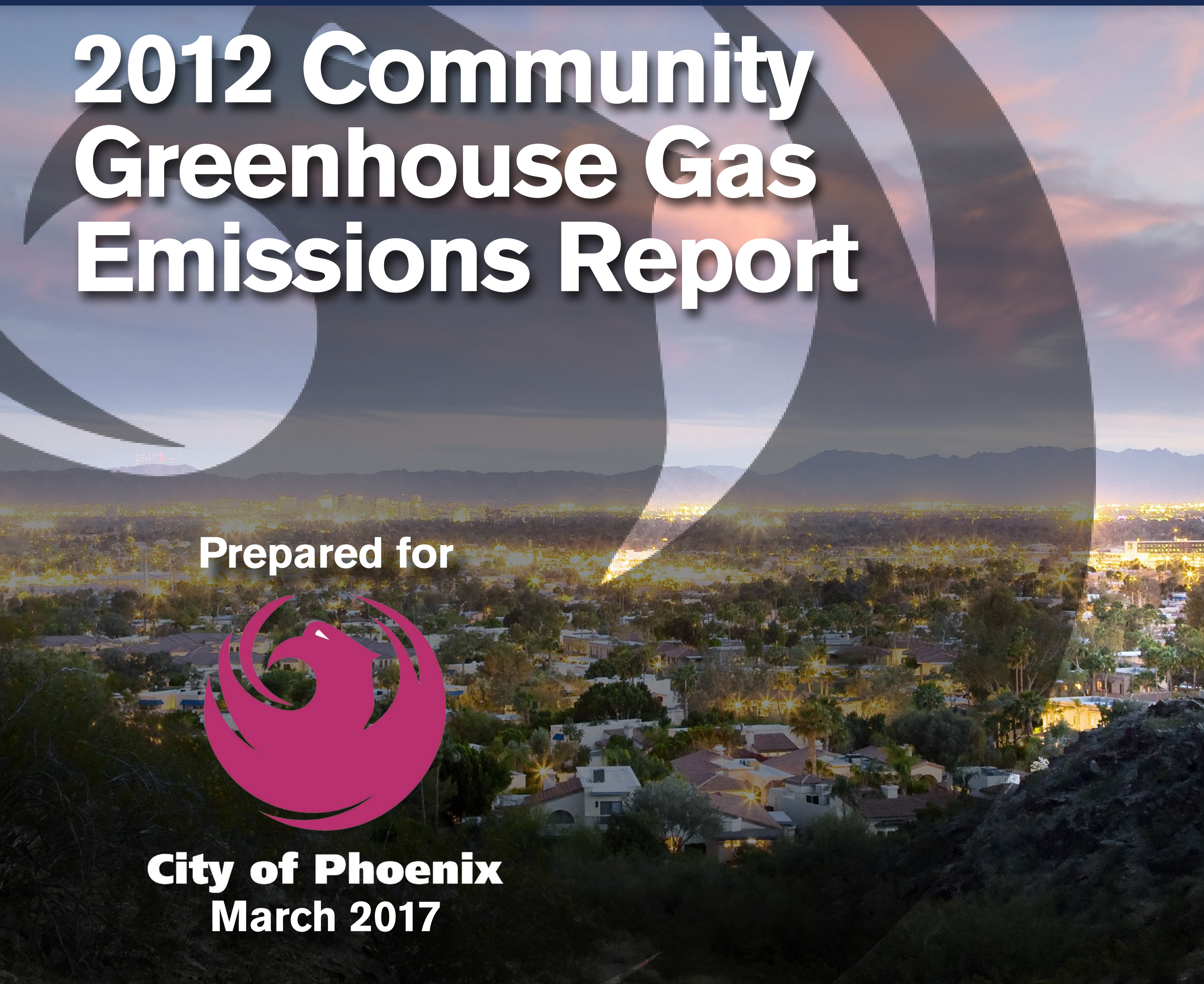
Walton Sustainability Solutions Initiatives

ARIZONA STATE UNIVERSITY

2012 Community Greenhouse Gas Emissions Report



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Acronyms

AZNM	Arizona and New Mexico eGRID Subregion
APS	Arizona Public Service
AR4	4th Assessment Report of the Intergovernmental Panel on Climate Change
BT	Biological Treatment
CAP	Climate Action Plan
CDP	Carbon Disclosure Project
CH4	Methane
CNG	Compressed Natural Gas
CO2	Carbon Dioxide
CO2e	Carbon Dioxide Equivalent Emissions
eGRID	EPA's Emissions and General Resource Integrated Database
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
FTE	Full-time-equivalent
GAC	Granulated Activated Carbon
GHG	Greenhouse Gas
GPC	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (also GPC Protocol)
GWP	Global Warming Potential
ICLEI	International Council for Local Environmental Initiatives
IGCC	International Green Construction Codes
IPCC	Intergovernmental Panel on Climate Change
LED	Light Emitting Diode
LEED	Leadership in Energy and Environmental Design
LGOP	Local Government Operations Protocol
LNG	Liquid Natural Gas
LPG	Liquefied Petroleum Gas
LTO	Landing and Takeoff
MT	Metric Tons
NEI	National Emissions Inventory
N2O	Nitrous Oxide
SRP	Salt River Project
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

Resource Innovation and Solutions Network

Executive Summary

Climate change is one of the most pressing global issues today, as human development continues to cause increases in greenhouse gas (GHG) emissions. Cities have become the focus for climate change mitigation, both because cities are a major source of greenhouse gases and because of their ability to implement real solutions to climate change. Municipal sustainability goals promote both sustainable development and climate change adaptation to bolster our community resilience. As the sixth largest city in the United States, Phoenix has the potential to emerge as a leader in the climate change arena and set an example for other cities.

In 2008, Phoenix City Council embraced this challenge and adopted a goal to reduce GHG emissions from city operations to five percent below 2005 levels by 2015. After conducting two municipal scale greenhouse gas inventories, according to the Local Government Operations Protocol of the International Council for Local Environmental Initiatives (ICLEI), the city revised this goal to 15 percent below the 2005 levels by 2015. According to the results of the 2015 GHG inventory Update, the city of Phoenix met its goals and reduced emissions by 15.6 percent. While that success only addressed municipal operations, Phoenix has now completed its first community-scale GHG emissions inventory using the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC or GPC Protocol), a worldwide standard for inventorying city-induced GHG emissions developed by the World Resources Institute, C40 Cities Climate Leadership Group, and ICLEI[1]. The GPC is also the standard supported by the Global Covenant of Mayors for Climate and Energy, of which Phoenix is a member.

The findings summarized in this Phoenix community-wide inventory report consists of all direct and indirect emissions from Phoenix categorized into three main sectors: stationary energy, transportation and waste. Stationary energy sources include natural gas consumption for heating as well as electricity use. Transportation includes vehicles, rail and aircraft landings and take-offs within city boundary. Waste is solid waste and wastewater emissions. Industrial Processes and Product Use and Agriculture, Forestry and Other Land Uses sectors were not reported due to data limitations and low relevance. The sources surveyed in this inventory are those sources generally

[1] Greenhouse Gas Protocol. (n.d.). GHG Protocol for Cities | Greenhouse Gas Protocol. Retrieved from http://www.ghgprotocol.org/city-accounting.

addressed by other comparable communities such as Portland, Austin, Houston and Las Vegas.

Major Findings

In 2012 total GHG emissions in Phoenix were 16,148,539 MT CO_2e, shown by sector in Figure 1.

A BASIC level community-scale GHG emissions inventory was conducted for the City of Phoenix, which included the stationary energy, transportation and waste sectors. Of the GHG emissions sectors, transportation was the largest source of GHG emissions, followed by stationary energy and then waste.

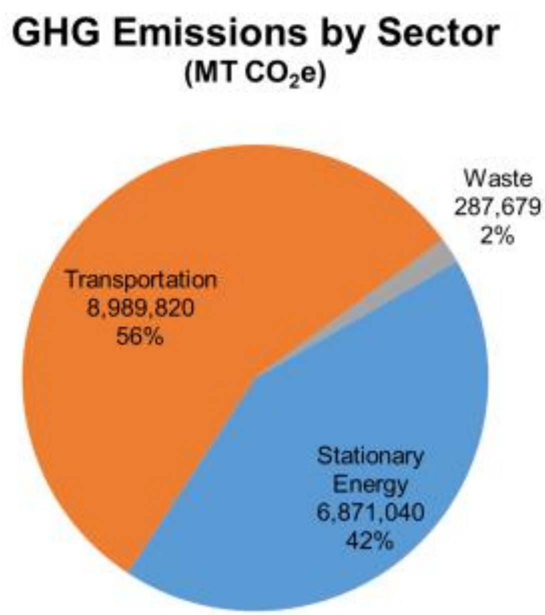

Figure 1: Breakdown of City of Phoenix Community-Scale GHG Emissions by Sector

The following pages illustrated a detailed breakdown for each of these sectors along with comparison to other cities by sector.

Stationary Energy

Total GHG emissions from stationary energy sources, electricity consumption and natural gas combustion were 6,871,040 MT CO_2e. Stationary energy sources include residential, commercial and manufacturing buildings, energy industries and agriculture. For Phoenix, residential buildings were the largest emission source, followed by commercial buildings and finally manufacturing industries, as shown in Figure 2.

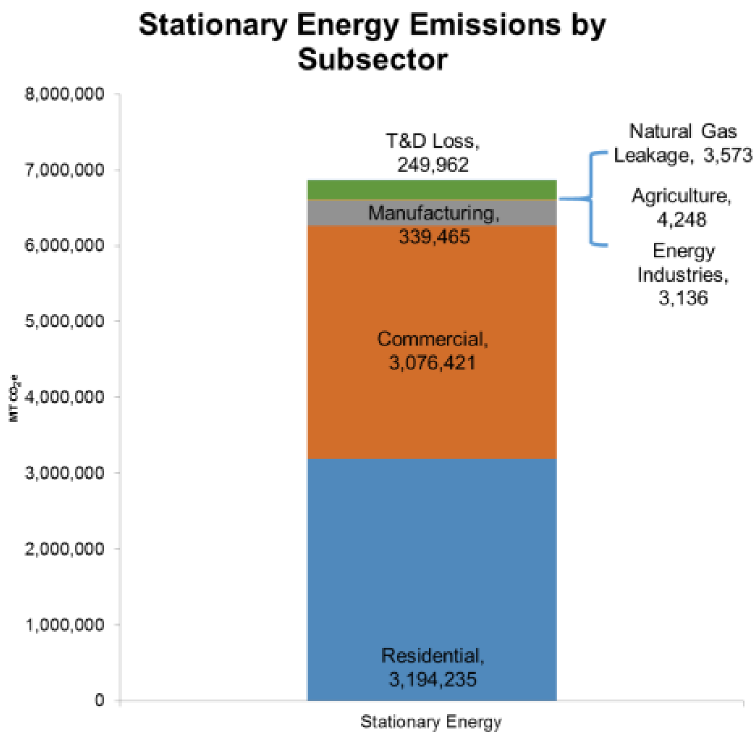

Figure 2: GHG Emissions from Stationary Energy Sources

Transportation

GHG emissions from transportation totaled 8,989,820 MT CO_2e. This category includes on-road transport, railways, water transportation, aviation and off-road transport. The highest emissions were from on-road transportation with 5,688,102 MT CO_2e as shown in Figure 3.

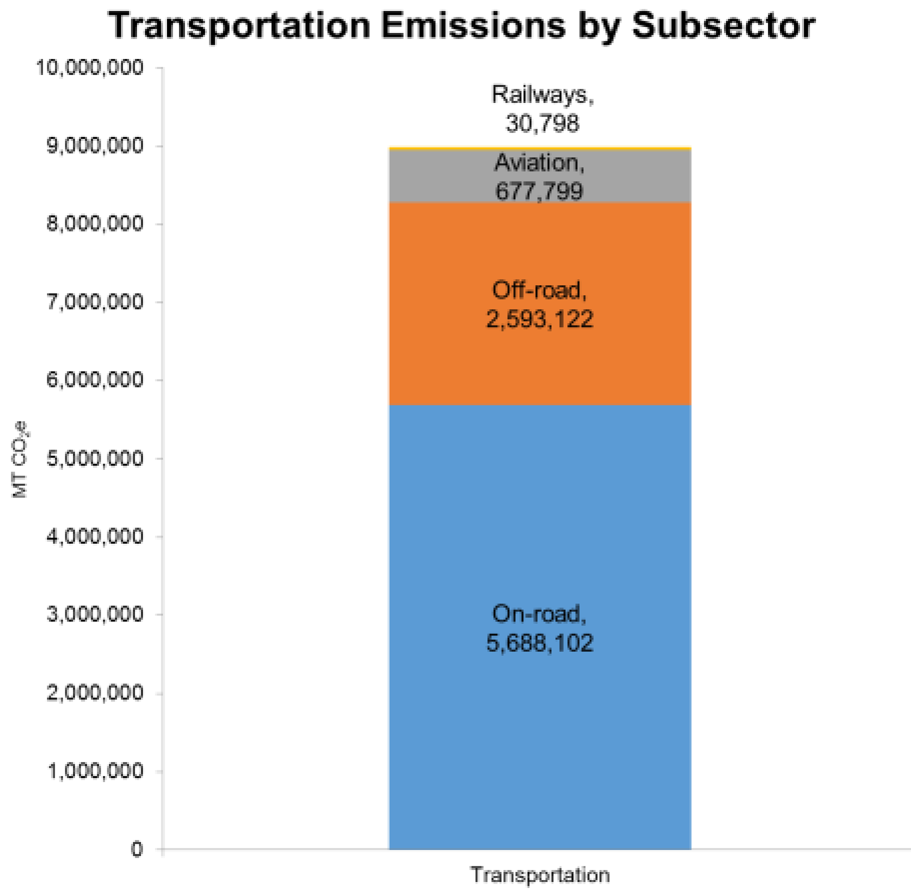

Figure 3: GHG Emissions from Transportation Sources

Waste

GHG emissions in the waste sector totaled 287,679 MT CO_2e and are a result of the disposal of solid waste, the biological treatment of waste, including composting, and wastewater generated inside and outside of the city, as shown in Figure 4.

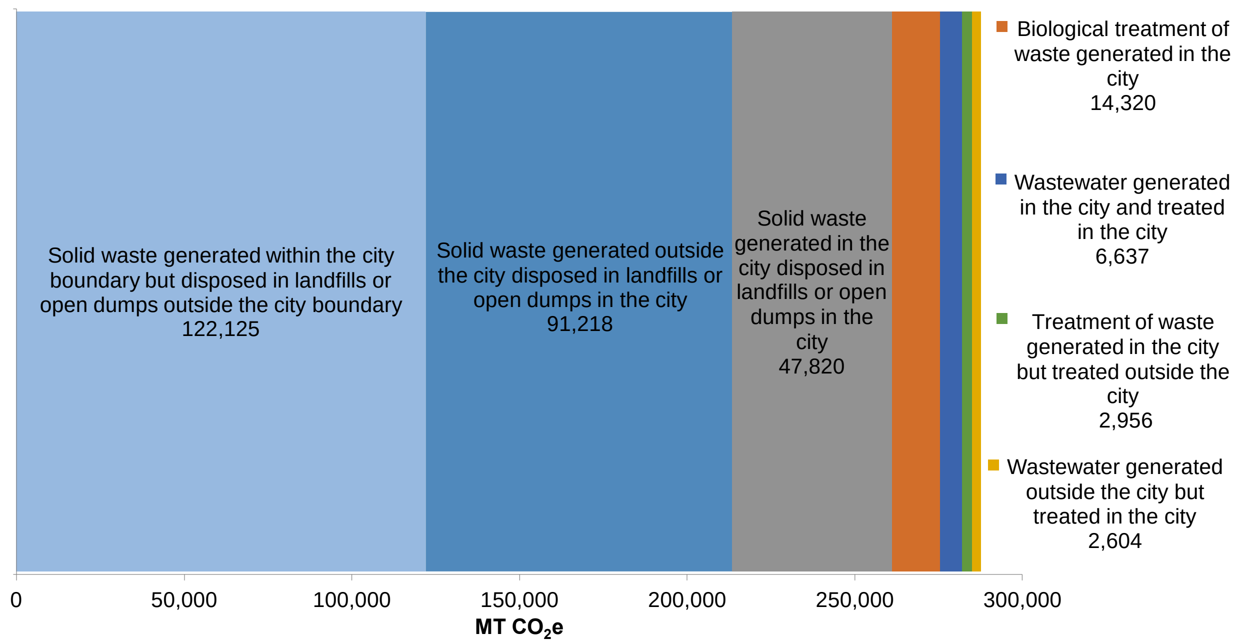

Figure 4: GHG Emissions from Waste Sources

Comparison of City of Phoenix 2012 Community-Scale GHG Emissions to Municipal Operations GHG Emissions

Overall, the city of Phoenix municipal operations accounted for approximately 3.9% of its community-scale GHG emissions, as compared in Figure 5. Operations comprises approximately 1.8% of scope 1 community emissions and approximately 7.3% of scope 2 community emissions. Scope 3 emissions were higher in the municipal operations GHG emissions inventory because these emissions were accounted as scope 1 emissions in the community-scale GHG emissions inventory, in accordance with GPC Protocol.

