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2022 Greenhouse Gas Emissions Inventory

A comprehensive report prepared for

CITY OF SCOTTSDALE

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sustainabilitysolutions.asu.edu

Acknowledgments

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Executive Summary

The City of Scottsdale in partnership with Arizona State University and Northern Arizona University conducted its first city-wide and city-operations greenhouse gas (GHG) emissions inventories. The inventory period covered calendar years 2018, 2020, and 2022.

Between 2018 and 2022, city-wide GHG emissions *decreased by 7%,* from 3,312,761 metric tons (MT) CO_2e to 3,078,925 MT CO_2e. Over the same 2018 to 2022 period, Scottsdale's *municipal operations GHG emissions decreased roughly 11%* from 203,564 MT CO_2e to 181,584 MT CO_2e (Figure 1).

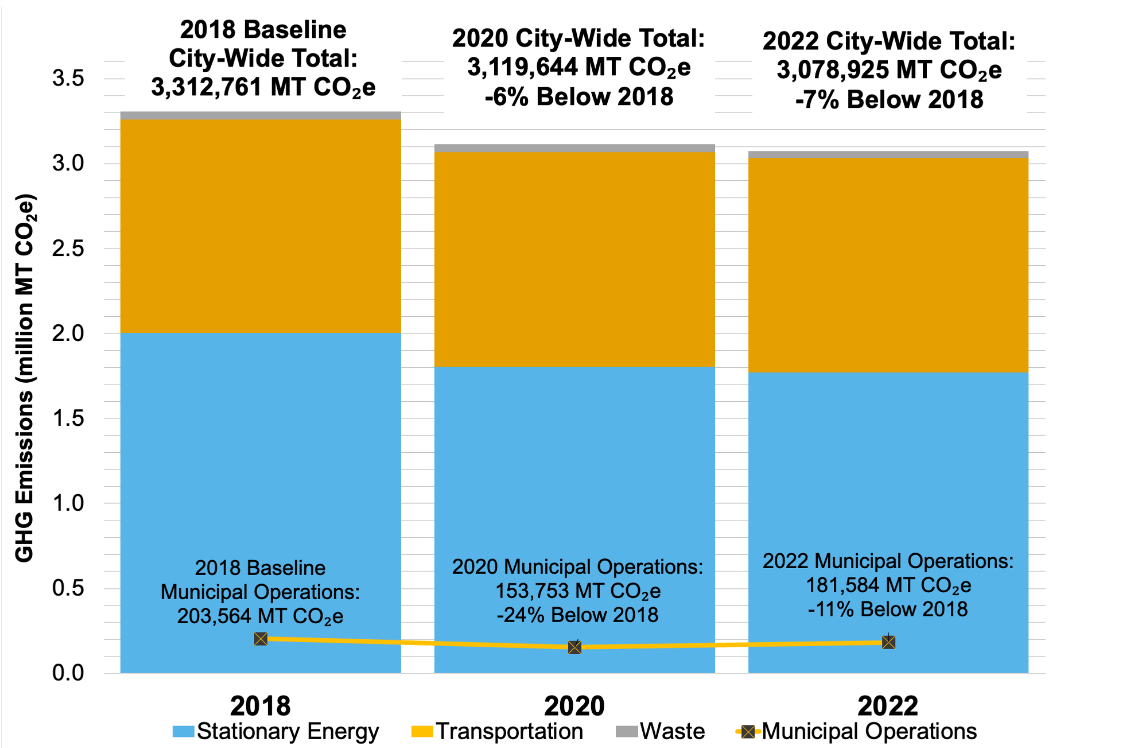

Figure 1. Change in City-wide and Municipal Operations Between 2018 and 2022.

Scottsdale's city-wide GHG emissions inventory was conducted in accordance with the GHG Protocol for Cities (GPC) BASIC level reporting requirements (Appendix A). The municipal operations GHG emissions inventory was conducted according to the Local Government Operations Protocol. Both protocols are the international standard for conducting city-wide and municipal operations GHG emissions inventories, respectively.

Scottsdale's GHG emissions fell due to several factors, including: less GHG intensive electricity delivered by Arizona Public Service and the Salt River Project; increased energy efficiency; and increased distributed solar generation across Scottsdale's homes and businesses. On a per capita basis, city-wide Scottsdale's GHG emissions fell roughly 8.7% between 2018-2022 from 14.1 to 12.9 MT CO_2e per capita (Figure 2). Scottsdale's per capita GHG emissions rate is comparable to regional cities, such as Phoenix, Tempe, and Tucson.