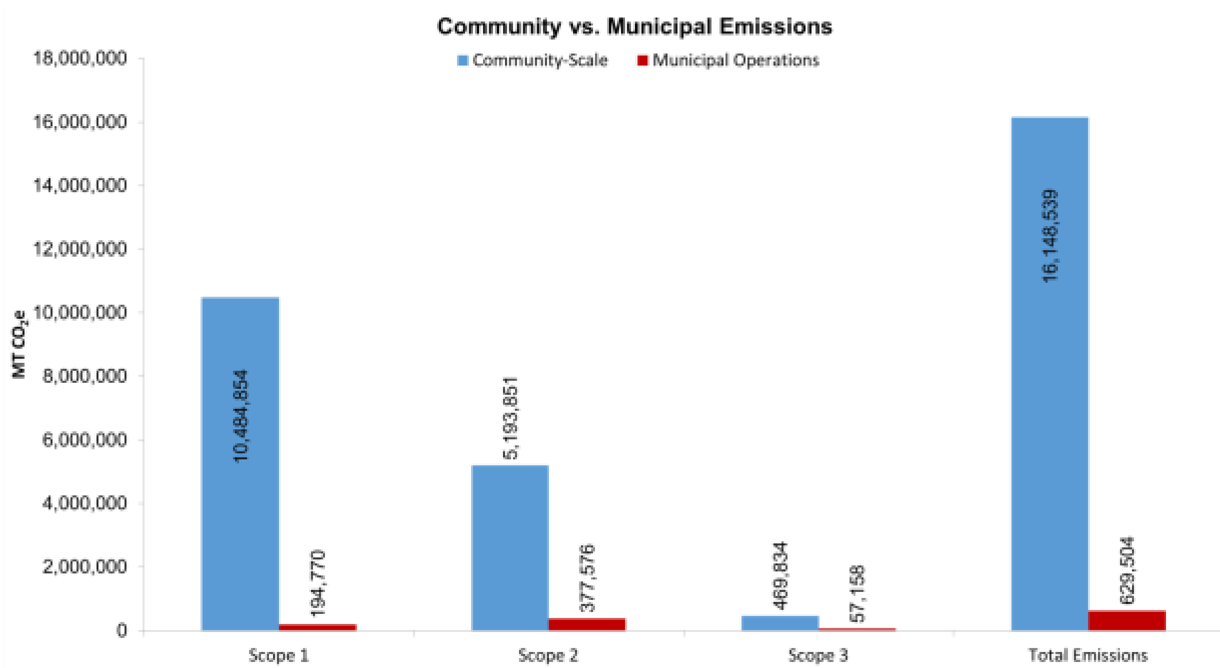

Figure 5. A Comparison of 2012 City of Phoenix 2012 Community-Scale GHG Emissions to Municipal Operations GHG Emissions[2]

[2] City of Phoenix. (2013) 2012 Greenhouse Gas Emissions Inventory for Government Operations. Report Prepared by ASU Global Sustainability Solutions Services. Retrieved from https://www.phoenix.gov/Documents/106457.pdf.

Comparison to Other Cities

Overall

Phoenix emitted 11.0 MT CO_2e per person, which ranks Phoenix higher than cities like Seattle, but lower than Houston, Portland and Las Vegas, as shown in Figure 6. This data was normalized to Phoenix's inventory by only comparing stationary energy, transportation and waste emissions between cities. Factors that are important to consider when making comparisons are varying levels of population, areal size of the city, climate, gross domestic product, renewable energy mix, transportation fuel mixes and the type of inventory conducted.

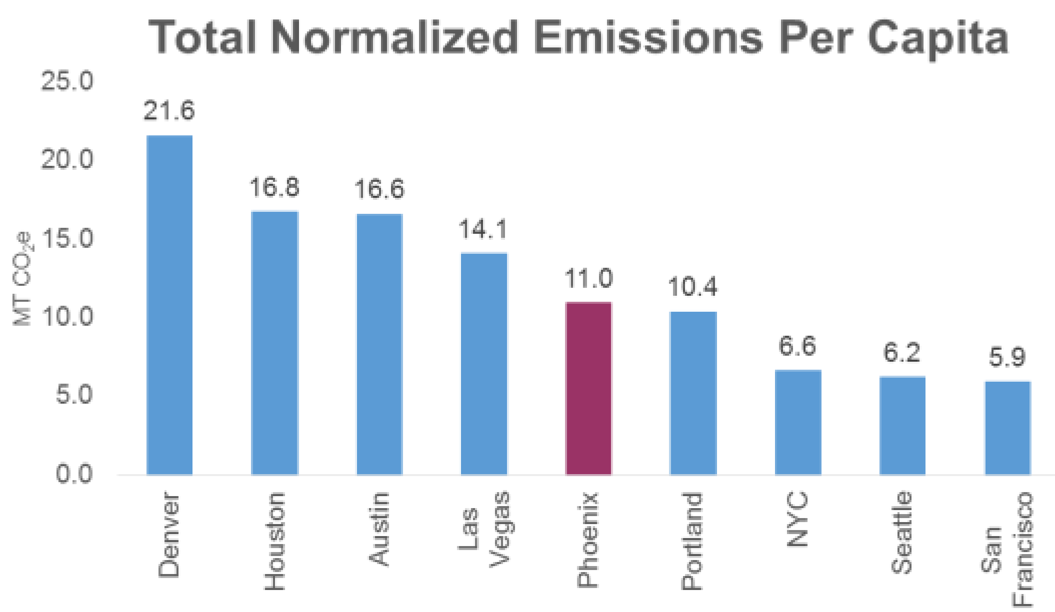

Figure 6: A comparison of the per-capita GHG emissions from City of Phoenix to other major U.S. cities.
Disclaimer: While attempts were made to normalize the level of emissions to better compare recent GHG inventories across various U.S. cities, some inventories are not easily comparable due to the use of a customized inventory methodology.

Stationary Energy

For the stationary energy emissions per capita, Phoenix ranks lower than Denver, Houston, Las Vegas, Austin, and NYC, as shown in Figure 7. This could be due to the cleaner energy supply from purchased grid electricity. Another factor could be that there is a portion of the year when Phoenix buildings do not need to be heated or cooled, and cooling is less energy intensive than heating buildings[3].

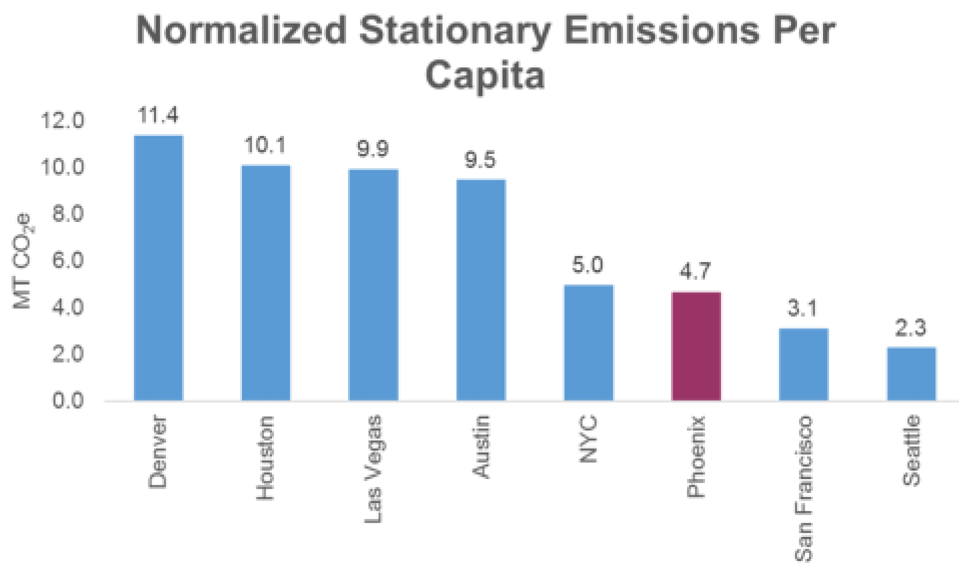

Figure 7: A comparison of the per-capita GHG emissions from Phoenix's stationary energy emissions to other U.S. cities

[3] Sivak, M. (2013). Air conditioning versus heating: climate control is more energy demanding in Minneapolis than in Miami. *Environmental Research Letters*, *8*(1), doi: 10.1088/1748-9326/8/1/014050.

Transportation

Phoenix ranked relatively high in its transportation emissions, with only Denver and Austin having higher emissions intensity, as shown in Figure 8. Cities known for their public transportation, such as Seattle and NYC, ranked much lower than Phoenix. This sector is where the city could improve the most to lower emissions.

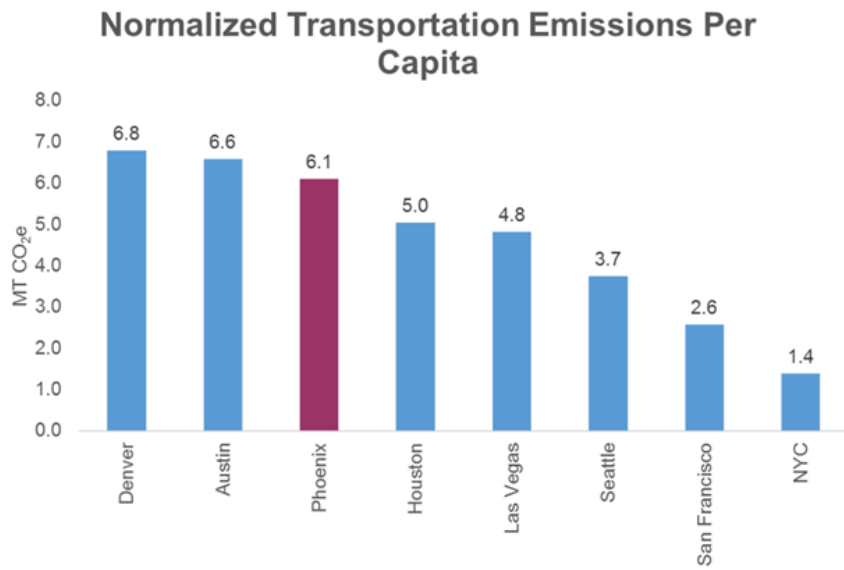

Figure 8: A comparison of the per-capita GHG emissions from Phoenix's transportation emissions to other U.S. cities

Waste

Phoenix only ranked higher than Seattle for its waste emissions per capita, as shown in Figure 9. This could be due to the highly efficient methane collection systems in Phoenix landfills, as well as the limited agricultural waste being produced in the city.

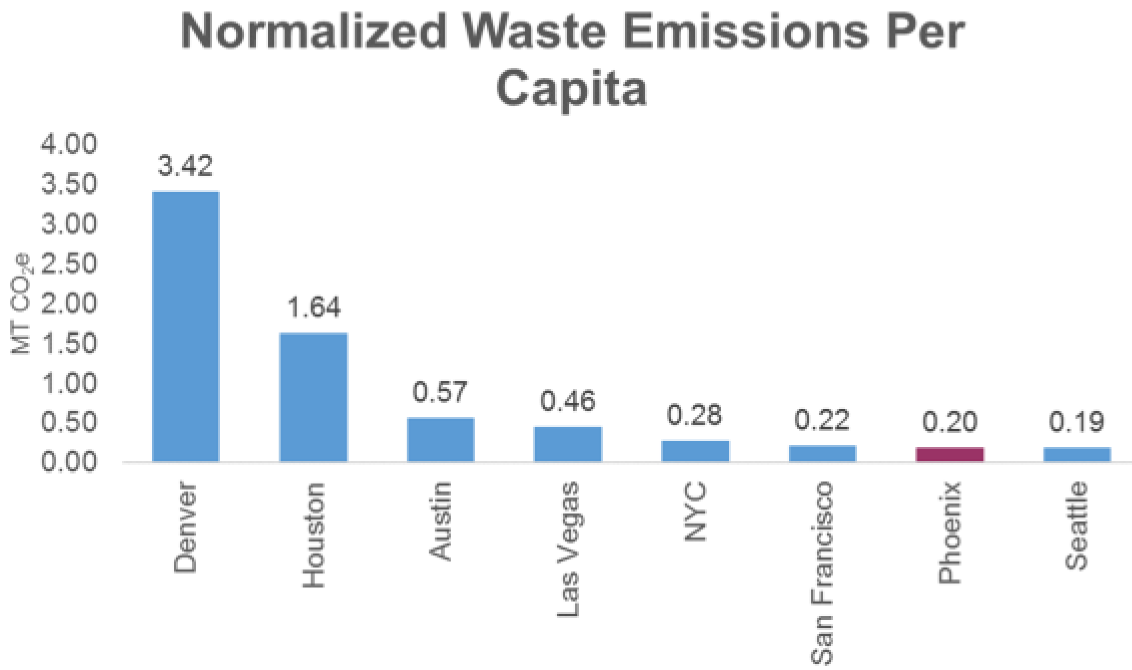

Figure 9: A comparison of the per-capita GHG emissions from Phoenix's waste emissions to other U.S. cities

Emissions by Scope

As shown in Figure 10:

Scope 1 GHG emissions: 10,484,854 MT CO_2e.

- These are direct GHG emissions from on-site fuel combustion, mobile fuel combustion, or fugitive emissions from waste disposal and treatment within the boundaries of Phoenix.

Scope 2 GHG emissions: 5,193,851 MT CO_2e

- These are indirect GHG emissions from energy generated outside Phoenix but consumed within the city, such as electricity, including electricity for transportation.

Scope 3 GHG emissions: 469,834 MT CO_2e

These are indirect GHG emissions not within the city of Phoenix boundary, such as waste generated within the city but disposed of outside the city boundary.

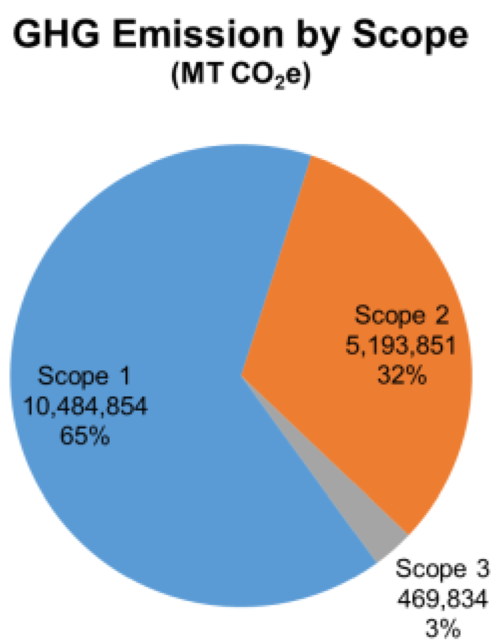

Figure 10. City of Phoenix Community-Scale GHG Emissions by Scope.

On a per capita basis, the city of Phoenix emitted 11.0 MT CO_2e per person, which ranks Phoenix higher than cities like Seattle, but lower than Houston, Austin, and Las Vegas. This data was normalized to Phoenix's inventory by only comparing stationary energy, transportation and waste emissions between cities. Factors that are important to consider when making comparisons are varying levels of population, areal size of the city, climate, gross domestic product, renewable energy mix, transportation fuel mixes and the type of inventory conducted.

Review and Recommendations

In review, the 2012 community GHG inventory showed us that:

- Phoenix is one of the first US cities using the GPC protocol for methodology.
- Reporting methods between cities are still very different, and this makes comparing city to city difficult. Until more cities apply the GPC, normalization is necessary to accurately make comparisons.
- Total per capita emissions were 11.0 MT CO_2e for Phoenix
- The transportation sector is the largest source of emissions for Phoenix

To further the implications of these findings and Phoenix's commitment to climate leadership, the following actions are recommended:

1. The city of Phoenix should create a Community Climate Action Plan that will set goals and reduction targets community-wide moving forward. This will allow Phoenix to challenge itself again to meet reduction targets and create effective policy to do so.
2. A community scale inventory allows the citizens of Phoenix to more directly engage with the emissions sources being reported. However, several emissions are still not accounted for on a community scale, due to the inability to isolate certain types of data to just within the Phoenix boundary. Phoenix should also consider a consumption-based or regional GHG inventory for future GHG studies. A consumption-based inventory will provide the consequences in emissions from the products citizens buy and consume. A regional inventory will provide more guidance to policy-makers toward those emissions sources that cannot be addressed within a single municipal boundary, such as vehicular traffic.
3. Finally, Phoenix has already taken several steps to measure, set reductions and implement policies to reduce GHG inventories. Therefore, Phoenix should continue to showcase its commitment to the Global Covenant of Mayors for Climate and Energy, to increase the city's visibility in its response to climate change.

1. Introduction

Climate change is one of the most pressing global issues today, as human development continues to cause increases in greenhouse gas (GHG) emissions. Cities have become the focus for climate change mitigation, both because cities are a major source of greenhouse gases and because of their ability to implement real solutions to climate change. Municipal sustainability goals promote both sustainable development and climate change adaptation to bolster our community resilience. As the sixth largest city in the United States, Phoenix has the potential to emerge as a leader in the climate change arena and set an example for other cities.

In 2008, Phoenix City Council embraced this challenge and adopted a goal to reduce GHG emissions from city operations to five percent below 2005 levels by 2015. After conducting two municipal scale greenhouse gas inventories, according to the Local Government Operations Protocol of the International Council for Local Environmental Initiatives (ICLEI), the city revised this goal to 15 percent below the 2005 levels by 2015. According to the results of the 2015 GHG inventory Update, the city of Phoenix met its goals and reduced emissions by 15.6 percent. While that success only addressed municipal operations, Phoenix has now completed its first community-scale GHG emissions inventory using the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC or GPC Protocol), a worldwide standard for inventorying city-induced GHG emissions developed by the World Resources Institute, C40 Cities Climate Leadership Group, and ICLEI[4]. The GPC is also the standard supported by the Global Covenant of Mayors for Climate and Energy, of which Phoenix is a member.

Greenhouse gas inventories are the primary method that cities use to track and report on greenhouse gas emissions and greenhouse gas reduction goals. There are several different types of inventories that exist, from municipal scale to community to consumption based inventories that are used to identify different types of emissions within a city. Phoenix has already conducted a baseline municipal operations inventory, set reduction goals and surpassed those goals for its municipal scale greenhouse gas inventory. Because of this, Phoenix has decided to continue to challenge itself by expanding its inventory to a community level.

[4] Greenhouse Gas Protocol. (n.d.). GHG Protocol for Cities | Greenhouse Gas Protocol. Retrieved from http://www.ghgprotocol.org/city-accounting.

A community scale inventory offers several advantages over a municipal scale inventory. First, a municipal scale inventory only accounts for government operations, and doesn't include major sources of emissions that are occurring within the city, such as emissions from residential buildings. This limits the ability of the city of Phoenix to track these emissions and set policies and programs that can create incentives to reduce them. A community scale inventory also allows for comparisons within the state, and highlights opportunities for reducing greenhouse gases in Arizona. Cities within the state have more similar climates and social norms, which provides a great learning opportunity from one another. Finally, on a global scale, a community inventory, using the GPC, can provide consistent reporting that makes Phoenix comparable to other cities worldwide while also allowing consistency with a national inventory without double-counting emissions.

This report provides a detailed explanation of the methodology and findings of the 2012 inventory of the city of Phoenix community GHG emissions in three major sectors-stationary energy, transportation and waste. These sectors can also be categorized into three scopes to capture direct emissions (scope 1) and indirect emissions (scope 2 and 3). The inventory provides a baseline for future inventories on the community scale and will allow Phoenix to evaluate the effectiveness of its reduction policies and programs. Most importantly, it will help both Phoenix and its residents to develop effective ways to reduce their own carbon footprint.

Section 2 of this report explains the Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories GPC methodology and the specific Phoenix organizational boundaries, emissions scope definitions and scaling factors used in this inventory. Section 3 is a summary of the inventory results, broken down by reporting sector of stationary energy, transportation and waste and their respective subsectors. Section 4 provides a city comparison of their reported greenhouse gas emissions and major methodological differences between Phoenix and other US cities. Section 5 reviews climate actions the city is already taking and Section 6 provides recommendations moving forward. Finally, Section 7 discusses the results for calculating biogenic emissions. Biogenic emissions do not count as fossil GHG emissions and are tabulated as informational items for the purposes of the Community GHG inventory.

2. Methodology

While cities worldwide have recognized the importance of community scale inventories for some time now, a consistent and transparent way to measure and report emissions did not previously exist. This led cities to use a variety of methodologies and created questions of data quality, including:

- What emissions sources are included/not included in the inventory,
- How emissions sources are defined and categorized
- How transboundary emissions are treated.

In turn this decreased the comparability of inventories between local, regional and national governments and hurt the legitimacy of community GHG inventories. The Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories (GPC), created by the World Resources Institute (WRI), C40 Cities Climate Leadership Group (C40) and International Council for Local Environmental Initiatives (ICLEI), is the first widely endorsed global standard for citywide reporting which seeks to address these issues. GPC requires cities to measure and report a comprehensive inventory that follows the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. GPC also supports the Global Covenant of Mayors for Climate and Energy, a network of the world's cities dedicated to addressing climate change, which has adopted the GPC to promote a higher quality of GHG inventory reporting. Phoenix will benefit from using this methodology by improving the quality and transparency of the inventory, increasing the credibility of comparisons across geographies and timescales and creating a meaningful benchmark to identify strategies for GHG mitigation moving forward.

2.1. Scope Classifications and Sectors

The GPC requires that cities report emissions in two different, but complementary frameworks. The first approach is the scopes framework, shown in Figure 11 (next page), where total emissions are reported in scopes 1, 2 and 3 emissions. This framework helps to differentiate where emissions are occurring physically within the city, outside the city or cross boundary and aligns with national-level GHG reporting. These scopes are defined as follows:

- **Scope 1**: All direct emissions from sources located within the city boundary
- **Scope 2**: Indirect GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the boundaries of Phoenix.
- **Scope 3**: All other indirect emissions that occur outside the city boundary as a result of activities taking place within Phoenix

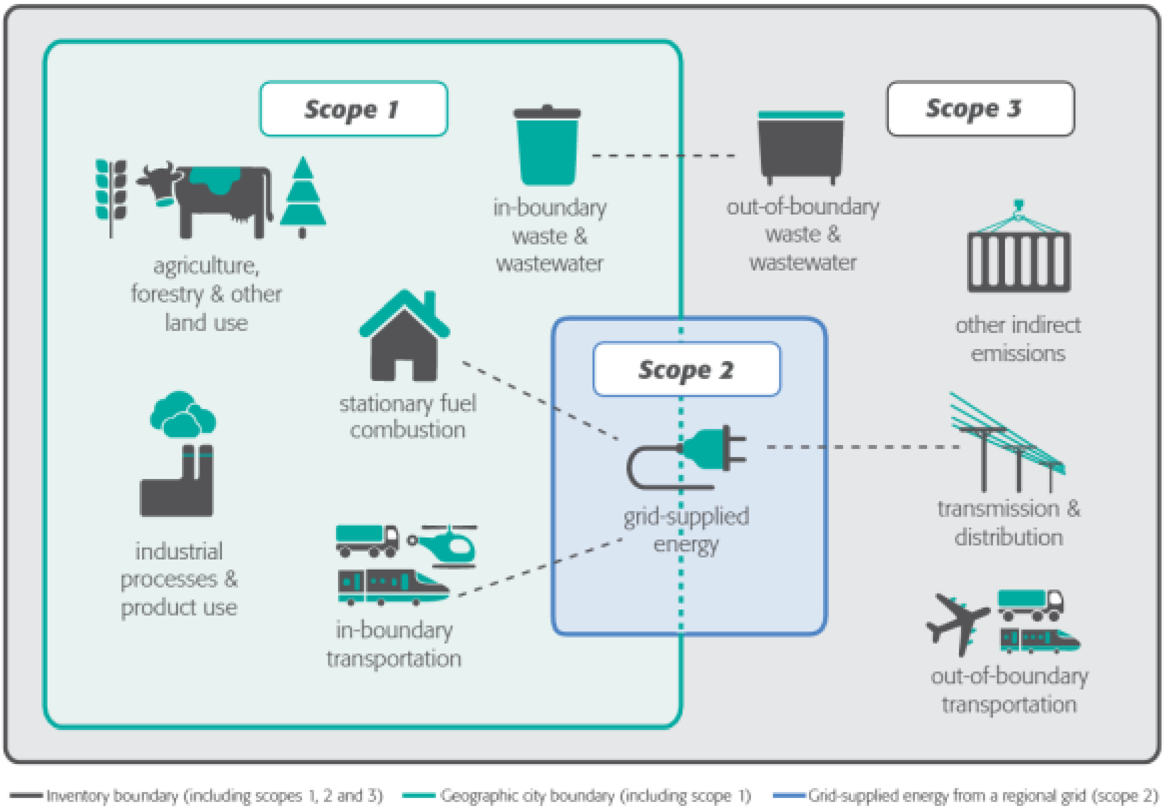

Figure 11. Sources and boundaries of city GHG emissions, adapted from GPC Protocol.

In addition to categorizing emissions by scope, the inventory is organized into six sectors, which are defined by the GPC as follows:

- **Stationary Energy**: Stationary energy sources encompass any emissions from the combustion of fuel in residential, commercial, institutional and manufacturing buildings and facilities and construction. It also includes power plants that generate grid-supplied electricity consumed in-boundary and fugitive emissions, or emissions of gases or vapors from pressurized equipment due to leaks and other unintended releases of gases, which occur from extraction and transport of fossil fuels.
- **Transportation**: The transportation sector includes emissions from all trips by road, rail, water and air. These emissions are created directly from the combustion of vehicle fuel or indirectly through the consumption of electricity.
- **Waste:** The waste sector includes emissions from waste disposal and treatment through aerobic or anaerobic decomposition or incineration. If any

methane is recovered to use as an energy source, it is reported under Stationary Energy.

- **Industrial Processes and Product Use (IPPU):** The IPPU sector includes emissions from non-energy related industrial activities, the bulk of which are released during chemical or physical transformation of material. In addition, many industrial products, such as refrigerants, foams or aerosol cans, release GHGs. IPPU was not inventoried in this report.
- **Agriculture, Forestry and Other Land Use (AFOLU):** The AFOLU sector includes emissions from livestock, land use and land use change (such as the transition of forest to cropland) and aggregate sources and non-CO_2 emissions sources, such as fertilizer. AFOLU was not inventoried in this report.
- **Other**: Any other emissions occurring outside the geographic boundary as a result of city activities.

2.2. Basic vs. Basic+

The GPC allows a city to measure and report according to a minimal "Basic" methodology or a more comprehensive Basic+ methodology, or a combination, as long as the "Basic" components are included. These are defined as:

- **BASIC:** This level covers scope 1 and scope 2 emissions from stationary energy and transportation and scope 1 and scope 3 emissions from waste.
- **BASIC+:** All BASIC reporting, plus scope 3 emissions for most of stationary energy and transportation, as well as emissions from IPPU and AFOLU and transboundary transportation.

Figure 12 (next page) shows the overlap of sectors, scopes and BASIC/BASIC+ reporting.

Sectors and sub-sectors	Scope 1	Scope 2	Scope 3
STATIONARY ENERGY			
Residential buildings	✓	✓	✓
Commercial and institutional buildings and facilities	✓	✓	✓
Manufacturing industries and construction	✓	✓	✓
Energy industries	✓	✓	✓
Energy generation supplied to the grid	✓		
Agriculture, forestry, and fishing activities	✓	✓	✓
Non-specified sources	✓	✓	✓
Fugitive emissions from mining, processing, storage, and transportation of coal	✓		
Fugitive emissions from oil and natural gas systems	✓		
TRANSPORTATION			
On-road	✓	✓	✓
Railways	✓	✓	✓
Waterborne navigation	✓	✓	✓
Aviation	✓	✓	✓
Off-road	✓	✓	
WASTE			
Disposal of solid waste generated in the city	✓		✓
Disposal of solid waste generated outside the city	✓		
Biological treatment of waste generated in the city	✓		✓
Biological treatment of waste generated outside the city	✓		
Incineration and open burning of waste generated in the city	✓		✓
Incineration and open burning of waste generated outside the city	✓		
Wastewater generated in the city	✓		✓
Wastewater generated outside the city	✓		
INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)			
Industrial processes	✓		
Product use	✓		
AGRICULTURE, FORESTRY AND OTHER LAND USE (AFOLU)			
Livestock	✓		
Land	✓		
Aggregate sources and non-CO_2 emission sources on land	✓		
OTHER SCOPE 3			
Other Scope 3			

✓ Sources covered by the GPC
● + ● Sources required for BASIC+ reporting
● Sources included in Other Scope 3
● Sources required for BASIC reporting
● Sources required for territorial total but not for BASIC/BASIC+ reporting (*italics*)
● Non-applicable emissions

Figure 12. Sources and Scopes covered by the GPC. Source: GPC Protocol

2.3. 2012 City of Phoenix Methodology

The 2012 community GHG inventory covers the sources from the BASIC inventory that data were available for. Some of the sources covered in a BASIC inventory are not relevant to Phoenix, such as waterborne navigation. Other data sources are covered in the inventory but were only available in aggregated categories. For example, stationary energy data could only be broken down into commercial, residential and industrial sources. The remaining stationary energy sources are included in those three source categories, but could not be identified separately. Table 1 below shows the different sources identified for a BASIC inventory and the sources included by Phoenix.

GPC ref No.	Scope	GHG Emissions Source (By Sector and Sub-sector)	Notation Keys
I		Stationary Energy	
I.1		**Residential Buildings**	
I.1.1	1	Emissions from fuel combustion within the city boundary	IN
I.1.2	2	Emissions from grid-supplied energy consumed within the city boundary	IN
I.1.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	NE
I.2		**Commercial and institutional buildings and facilities**	
I.2.1	1	Emissions from fuel combustion within the city boundary	IN
I.2.2	2	Emissions from grid-supplied energy consumed within the city boundary	IN
I.2.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	NE
I.3		**Manufacturing industries and construction**	
I.1.1	1	Emissions from fuel combustion within the city boundary	IN
I.1.2	2	Emissions from grid-supplied energy consumed within the city boundary	IN
I.2.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	NE
I.4		**Energy Industries**	
I.4.1	1	Emissions from energy used in power plant auxiliary operations within the city boundary	IE
I.4.2	2	Emissions from grid-supplied energy consumed in power plant auxiliary operations within the city boundary	IN
I.4.3	3	Emissions from transmissions and distribution losses from grid-supplied energy consumption in power plant auxiliary operations	NE

I.4.4	1	*Emissions from energy generation supplied to the grid*	IN
I.5		**Agriculture, forestry and fishing activities**	
I.5.1	1	Emissions from fuel combustion within the city boundary	IN
I.5.2	2	Emissions from grid-supplied energy consumed within the city boundary	IE
I.5.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	NE
I.6		**Non-specified sources**	
I.1.1	1	Emissions from fuel combustion within the city boundary	IN
I.1.2	2	Emissions from grid-supplied energy consumed within the city boundary	IE
I.1.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	NE
I.7		**Fugitive emissions from mining, processing, storage, and transportation of coal**	
I.7.1	1	Emissions from fugitive emissions within the city boundary	NE
I.8		**Fugitive emissions from oil and natural gas systems**	
I.8.1	1	Emissions from fugitive emissions within the city boundary	NE
II		**Transportation**	
II.1		**On-road Transportation**	
II.1.1	1	Emissions from fuel combustion for on-road transportation occurring within the city boundary	IN
II.1.2	2	Emissions from grid-supplied energy consumed within the city boundary for on-road transportation	NE
II.1.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmissions and distribution losses from grid-supplied energy consumption	NE
II.2		**Railways**	
II.2.1	1	Emissions from fuel combustion for railway transportation occurring within the city boundary	IN
II.2.2	2	Emissions from grid-supplied energy consumed within the city boundary for railways	IN
II.2.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmissions and distribution losses from grid-supplied energy consumption	NE
II.3		**Waterborne navigation**	
II.3.1	1	Emissions from fuel combustion for waterborne navigation occurring within the city boundary	NO
II.3.2	2	Emissions from grid-supplied energy consumed within the city	NO

		boundary for waterborne navigation	
II.3.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmissions and distribution losses from grid-supplied energy consumption	NO
II.4		**Aviation**	
II.4.1	1	Emissions from fuel combustion for aviation occurring within the city boundary	IN
II.4.2	2	Emissions from grid-supplied energy consumed within the city boundary for aviation	NE
II.4.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmissions and distribution losses from grid-supplied energy consumption	NE
II.5		**Off-road transportation**	
II.5.1	1	Emissions from fuel combustion for off-road transportation occurring within the city boundary	IN
II.5.2	2	Emissions from grid-supplied energy consumed within the city boundary for off-road transportation	NE
III		**Waste**	
III.1		**Solid waste disposal**	
III.1.1	1	Emissions from solid waste generated within the city boundary and disposed in landfills or open dumps within the city boundary	IN
III.1.2	3	Emissions from solid waste generated within the city boundary and disposed in landfills or open dumps outside the city boundary	IN
III.1.3	1	*Emissions from waste generated outside the city boundary and disposed in landfills or open dumps within the city boundary*	IN
III.2		**Biological treatment of waste**	
III.2.1	1	Emissions from solid waste generated within the city boundary that is treated biologically within the city boundary	IN
III.2.2	3	Emissions from solid waste generated within the city boundary but treated biologically outside of the city boundary	NO
III.2.3	1	*Emissions from waste generated outside the city boundary but treated biologically within the city boundary*	NE
III.3		**Incineration and open burning**	
III.3.1	1	Emissions from solid waste generated treated within the city boundary	NO
III.3.2	3	Emissions from solid waste generated within the city boundary but treated outside of the city boundary	NO
III.3.3	1	*Emissions from waste generated outside the city boundary but treated within the city boundary*	NO

III.4		**Wastewater treatment and discharge**	
III.4.1	1	Emissions from wastewater generated and treated within the city boundary	IN
III.4.2	3	Emissions from wastewater generated within the city boundary but treated outside of the city boundary	IN
III.4.3	1	*Emissions from wastewater generated outside the city boundary but treated within the city boundary*	NE
IV		**Industrial Processes and Product Uses (IPPU)**	
IV.1	1	Emissions from industrial processes occurring within the city boundary	NE
IV.2	1	Emissions from product use occurring within the city boundary	NE
V		**Agriculture, Forestry, and Other Land Use (AFOLU)**	
V.1	1	Emissions from livestock within the city boundary	NE
V.2	1	Emissions from land within the city boundary	NE
V.3	1	Emissions from aggregate sources and non-CO_2 emissions sources on land within the city boundary	NE
VI		**Other Scope 3**	
VI.1	3	Other Scope 3	NE

Key

Sources required for BASIC reporting

Sources required for BASIC+ reporting

Sources included in Other Scope 3

Sources required for territorial but not BASIC/BASIC+ reporting (*italics*)

Non-applicable emissions

Table 1. GPC Emissions by Source Sector and Sub-sector for Phoenix 2012 Community GHG Inventory.

IN represents included, IE is included elsewhere, meaning the emissions are calculated in another category but could not be separated, NE is not estimated, and NO is not occurring.

2.3.1. Organizational Boundaries

A boundary for a GHG inventory identifies the geographic area, time span, gases and emissions sources covered by the inventory and is necessary for limiting the inventory's scope. The GPC does not require that a specific boundary be used for the inventory, but based on the purpose of the inventory it does recommend that it align with the boundary of a local government, a ward or borough within a city, a metro area or other geographical area.

With the purpose of completing a GHG inventory to identify and reduce emissions, the city of Phoenix conducted its community inventory using the GPC Basic methodology. The inventory defines its organizational boundary as the boundary of the city, shown in Figure 13, a land area of 1,344.6 km^2, in addition to the boundary year of 2012, due to the completeness of data in this year. Figure 13 shows an outline of the city boundary. Though the GPC recommends GHG emissions inventories to include the seven gases covered by the Kyoto Protocol, this inventory only contains CO_2, CH_4, and N_2O to remain consistent with previous city of Phoenix GHG emissions inventories.

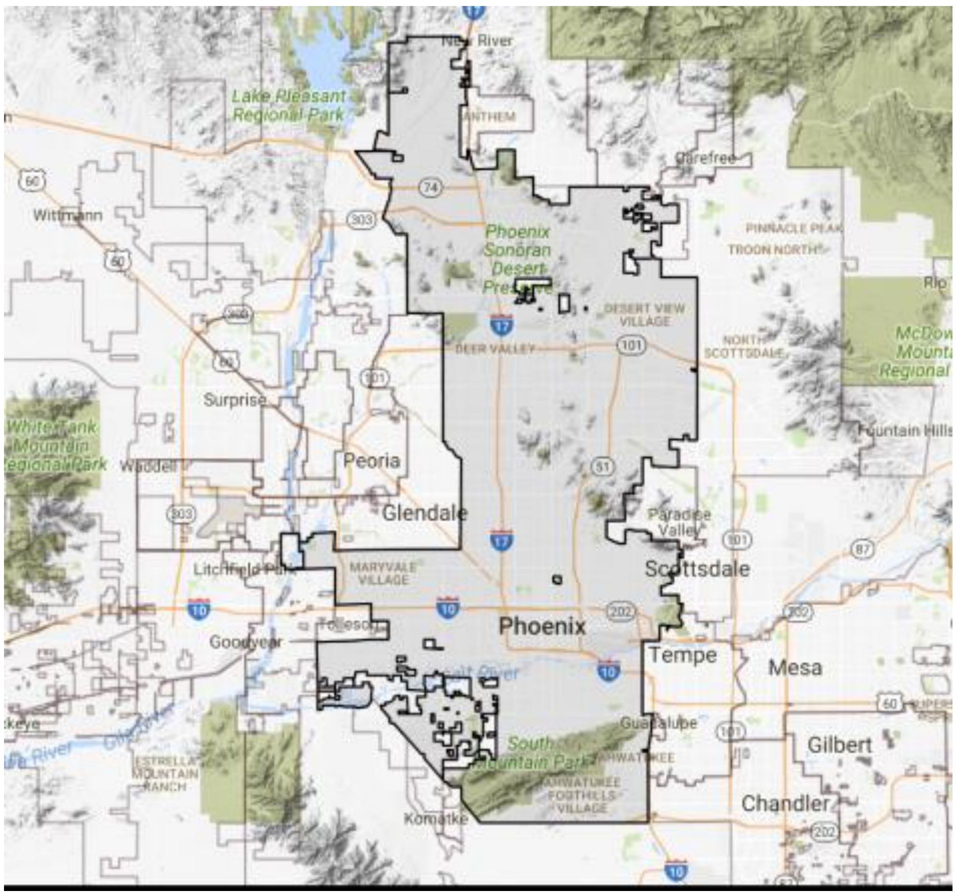

Figure 13. Map of City of Phoenix Boundary. Adopted from MapTechnica.com

2.3.2. Scaling Factors

Scaling factors are used when inventory data does not align with the geographical boundary of the city or the time period for which the assessment is being conducted, and are used to complete data that would otherwise be unavailable. The scaling factor is therefore the ratio between the available data and the required inventory data. A variety of scaling factors can be used based on the information needed to scale data up or down, depending on the source. Table 2 shows the main scaling factors used by the city of Phoenix. Additional scaling factors by city zip codes can be found in Appendix B.

Indicator	Unit	Use	Source Year	Phoenix	Maricopa County	Scaling Factor	Source
Light Rail	Miles	Railway	2012	27.32	40.26	0.68	National Transportation Atlas Database
Phoenix to Maricopa County Population 2015	People	Transportation	2015	1,563,025	4,167,947	0.38	US Census Bureau Population Estimates
Freight Rail	Miles	Transportation	2015	47	437	0.11	National Transportation Atlas Database
# of Restaurants in Phoenix	Ratio	Waste	2012	2,493	6,776	0.37	2012 Economic Census
Indicator	**Unit**	**Use**	**Source Year**	**Phoenix (2011)**	**Phoenix (2012)**	**Scaling Factor**	**Source**
Phoenix Population	People	General	2012	1,465,848	1,490,625	1.02	US Census Bureau Population Estimates

Table 2. Scaling Factors used by the City of Phoenix

2.3.3. Estimating Tailpipe Emissions of CH_4 and N_2O

The methodology used to estimate tailpipe methane (CH_4) and nitrous oxide (N_2O) emissions uses the Climate Registry's simple estimation method for tailpipe methane and nitrous oxide emissions via a fuels' carbon dioxide content that provides a comprehensive estimation of emissions across all fuel and vehicle types.

2.3.4. Landfill-Specific Characteristics for Solid Waste Landfills

In 2009, EPA published a rule requiring landfills and other pollution sources that emit more than 25,000 MT CO_2e per year to report emissions as part of the Greenhouse Gas Reporting Program (GHGRP). As of 2010, the city of Phoenix began reporting emissions to the GHGRP. These emissions data are publicly available with the Facility Level Information on Greenhouse Gases Tool (FLIGHT), a nationwide database of large GHG sources.

Under this program, Phoenix has reported landfill emissions using national average characteristics, which uses an assumed landfill gas collection efficiency of 75 percent for closed landfills in the region, based on an area with intermediate soil cover; an assumed collection efficiency of ~67 percent for open landfills with daily cover; and an assumed standard rate of 10 percent of the CH_4 that is oxidized near the surface of the landfill. These assumptions vary greatly from the landfill-specific metrics used internally by the city of Phoenix, in which the collection efficiencies are estimated at each facility. Phoenix municipal landfills are affected by local factors, such as the especially dry climate in Phoenix and the advanced technologies being implemented at specific landfills, like the SR-85, where there are horizontal as well as traditional vertical wells, surface monitoring, flare data and landfill cover maintenance; it was therefore appropriate to use site specific collection efficiency characteristics to estimate the GHG emissions of Phoenix-owned landfills for this report. These landfill specific characteristics were also reported in detail in the 2012 Municipal Operations GHG emissions inventory.

Table 3 shows all of landfills included in this inventory; which scope they are assigned and the scaling factor applied to emissions from each landfill.

Landfill	Scope	Scaling factor	Justification
Skunk Creek Landfill	1	100%	Owned and operated by City of Phoenix and located within city boundaries.
27th Ave Landfill	1	100%	Owned and operated by City of Phoenix and located within city boundaries.
Del Rio Landfill	1	100%	Owned and operated by City of Phoenix and located within city boundaries.
Deer Valley Landfill	1	100%	Owned and operated by City of Phoenix and located within city boundaries.
19th Avenue Landfill	1	100%	Owned and operated by City of Phoenix and located within city boundaries.
Estes Landfill	1	100%	Owned and operated by City of Phoenix and located within city boundaries.
SR-85 Landfill	3	100%	Owned and operated by City of Phoenix, but outside of city boundaries.
Lone Cactus Landfill	1	100%	Construction debris disposed inside city boundaries. Owned and Operated by Maricopa County.
Butterfield Station Landfill	3	22%	% is the multi-family residential population compared to the remainder of Maricopa County Population
Cave Creek Landfill	3	22%	% is the multi-family residential population compared to the remainder of Maricopa County Population
Northwest Regional Landfill	3	22%	% is the multi-family residential population compared to the remainder of Maricopa County Population
Southwest Regional Landfill	3	22%	% is the multi-family residential population compared to the remainder of Maricopa County Population

Table 3. The Landfills included in the Phoenix Community GHG Emissions Inventory, their Scope, Scaling Factor, and Justification

2.3.5. Site Specific CH_4 Emissions from Wastewater Treatment

Data provided for the 2012 Municipal Operations inventory contained CH_4 production, flaring and on-site use data at the 91st Avenue WWTP. Flaring emissions were separated into two emissions sources for the 91st Avenue and 23rd Avenue WWTP components.

2.3.6. 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. This inventory uses the same site-specific data as previous methodologies used by the city of Phoenix that would allow for comparability between the reports.

Facility	Scope	Scaling Factor	Justification
91st Avenue	1 & 3	100%	Owned and operated by City of Phoenix and located within city boundaries.
23rd Avenue	1	100%	Owned and operated by City of Phoenix and located within city boundaries.

Table 4. The Wastewater Treatment Facilities Included in the Community GHG Emissions Inventory, Their Scope, Scaling Factor, and Justification

3. Results by Sector

2.4. Overview

Overall, emissions for the city of Phoenix totaled 16,148,539 MT CO_2e. Table 5 (page 28) provides a breakdown of the CO_2e emissions by sector and scope. Scope 1 emissions account for approximately 65 percent of community GHG emissions from Phoenix, followed by purchased electricity (scope 2 emissions) which accounts for 32 percent and scope 3 which accounts for just three percent of emissions.

Emissions in Phoenix can also be broken down into three major sectors: transportation, stationary energy and waste. As illustrated in Figure 14 (next page), transportation accounted for approximately 56 percentof all emissions. Stationary energy represents approximately 42 percentof emissions and waste accounts for two percent of total emissions.

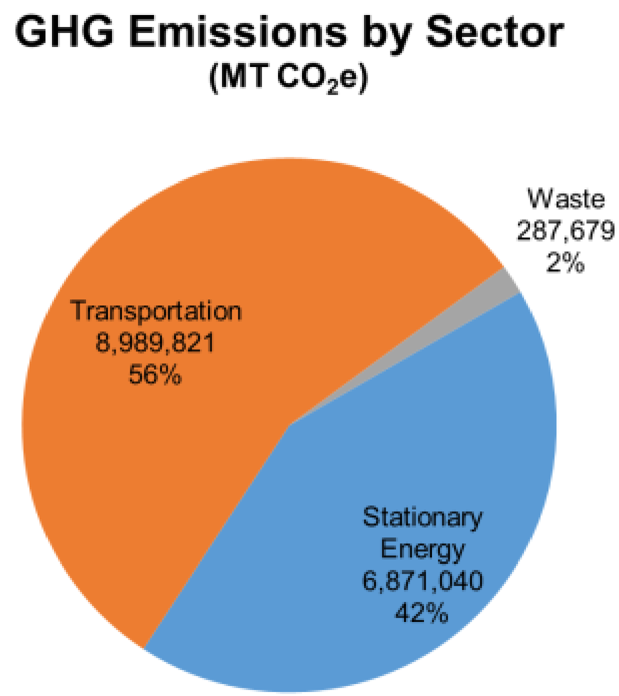

Figure 14. Total GHG Emissions in metric tons CO_2e by Reporting Sector

Sector		Total by Scope (MT CO_2e)				Total by city-induced reporting level	
		Scope 1 (Territorial)	Scope 2	Scope 3 Included in BASIC/BASIC+	Other Scope 3	BASIC	BASIC+
Stationary Energy	Energy Use (All I emissions except I.4.4)	1,430,849	5,186,656	253,535	--	6,617,505	6,871,040
	Energy Generation supplied to the grid (I.4.4)	986,294					
Transportation		8,982,626	7,195	--	--	8,989,821	8,989,821
Waste	Generated in the city (All III.1 and III.X.2)	71,380		216,299	--	287,679	287,679
	Generated in the city (All III.3)	--					
IPPU		--			--	--	--
AFOLU		--			--	--	--
Total		10,484,854	5,193,851	469,834	0	15,895,005	16,148,539

Table 5. Emissions by Scope and Sector (metric tons CO_2e)

2.5. Stationary Energy

2.5.1. Findings

Stationary energy includes energy use in residential buildings; commercial and institutional buildings and facilities; manufacturing industries and construction; energy industries; agriculture, forestry, and fishing energy use; transmission and distribution loss; and natural gas leakage. There were no emissions reported for non-specified sources, fugitive emissions from mining, processing, storage, and transport of coal; or fugitive emissions from oil and natural gas systems. This is both because the city of Phoenix does not have significant sources of emissions in these categories and that data collection on these sources was not possible.

Table 6 shows the breakdown of stationary energy emissions by each scope. Overall, scope 2 emissions were the highest at 76 percent, followed by scope 1 emissions with 21 percent, and finally by scope 3 emissions with four percent.

Scope	Emissions (MT CO_2e)	% of Total Emissions
Scope 1	1,430,849	20.8%
Scope 2	5,186,656	75.5%
Scope 3	253,535	3.7%
Total GHG Emissions	**6,871,040**	**100.0%**

Table 6. Stationary Energy Emissions by Scope

Figures 15 and 16 (next page) show the breakdown of each scope by the subsectors in stationary energy. Figure 15 shows that scope 1 emissions were primarily from residential buildings and commercial and institutional buildings. Scope 2 emissions were also mainly from commercial and residential buildings, as well as manufacturing industries and construction. Scope 3 emissions were from transmission and distribution loss, as well as natural gas leakage.

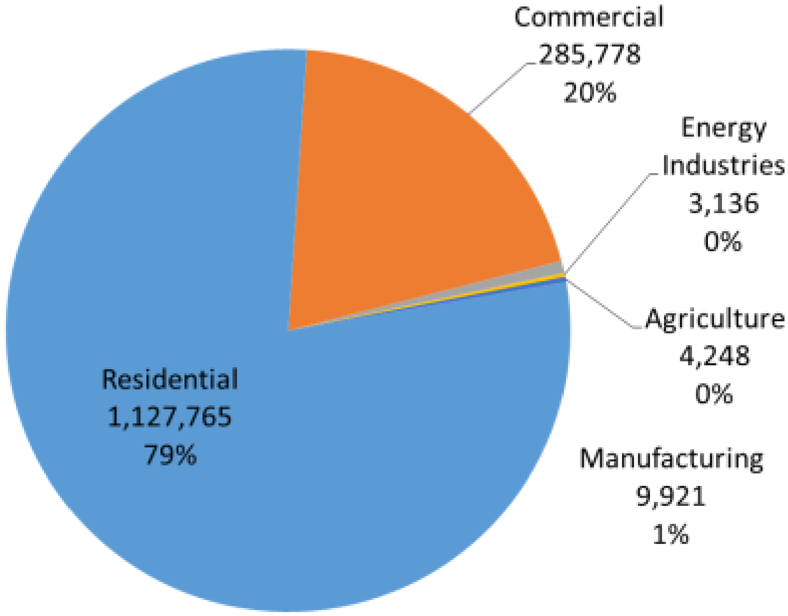

Figure 15. Total Scope 1 GHG Emissions in metric tons CO_2e by Stationary Energy Sub-Sectors

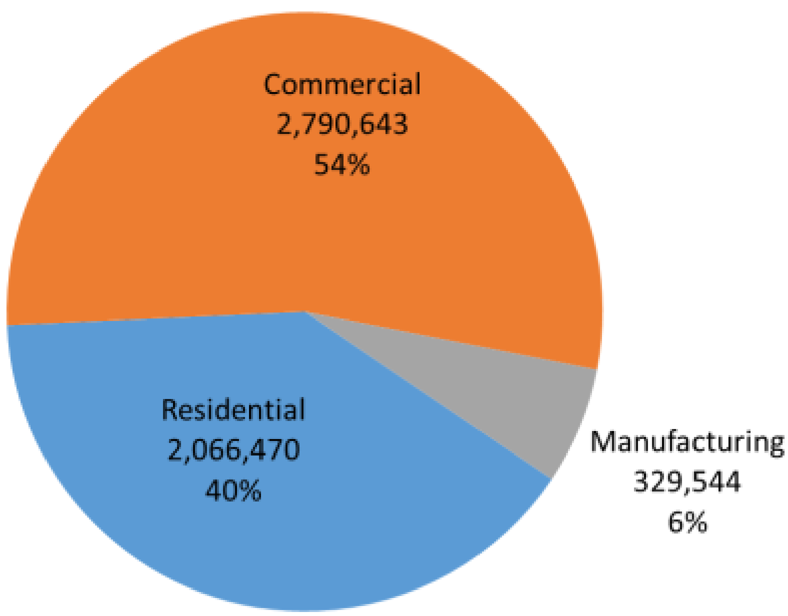

Figure 16. Total Scope 2 GHG Emissions in metric tons CO_2e by Stationary Energy Sub-Sectors

Finally, Figure 17 shows the breakdown of total stationary energy emissions by subsector, with residential buildings having the largest emissions, followed by commercial buildings. Emissions also occurred in manufacturing industries; energy industries; agriculture, forestry and fishing energy use; and transmission and distribution loss.

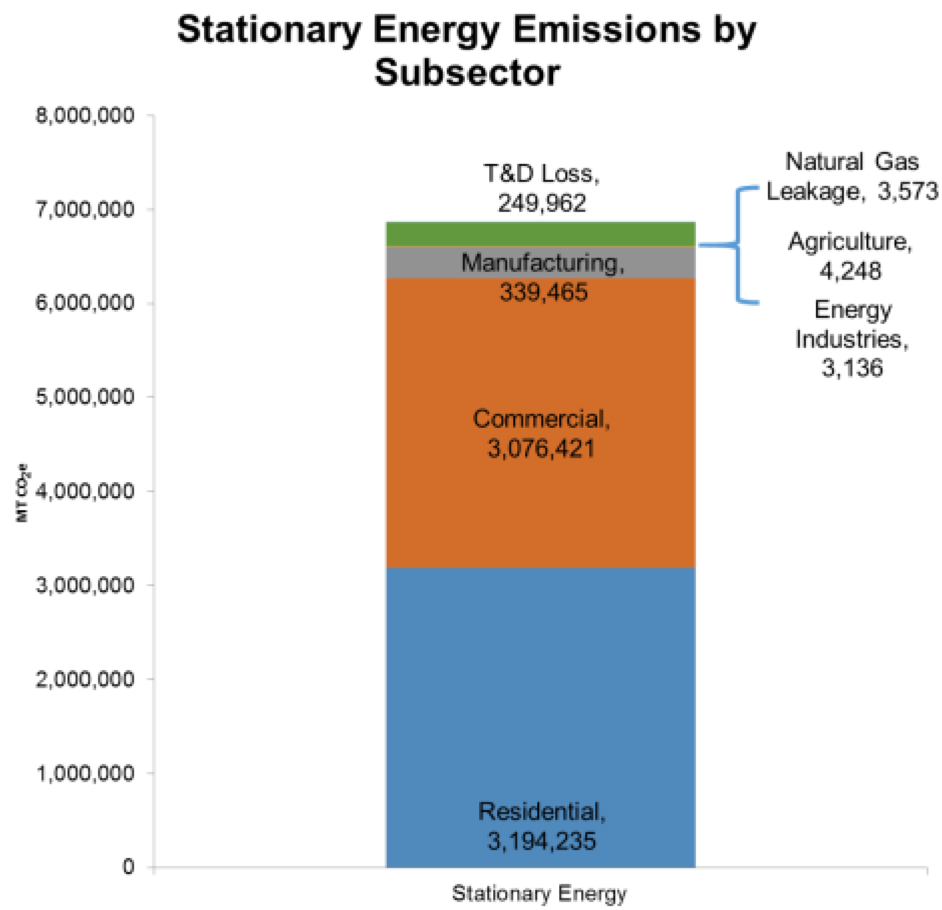

Figure 17. The Breakdown of all Stationary Energy GHG Emissions by subsectors in metric tons CO_2e.

2.5.2. Stationary Data Quality Assessment

The GPC requires that each inventory also include information about the data quality of the activity data and the emissions factor used for each sector. However, because many of the datasets that the city of Phoenix used needed adjustment, the scaling factor for the data should also be evaluated for data quality and quality assurance. Overall, confidence is high in the data quality for stationary energy which is summarized in Table 7. Data was collected from APS, SRP and Southwest Gas, the local utilities that keep track of residential, commercial and manufacturing energy use. The data was checked against the 2012 Municipal Operations GHG inventory for quality assurance.

GHG Emissions Source	Data Quality		
	Activity Data	Scaling Factor	Emissions Factor
Fuel combustion within the city (residential, commercial, and manufacturing industries)	High	Medium	High
Grid-supplied energy consumed within the city	High	High	High
Grid-supplied energy consumed in power plant auxiliary operations within the city	Medium	Medium	High
Emissions from energy generation supplied to the grid	High	High	High
Fuel combustion within the city (agriculture, forestry, and fishing activities)	Medium	High	High

Table 7. A Quality Assessment of the Stationary Energy Data

2.6. Transportation

2.6.1. Findings

Emissions from the transportation sector include the subsectors of on-road transport, railways, water, aviation, and off-road transport. On-road transport includes all electric and fuel-powered vehicles occurring within the city. Fuel sales data for Maricopa County was used to determine emissions for on-road transport and scaled using population data for Phoenix compared to Maricopa County. Railway emissions include freight rail emissions as well as emissions from the light rail. Electricity data from the light rail was used and then scaled down based on the portion of miles of rail within the City of Phoenix to the total miles of light rail. The city of Phoenix does not operate any water vehicles and therefore no emissions were reported for water. GHG emissions from the aviation subsector arise from the combustion of aviation fuel within the city, including aviation used by commercial and private flights into and out of Phoenix Sky Harbor International Airport and Deer Valley Airport; these emissions were approximated using landing and takeoff (LTO) data obtained from the Federal Aviation Agency (FAA). Finally, the inventory includes the fuels used by off-road transport vehicles, which include airport ground support equipment, agricultural and construction equipment, chain saws, forklifts, etc.

For BASIC reporting all GHG emissions from the combustion of transportation fuels within the city is in scope 1 and emissions from electricity used for transportation within the city boundary are in scope 2. Table 8 shows the emissions for transportation broken down by scope, with scope 1 emissions being the largest, followed by scope 2 and no emissions reported for scope 3.

Scope	Emissions (MT CO_2e)	% of Total Emissions
Scope 1	8,982,626	99.9%
Scope 2	7,195	0.01%
Scope 3	--	--
Total GHG Emissions	**8,989,821**	**100.0%**

Table 8. Transportation Emissions by Scope

Figure 18 shows the emissions for scope 1 broken down by subsector. The majority of emissions were from on-road transport, off-road transport and aviation, with a minor portion of emissions coming from railways. Scope 2 emissions were entirely from emissions from the light rail. Although GHG emissions from electric vehicle use is classified as a scope 2 transportation emissions, the data did not support estimating these emissions and would most likely comprise a small fraction of transportation GHG emissions.

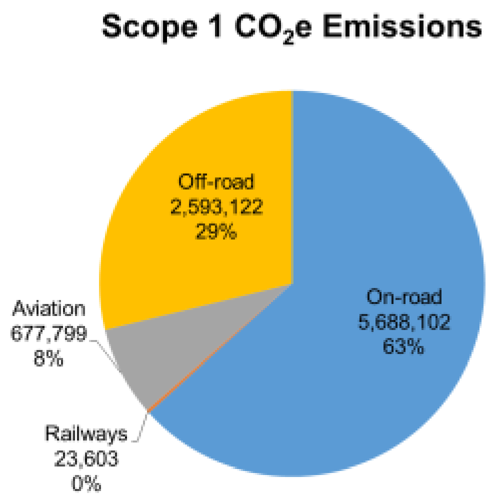

Figure 18. Breakdown of Scope 1 Transportation Emissions in metric tons CO_2e

Finally, transportation emissions were broken down by subsector, as shown in Figure 19. The majority of emissions were from on-road transportation vehicles, which accounted for 5,688,102 MT CO_2e, followed by off-road transportation vehicles with 2,593,121 MT CO_2e. There were also emissions from aviation and railways, 677,799 MT CO_2e and 23,603 MT CO_2e respectively.

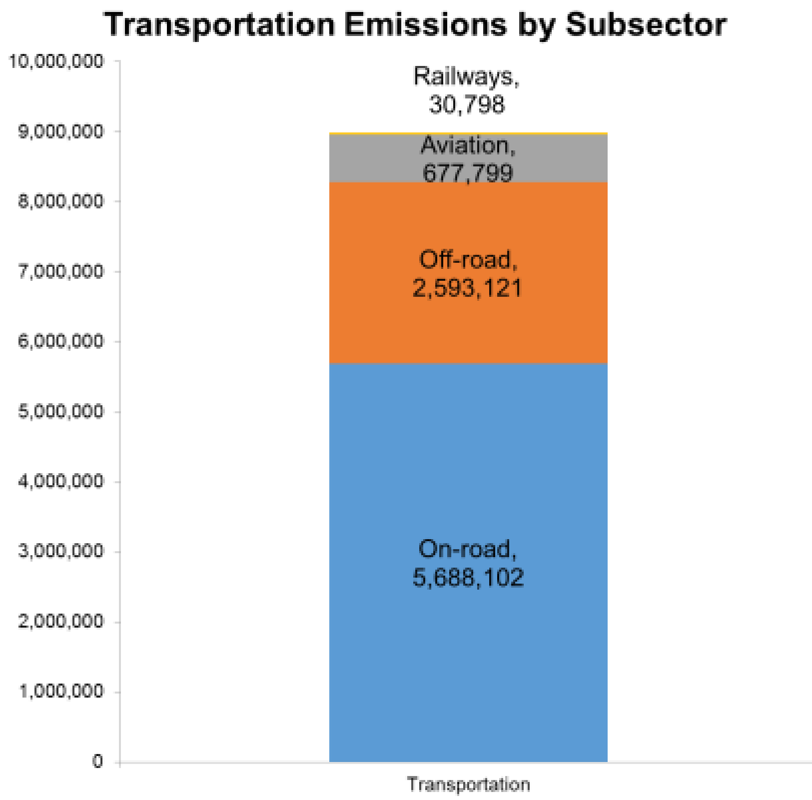

Figure 19. Breakdown of Transportation Emissions by All Subsectors in metric tons CO_2e

2.6.2. Transportation Data Quality Assessment

The GPC requires that each inventory also include information about the data quality of the activity data and the emission factors used for each sector. However, because many of the datasets used by the city of Phoenix needed adjustment, the scaling factor for the data should also be evaluated for data quality and quality assurance, as summarized in Table 9. Collecting transportation data was more difficult than stationary energy and required using a combination of activity data and scaling factors. On-road transportation emissions were calculated from Maricopa County fuel sales data using a population scaling factor, so data confidence was relatively high. Railway emissions data was collected from the National Emissions Inventory (NEI) and was adjusted using the railway length within the city boundary. While this methodology is accepted, confidence is low in its ability to capture all railway emissions. Light rail emissions were calculated from Valley Metro electricity consumption and scaled using miles of light rail within the city of Phoenix. Aviation data was collected from the city of Phoenix and emissions were calculated using Landing and Takeoff (LTO) cycle fuel use data (commercial aviation) and from the NEI (civil aviation). This methodology followed similar methodology reported by the City of Seattle[5].

GHG Emissions Source	Data Quality		
	Activity Data	**Scaling Factor**	**Emissions Factor**
Fuel combustion for on-road transportation within the city	High	Medium	High
Fuel combustion for railway transportation occurring within the city	Low	Low	Low
Grid-supplied energy consumed within the city for railways	High	High	High
Fuel combustion for aviation occurring within the city	Medium	Medium	Medium
Fuel combustion for off-road transportation occurring within the city	High	Medium	High

Table 9. A Quality Assessment of the Transportation Data

2.7. Waste

2.7.1. Findings

The Waste Sector includes emissions from the:

- Disposal of solid waste generated and treated in the city (scope 1)
- Disposal of solid waste generated in the city but disposed outside the city (scope 3
- Biological treatment of waste generated and treated in the city (scope 1)
- Wastewater generated and treated in the city (scope 1)

[5] Erickson, P & Tempest K. (2014). 2012 Seattle Community Greenhouse Gas Emissions Inventory. Seattle, WA: Stockholm Environment Institute. Report prepared for the City of Seattle. Retrieved from: https://www.seattle.gov/Documents/Departments/OSE/2012%20GHG%20inventory%20report_final.pdf.

- Wastewater generated outside of the city but treated in the city (scope 1)

By scope, these emissions are:

- Scope 1 emissions: 162,598 MT CO_2e
- Scope 3 emissions: 125,081 MT CO_2e
- Total GHG emissions: 287,679 MT CO_2e

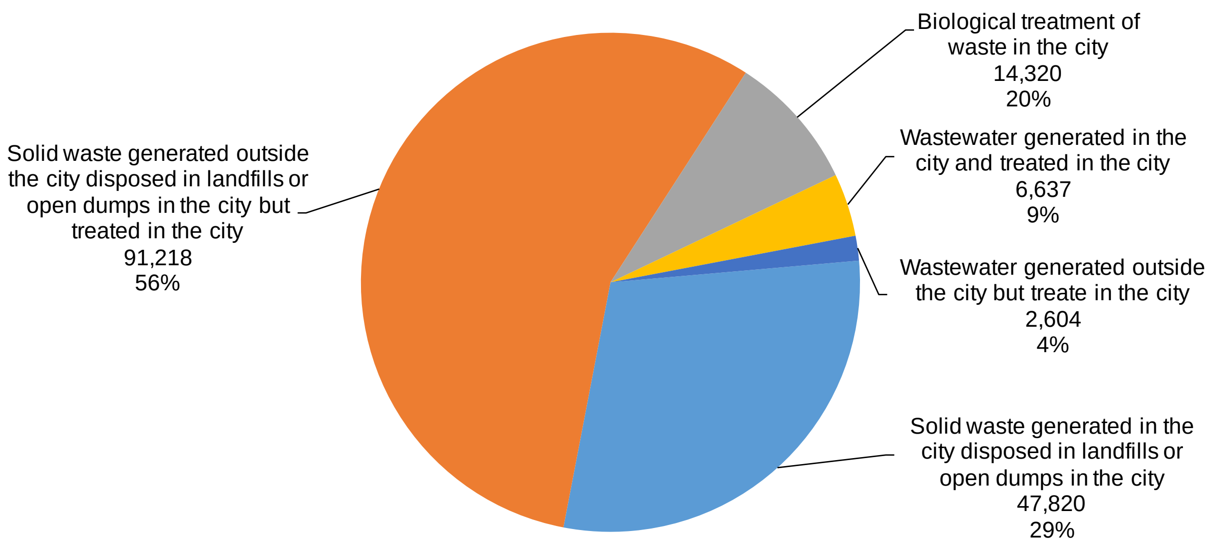

Figure 20. Breakdown of Scope 1 Waste Emissions in metric tons CO_2e

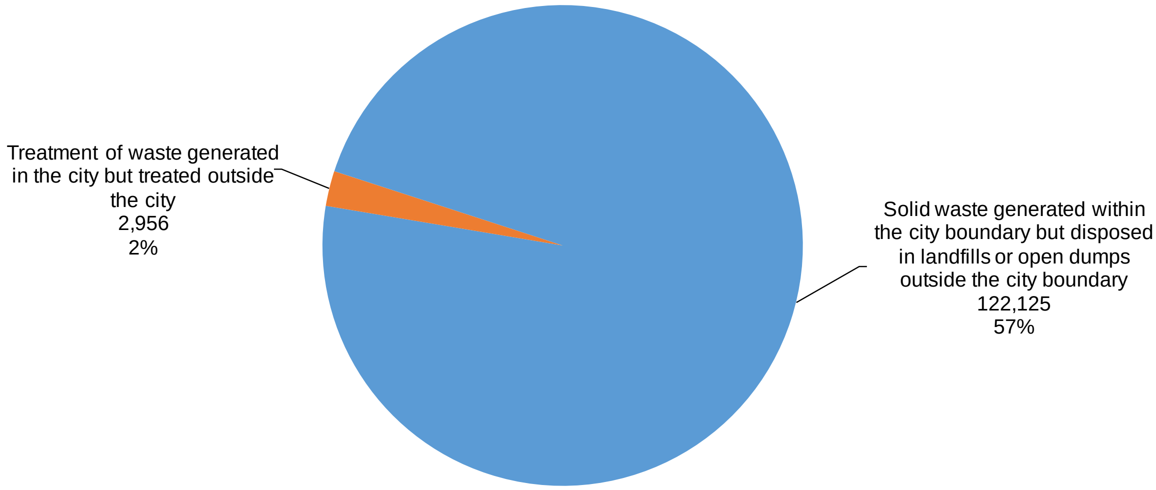

Figure 21. Breakdown of Scope 3 Waste Emissions in metric tons CO_2e

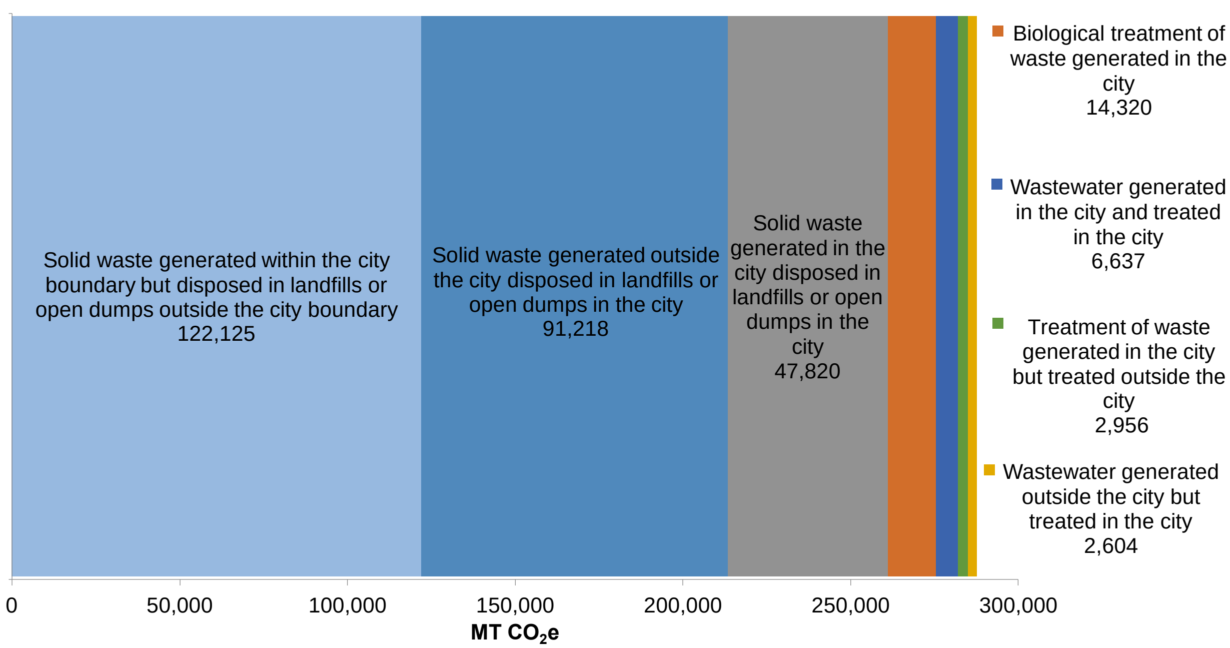

Figure 22. Breakdown of Waste Emissions by Subsector in metric tons CO_2e

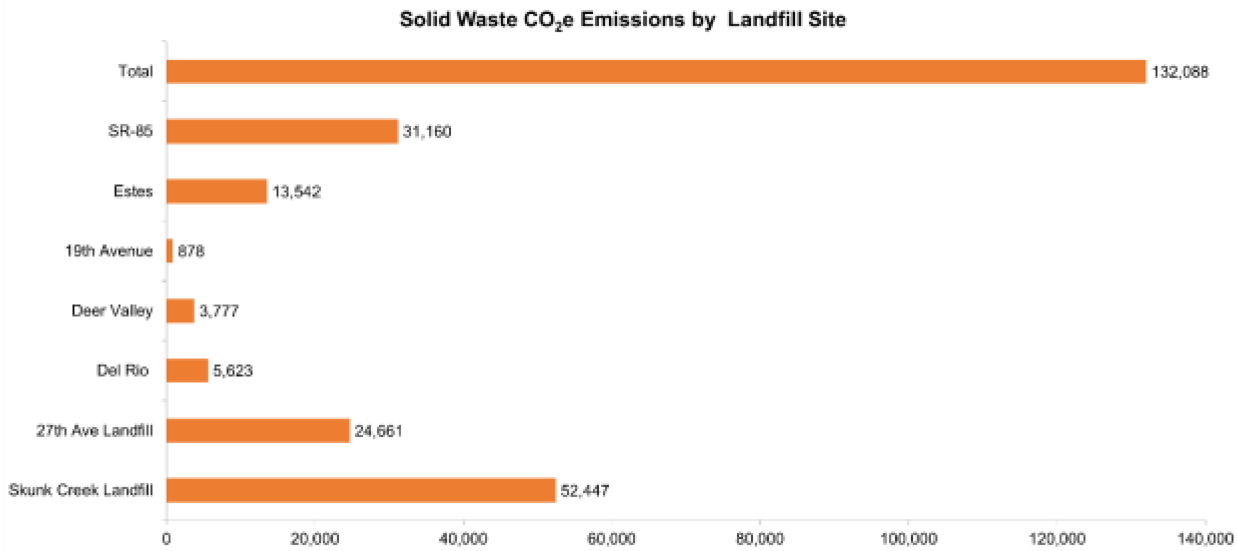

Figure 23. Solid Waste Emissions by Specific Municipal Landfills in Phoenix in metric tons CO_2e. Note that the total tonnage is the same from the 2012 Municipal Inventory, however GWPs were updated.

2.7.2.Waste Data Quality Assessment

The GPC requires that each inventory also include information about the data quality of the activity data and the emissions factor used for each sector. However, because many of the datasets used by the city of Phoenix needed adjustment, the scaling factor for the data should also be evaluated for data quality. Overall, confidence in waste methodology was high, as summarized in Table 10 (next page). Data for waste generated within the city via municipal disposal was collected from the 2012 Municipal GHG Inventory. Non-municipal waste data generated within the city boundary but disposed outside of the city boundary and waste generated outside the city boundary but disposed of within the city boundary was collected from the EPA FLIGHT Tool[6].

[6] United Stated Environmental Protection Agency. (2016). EPA Facility Level Information on Greenhouse Gasses Tool. Retrieved from https://ghgdata.epa.gov/ghgp/main.do.

GHG Emissions Source	Data Quality		
	Activity Data	**Scaling Factor**	**Emissions Factor**
Waste generated within the city boundary and disposed in landfills in the city	High	High	High
Waste generated within the city boundary and disposed in landfills outside the city	High	Low/Med	High
Waste generated outside the city but disposed within the city	High	High	High
Wastewater generated and treated within the city	High	High	High
Wastewater generated outside the city boundary but treated within the city	High	High	High

Table 10. A Quality Assessment of Waste Data

4. City Comparison

While it is important for the city of Phoenix to understand its local impact by completing a community GHG inventory and looking internally, it is also important to understand the impact of these results in a regional and national context. A review of other US cities that have completed community GHG inventories was conducted in order to understand what methodologies have been used across the US, how results differ between cities and where Phoenix is leading the way or can identify areas of improvements for GHG reporting. Total GHG emissions and reporting methodology information was collected from the Carbon Disclosure Project (CDP) for the year 2012, the year for which this inventory was completed[7]. Different inventory types, inventory years, climate, population size, land size and inventory methods are important to identify when making comparisons between cities.

2.8. Normalization Process

The purpose of the GPC protocol is to standardize the methodology used by cities for community wide GHG reporting. The benefit of this protocol is evident by the different methodologies used by the cities reviewed in this report. Table 11 (next page) shows the differences in reporting methods and sectors by each of the cities reviewed. In an attempt to normalize the data for comparison purposes, emissions from other cities were altered to just include stationary energy, transportation, and waste, as reported in the Phoenix inventory. It is important to note that this will alter each city's total emissions from those reported to the CDP. As one of the first US cities to use the GPC protocol, it is important for Phoenix to acknowledge the different methodologies being used when attempting to make comparisons.

[7] Citywide GHG Emissions. *In Carbon Disclosure Project*. Retrieved from: https://data.cdp.net/Cities/Citywide-GHG-Emissions-2012/uv3y-kwxb

City	Reporting Method	Stationary Energy	Transportation	Waste	IPPU	AFOLU	Other
Phoenix	GPC	✓	✓	✓	No	No	
Portland	ICLEI	✓	✓	✓	✓	No	Consumption based inventory
Seattle	2004 IPCC	✓	✓	✓	✓	No	carbon offsets -Consumption based inventory
Austin	(draft) ICLEI	✓	✓	✓	✓	No	
Houston	2008 LGOP and 2006 IPCC	✓	✓	✓	No	No	-Criteria Air Pollutants -Building retrofits
Las Vegas	ICLEI	✓	✓	✓	No	No	Reduction strategies
Denver	Other: Demand-centered hybrid life cycle method	✓	✓	✓	✓	No	-Full life cycle of product use
San Francisco	ICLEI	✓	✓	✓	No	No	
NYC	(draft) ICLEI	✓	✓	✓	No	No	

Table 11. Comparison of Sectors Included in various City Community Greenhouse Gas Emissions Inventories

2.9. Portland/ Multnomah County

The city of Portland and Multnomah County reported their community GHG inventory for 2012 and completed the inventory for the year 2010.

Portland's inventory showed:

- Total reported GHG emissions: 7,664,696 MT CO_2e
- Total normalized GHG emissions: 7,664,696 MT CO_2e
- Land area: 145 mi^2
- Population: 737,269
- Emissions per capita (reported): 10.4
- Emissions per capita (normalized): 10.4
- Reporting Method: ICLEI

Portland completed two different inventories, an in-boundary inventory and a consumption based emissions inventory[8]. The consumption based inventory included a breakdown of emissions by the life cycle stage of production, wholesale/retail, and pre-purchase transportation, use and disposal. For comparison purposes, only the in-boundary inventory was used to compare results and methodology to Phoenix. However, it is important to note that different inventory types can report significantly different emissions, as shown in figure 24. The benefits of completing multiple types of GHG inventories is that they can identify different major sources of emissions and can be used internally to create new policies and regulation.

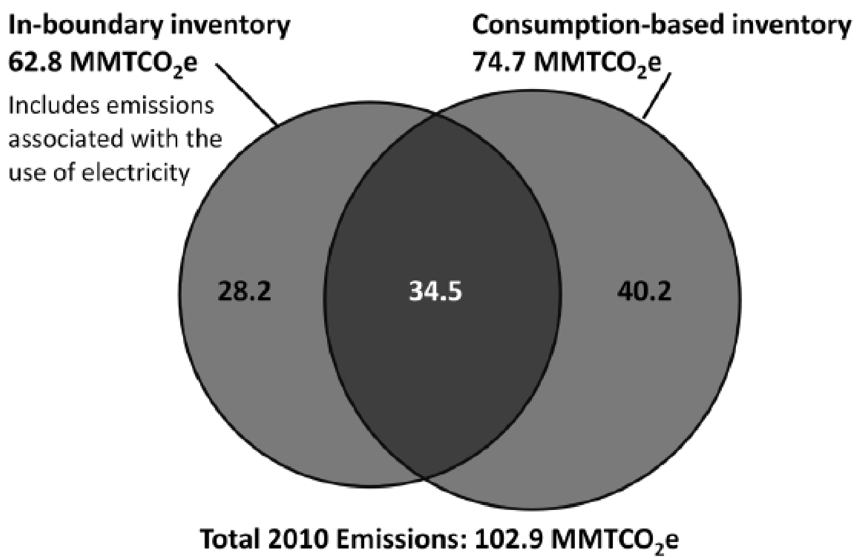

Figure 24. Comparison of the in-boundary and consumption based inventories for Portland (2010).
Adopted from Oregon's Greenhouse Gas Emissions Through 2010: In-Boundary, Consumption-Based and Expanded Transportation Sector Inventories.

The in-boundary inventory used several methodological choices that are worth mentioning, which either show discrepancies or similarities between the methods used by the City of Phoenix. First, Portland used an eGRID factor specific to local power

[7] Citywide GHG Emissions. *In Carbon Disclosure Project*. Retrieved from: https://data.cdp.net/Cities/Citywide-GHG-Emissions-2012/uv3y-kwxb

[9] Erickson, P & Tempest K. (2014). 2012 Seattle Community Greenhouse Gas Emissions Inventory. Seattle, WA: Stockholm Environment Institute. Report prepared for the City of Seattle. Retrieved from: https://www.seattle.gov/Documents/Departments/OSE/2012%20GHG%20inventory%20report_final.pdf.

companies, instead of a regional eGRID factor like Phoenix. Next, Portland did not include emissions from air, rail and shipping when quantifying transportation emissions. This is attributed to the different protocol used by Portland to conduct the inventory compared to Phoenix. Third, Portland's waste calculations were made to reflect the cumulative future methane emissions that can be expected in a year, as opposed to the amount of actual methane emissions, which is the methodology used by Phoenix. Finally, Portland also included emissions from industrial process, while Phoenix conducted a GPC BASIC inventory, which does not include these emissions.

2.10. Seattle

The City of Seattle reported their community GHG inventory in 2012 and completed the inventory for the year 2008.

- Total reported GHG emissions: 7,042,000 MT CO_2e
- Total normalized GHG emissions: 3,745,000 MT CO_2e
- Land area: 84 mi^2
- Population : 602,934
- Emissions per capita (reported): 11.7
- Emissions per capita (normalized): 6.2
- Reporting method: 2004 IPCC

Seattle also completed two different inventories, one on its "core emissions" which included building energy use, road transport, waste management and an "expanded emissions" inventory which included industry, marine, rail,and air travel[9]. Seattle had a significant amount of marine transportation to account for when calculating emissions, which Phoenix does not have. For air travel, Seattle calculated a percentage of emissions from the SEA-TAC airport based on population, which is due to the airport being located outside of the city boundaries. Seattle also included emissions from IPPU, but tracked the intensity of the manufacturing facilities, which allows local governments to find ways to influence GHG emissions at these facilities. Finally, Seattle included GHG offsets that are purchased by the city.

[9] Erickson, P & Tempest K. (2014). 2012 Seattle Community Greenhouse Gas Emissions Inventory. Seattle, WA: Stockholm Environment Institute. Report prepared for the City of Seattle. Retrieved from: https://www.seattle.gov/Documents/Departments/OSE/2012%20GHG%20inventory%20report_final.pdf.

2.11. Austin

The city of Austin[10] reported their community GHG inventory in 2012 and completed the inventory for the year 2010.

- Total reported GHG emissions: 14,926,864 MT CO_2e
- Total normalized GHG emissions: 13,550,775 MT CO_2e
- Land area: 272 mi^2
- Population: 815,260
- Emissions per capita (reported): 18.3
- Emissions per capita (normalized): 16.6
- Reporting method: (draft) ICLEI

Austin used very standard methodological choices for their inventory, and mostly reported on the main reporting areas of waste, transportation and energy. Austin did include IPPU using the EPA large facilities data publication tool, which allowed them to report emissions from several industrial facilities. This methodology was also used by Phoenix, however no industrial facilities were listed that were not already accounted for in stationary energy.

2.12. Houston

The city of Houston[11] reported their community GHG inventory in 2012 and completed the inventory for the year 2007.

- Total reported GHG emissions: 37,031,473 MT CO_2e
- Total normalized GHG emissions: 37,031,473 MT CO_2e
- Land area: 627 mi^2
- Population: 2,207,000
- Emissions per capita (reported): 16.8
- Emissions per capita (normalized): 16.8
- Reporting method: 2008 LGOP and 2006 IPCC

[10] City of Austin Office of Sustainability. (2014). Baseline Community GHG Inventory. Retrieved from https://austintexas.gov/sites/default/files/files/Sustainability/Climate/2014-08-6_Baseline_Inventory.pdf.

[11] City of Houston Office of Sustainability. (2014). Carbon Disclosure Report Response 2012. Retrieved from http://www.greenhoustontx.gov/reports/Carbon_Disclosure_Report_Response_2012.pdf.

Houston has one of the oldest inventory years of the US cities reviewed. An interesting methodology that Houston used was for collecting energy usage data by zip code. Some of the zip codes were transboundary and not entirely within the city limits, therefore they were adjusted based on a % within the city limits. The same methodology was used by Phoenix, as several zip codes crossed into neighboring cities. In addition, air emissions were calculated by only including emissions from take-off and landings within 3,000 feet, and did not include in route emissions. Phoenix used this methodology as well.

2.13. Las Vegas/Clark County

The city of Las Vegas and Clark County conducted a greenhouse gas inventory that reported on the five required areas of waste, wastewater, transportation, building energy use and stationary energy[12].

- Total reported GHG emissions: 27,803,600 MT CO_2e
- Total normalized GHG emissions: 27,803,600 MT CO_2e
- Land area: ~600 mi^2
- Population:1,967,000
- Emissions per capita (reported): 14.1
- Emissions per capita (normalized): 14.1
- Reporting method: ICLEI

Las Vegas also participated in a Regional Greenhouse Gas Emissions inventory, which analyzed regional energy consumption for power, gas, transportation and waste, as well as commercial and industrial sectors from community-related activities. The use of a regional GHG inventory allowed the city of Las Vegas/Clark County to account for more emission sources that otherwise could not be broken down to just a community-wide level.

2.14. Denver

The city of Denver used a reporting method unique in design, which mixed life-cycle analysis and greenhouse gas reporting[13].

[12] Stephen, H. & Houyela-Alcaraz, E.. (2014). Clark County Regional Emission Inventory. Report prepared for the Clark County Office of Sustainability. Retrieved from http://www.clarkcountynv.gov/comprehensive-planning/eco-county/Documents/RegionalGHG.pdf.

- Total reported GHG emissions:13,028,000
- Total normalized GHG emissions: 13,031,473
- Land area:155 mi^2
- Population: 603,421
- Emissions per capita (reported): 21.6
- Emissions per capita (normalized): 21.6
- Reporting method: Demand-centered hybrid life-cycle method

This method looks at the full life cycle of goods produced, used and thrown away in the city. In this method World Resources Institute (WRI) protocols were used for upstream (indirect) emissions that occur outside of Denver's political boundaries, such as fuel, concrete, food and packaging. Because of this, Denver's emissions appear much higher than if it used a methodology similar to that of Phoenix or Las Vegas.

2.15. San Francisco

The city of San Francisco reported their community GHG inventory in 2012 and conducted the inventory for 2010[14].

- Total reported GHG emissions: 5,255,665 MT CO_2e
- Total normalized GHG emissions: 4,754,976 MT CO_2e
- Land area: 46.87 mi^2
- Population: 805,704
- Emissions per capita (reported): 6.5
- Emissions per capita (normalized): 5.9
- Reporting method: ICLEI

San Francisco used electricity data from the local utility, and then applied a San Francisco-specific electricity factor, creating a local eGRID factor to determine CO_2 emissions for grid electricity consumption.

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[13] Denver Environmental Health. (2015). City and County of Denver Climate Action Plan. Retrieved from https://www.denvergov.org/content/dam/denvergov/Portals/771/documents/Climate/CAP%20-%20FINAL%20WEB.pdf.

[14] Citywide GHG Emissions. *In Carbon Disclosure Project*. Retrieved from: https://data.cdp.net/Cities/Citywide-GHG-Emissions-2012/uv3y-kwxb

2.16. New York City

New York City reported its community GHG report in 2012 and completed the inventory for the year 2010[15].

- Total reported GHG emissions: 54,348,841 MT CO2e
- Total normalized GHG emissions: 54,300,000 MT CO2e
- Land area: 304.6 mi2
- Population: 8,190,000
- Emissions per capita (reported): 6.6
- Emissions per capita (normalized): 6.6
- Reporting method: ICLEI

New York City completed this inventory when the draft phase of ICLEI was still under development and therefore was unable to verify full compliance with this standard. Due to this, New York City did not include emissions from the transportation of solid waste outside of the cityor the decomposition of solid waste disposed of outside of the city and used a waste commitment method for estimated emissions from landfills instead of the first order decay method required by ICLEI. In addition, New York City did not include emissions from marine transportation. However, New York City plans to incorporate all these emissions in future inventories.

[15] Citywide GHG Emissions. *In Carbon Disclosure Project*. Retrieved from: https://data.cdp.net/Cities/Citywide-GHG-Emissions-2012/uv3y-kwxb

2.17. City to City

2.17.1. Overall Emissions

Figure 25 shows a comparison of total GHG emissions of nine U.S. cities including Phoenix. Totals were normalized to include stationary energy, transportation and waste to make them comparable to those of the Phoenix Community GHG inventory.

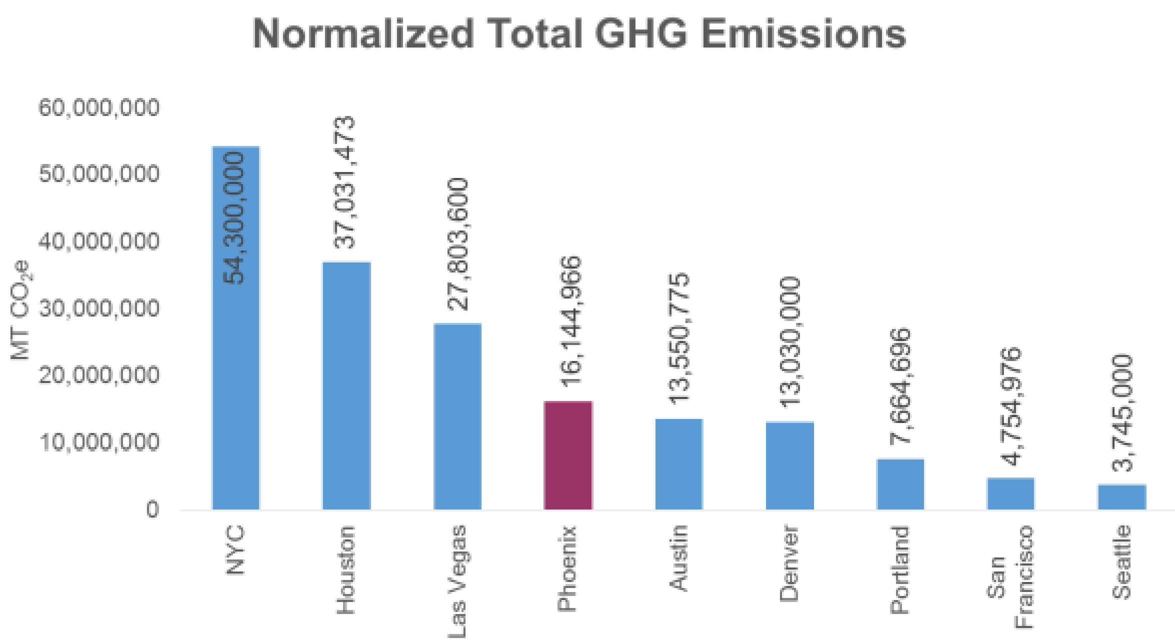

Figure 25. Total GHG Emissions after Normalization. Total emissions include stationary energy, transportation, and waste emissions.

2.17.2. Per Capita Comparisons

Per capita emissions were calculated using the normalized total emissions above. Portland was only included in total emissions reporting due to unavailable data for reporting its breakdown by sector. Overall, Phoenix ranks fifth out of the nine cities for lowest emissions per capita, shown in Figure 26.

Overall

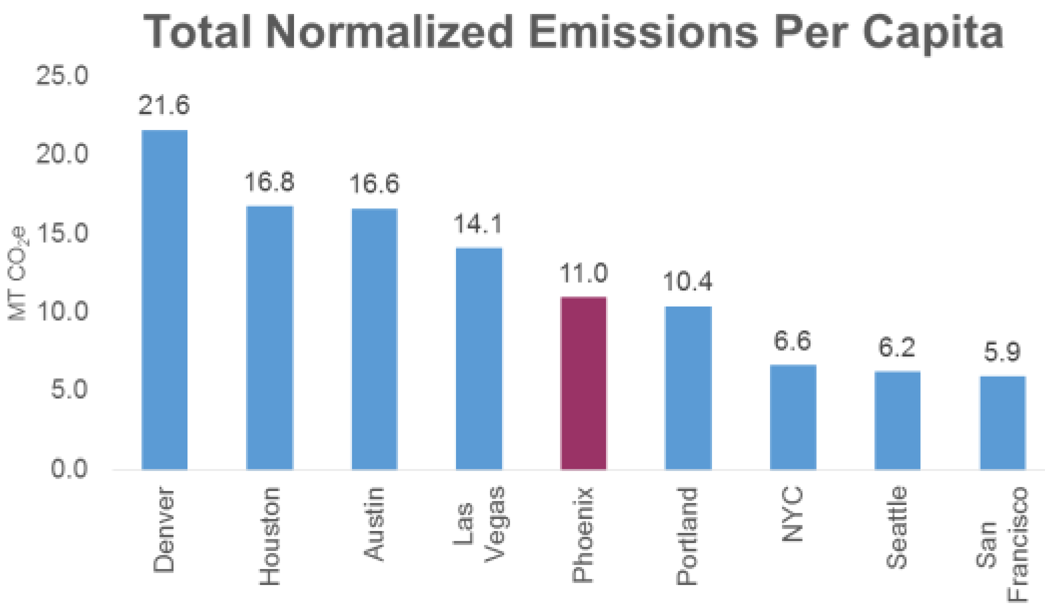

Figure 26. Total GHG Emissions Per Capita after Normalization

Stationary Energy

Phoenix had relatively low stationary energy emissions per capita, as shown in Figure 27. This could be attributed to several factors: while Phoenix is located in the desert, during a significant portion of the year neither heating nor cooling is needed; in addition, the regional e-GRID factor ANZW for Phoenix has a relatively low emissions intensity, which has lowered the emissions from Phoenix's stationary energy over time.

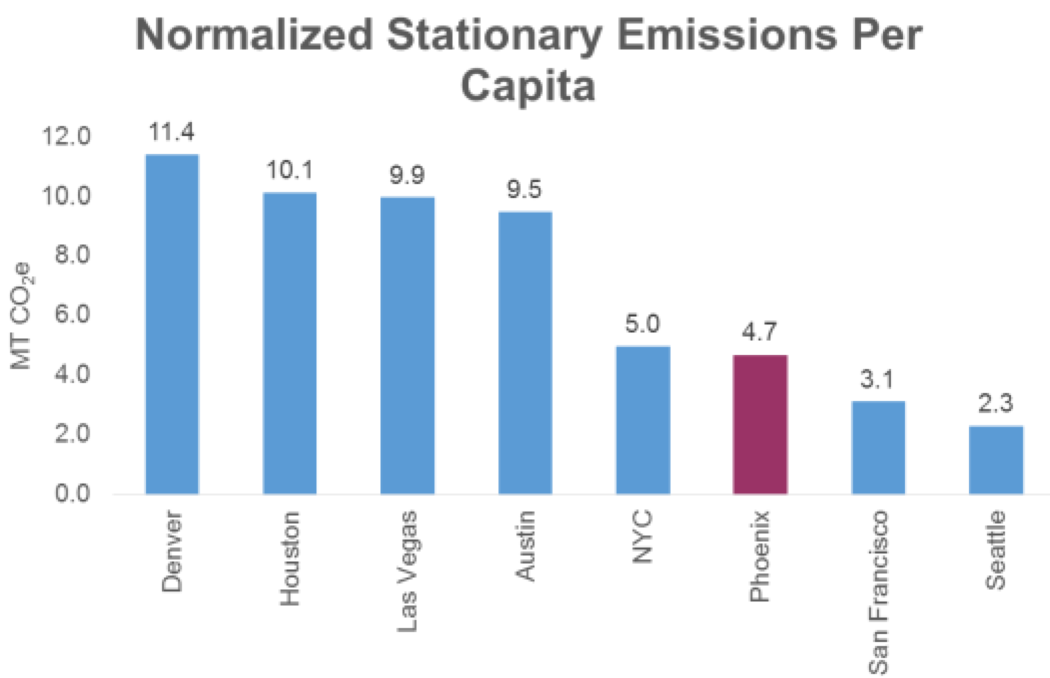

Figure 27. Stationary Emissions Per Capita after Normalization

Transportation

Phoenix ranked relatively high for the transportation sector, which is also the largest source of emissions for the city. In this comparison, cities with well-developed public transportation systems ranked lower in transportation emissions per capita, while those cities that are less dense had higher emissions intensity. *This suggests that transportation might be the largest area of improvement for Phoenix.*

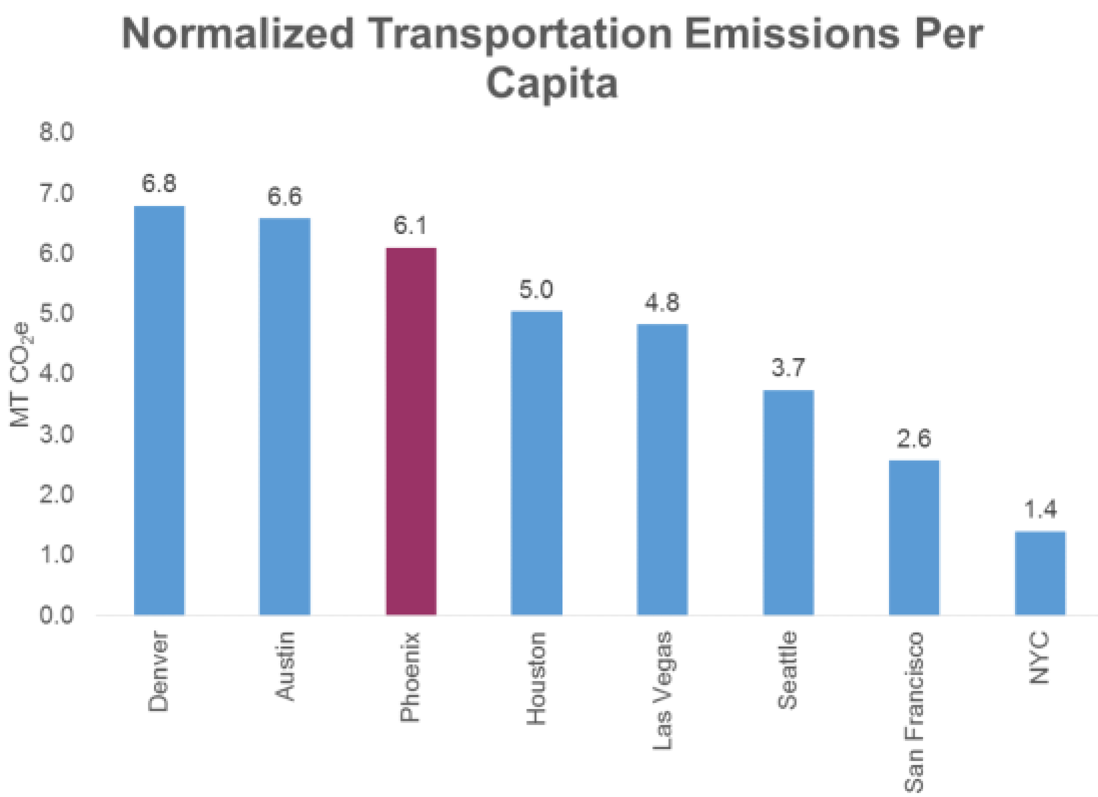

Figure 28. Normalized Transportation Emissions Per Capita

Waste

Overall, waste emissions were only a small percentage of emissions for all cities. Phoenix had one of the lowest waste emissions per capita. This may be due to the efficient methane capture systems within Phoenix's municipal landfills.

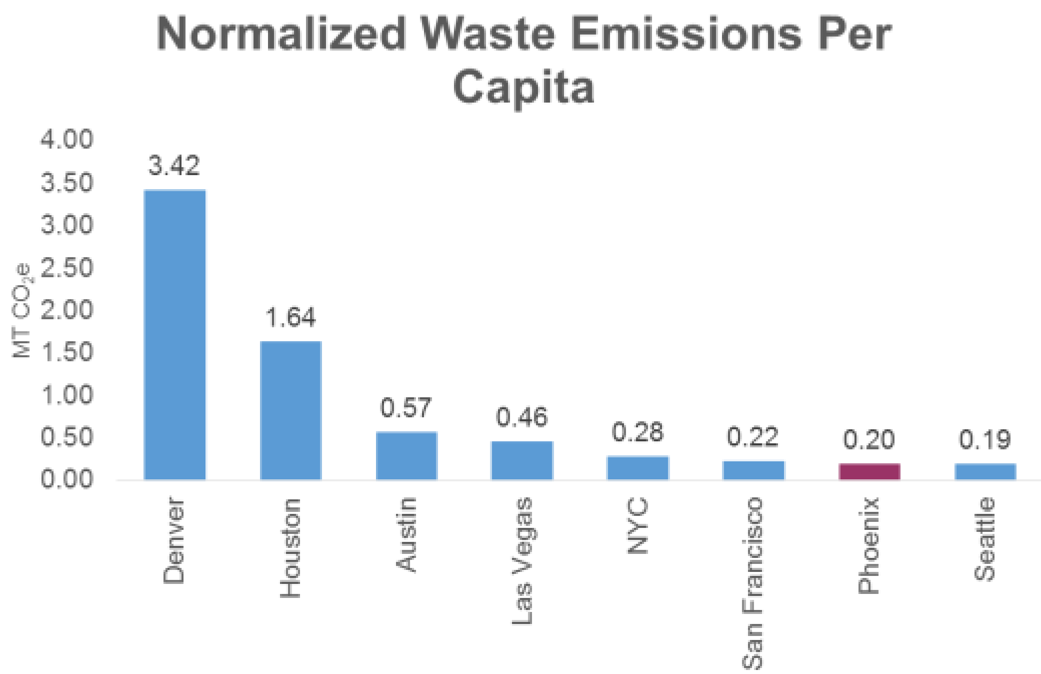

Figure 29. Normalized Waste Emissions Per Capita

5. City Action Highlights

It is important for the city of Phoenix to reflect on emission reduction programs that it has implemented so far, to highlight the success of these programs. Some of the improvements that the city has made are:

- Implemented an Environmental Preferable Purchasing (EPP) Policy in 2005
- Created a Tree and Shade Master Plan in 2010 for 25 percent tree canopy by 2030
- Retrofitted existing traffic signals and traffic lights with LED bulbs
- Completed Stages I and II of the construction of the Phoenix Sky Train and Sky Harbor Airport
- Enhanced landfill methane collection systems to reduce methane leakage
- Transitioned city fleet fuels from LNG and diesel to less carbon-intensive CNG and B20 fuels.
- Installed several city solar power projects with future projects in motion
- Increased bus ridership by city employees through free bus passes.
- Improved energy efficiency in over 45 buildings

6. Recommendations

The 2012 community greenhouse gas inventory reflects a huge step taken by Phoenix's leadership to continue to bolster its role in reducing the effects of climate change. To further support the implications of these findings and Phoenix's commitment to climate leadership, the following actions are recommended:

1. The City of Phoenix should create a **Community Climate Action Plan** that will set goals and reduction targets community-wide moving forward. This will allow Phoenix to challenge itself again to meet reduction targets, and create effective policy to do so.
2. A community scale inventory allows the citizens of Phoenix to more directly engage with the emissions being reported. However, several emissions are still not accounted for on a community scale, due to the inability to isolate certain types of data to just within Phoenix. The city should also consider both a **consumption-based and regional GHG inventory** for future GHG studies.
3. As one of the first US cities to use the GPC Protocol, many cities will be looking to Phoenix for guidance in using these standards. Transparency and accountability are critical for communication on how the inventory was

completed. Phoenix should help host a **community GHG webinar** to help other cities that would like to switch to the GPC Protocol.

4. When looking at the breakdown of sector emissions per capita, Phoenix has the biggest opportunity for improvement in the transportation sector. A **Transportation GHG Reduction Plan** should be created in order to directly focus on its largest emissions source.
5. Two major sectors, IPPU and AFOLU were not included in this report. Phoenix should work towards creating policies or relationships with industries within the city to create a more **inclusive GHG inventory for industrial emissions**. AFOLU was not included partially due to the unknown GHG emissions from land conversion from desert into developed land. Phoenix should consider **studying this land conversion** further, and whether it is contributing to or subtracting from its GHG emissions.
6. Finally, the Phoenix has already taken several steps to measure, set reductions and implement policies to reduce its GHG emissions. Therefore, Phoenix should consider increased involvement in the **Global Covenant of Majors for Climate and Energy**, to raise the city's visibility in its response to climate change.

7. 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 Community GHG inventory. Biogenic emissions were not estimated for the 2012 Community GHG Inventory. However, Figure 30 shows biogenic emissions from City of Phoenix government operations in 2012.

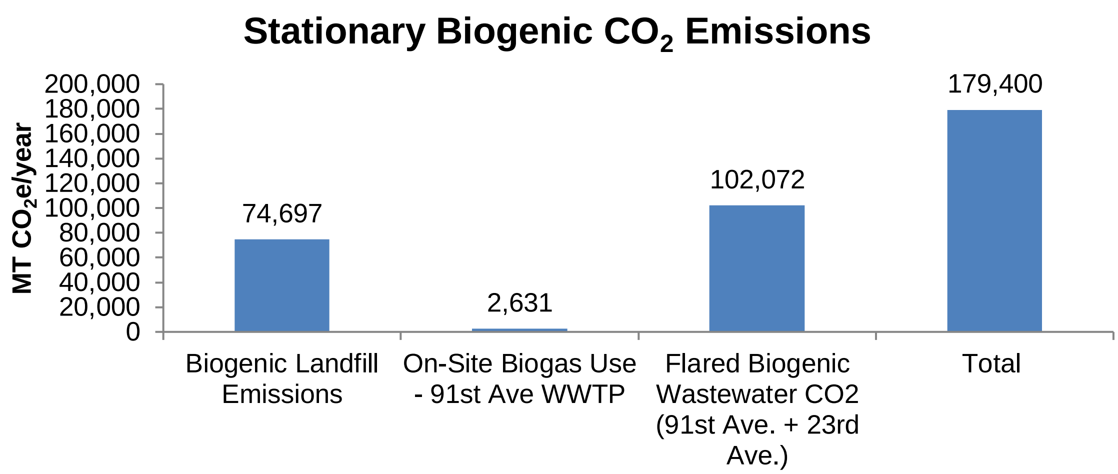

Figure 30. Sources and Quantities of Biogenic Emissions from City of Phoenix Municipal Operations for 2012

8. Appendix A: Greenhouse Gas Equivalents

Table 12. Greenhouse Gas Equivalents for the 2012 Community GHG Inventory

Greenhouse Gas	AR4 GWP Values[16]
Carbon Dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous Oxide (N_2O)	298

[16] International Panel on Climate Change. (n.d.). 2.10.2 Direct Global Warming Potentials - AR4 WGI Chapter 2: Changes in Atmospheric Constituents and in Radiative Forcing. Retrieved from: https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html.

9. Appendix B: GHG Scaling Factors by Zip Code

NAME	Zip Code	Phoenix Zip Area	Total Zip Area	Zip Scaling Factor
PHOENIX	85003	6,868,468	6,868,468	100.00%
PHOENIX	85004	7,993,824	7,993,824	100.00%
PHOENIX	85006	14,976,401	14,976,401	100.00%
PHOENIX	85007	17,021,758	17,021,758	100.00%
PHOENIX	85008	35,317,128	35,317,233	100.00%
PHOENIX	85009	54,119,790	54,147,577	99.95%
PHOENIX	85012	7,774,585	7,774,585	100.00%
PHOENIX	85013	14,675,528	14,675,528	100.00%
PHOENIX	85014	14,757,994	15,304,832	96.43%
PHOENIX	85015	18,127,766	18,127,766	100.00%
PHOENIX	85016	32,342,254	32,342,732	100.00%
PHOENIX	85017	18,764,639	18,764,639	100.00%
PHOENIX	85018	34,400,422	34,500,868	99.71%
PHOENIX	85019	14,764,498	14,764,498	100.00%
PHOENIX	85020	43,063,981	43,063,981	100.00%
PHOENIX	85021	26,831,848	26,831,848	100.00%
PHOENIX	85022	34,066,976	34,066,976	100.00%
PHOENIX	85023	28,875,890	28,875,891	100.00%
PHOENIX	85024	40,916,128	42,758,098	95.69%
PHOENIX	85027	45,075,189	45,075,189	100.00%
PHOENIX	85028	36,484,538	36,584,572	99.73%
PHOENIX	85029	31,890,936	31,890,936	100.00%
PHOENIX	85031	15,055,140	15,104,818	99.67%
PHOENIX	85032	47,382,223	47,382,223	100.00%
PHOENIX	85033	23,737,077	23,817,906	99.66%
PHOENIX	85034	42,491,084	42,680,033	99.56%
PHOENIX	85035	19,488,159	19,488,159	100.00%
PHOENIX	85037	31,013,155	32,590,972	95.16%
PHOENIX	85040	36,406,460	36,503,864	99.73%
PHOENIX	85041	59,716,058	66,109,894	90.33%
PHOENIX	85042	62,723,397	62,723,780	100.00%
PHOENIX	85043	64,010,077	75,449,903	84.84%

PHOENIX	85044	42,873,390	43,561,285	98.42%
PHOENIX	85045	28,356,417	28,470,837	99.60%
PHOENIX	85048	55,663,246	55,765,985	99.82%
PHOENIX	85050	53,523,579	53,523,579	100.00%
PHOENIX	85051	23,770,828	23,770,828	100.00%
PHOENIX	85053	19,350,615	19,350,614	100.00%
PHOENIX	85054	58,740,380	59,136,650	99.33%
PHOENIX	85083	77,227,807	78,092,613	98.89%
PHOENIX	85085	153,958,401	166,001,483	92.75%
PHOENIX	85086	91,491,042	194,567,659	47.02%
PHOENIX	85087	90,913,962	912,749,070	9.96%
PHOENIX	85226	1,453,317	276,169,735	0.53%
PHOENIX	85251	2,293,806	27,154,270	8.45%
PHOENIX	85253	5,968,351	68,852,007	8.67%
PHOENIX	85254	44,443,764	51,044,229	87.07%
PHOENIX	85255	439,606	197,641,274	0.22%
PHOENIX	85257	37,439	26,772,267	0.14%
PHOENIX	85266	93	63,003,046	0.00%
PHOENIX	85281	2,568,699	51,373,282	5.00%
PHOENIX	85282	40,734	40,172,714	0.10%
PHOENIX	85283	25,448	33,180,382	0.08%
PHOENIX	85301	77,413	34,791,561	0.22%
PHOENIX	85302	49,518	21,770,138	0.23%
PHOENIX	85304	5,834,413	21,384,409	27.28%
PHOENIX	85305	281,437	23,535,992	1.20%
PHOENIX	85306	7,275,002	21,331,040	34.11%
PHOENIX	85307	3,517,141	36,283,984	9.69%
PHOENIX	85308	19,302,757	64,282,669	30.03%
PHOENIX	85310	28,635,742	36,544,467	78.36%
PHOENIX	85331	29,833,379	234,325,880	12.73%
PHOENIX	85339	68,491,006	405,349,961	16.90%
PHOENIX	85340	102,028	93,736,137	0.11%
PHOENIX	85353	34,670,859	81,482,127	42.55%
PHOENIX	85383	725,849	800,923,651	0.09%
PHOENIX	85392	952	35,992,598	0.00%

Table 13. Scaling Factors of Zip Codes by Proportion of Land Area in Phoenix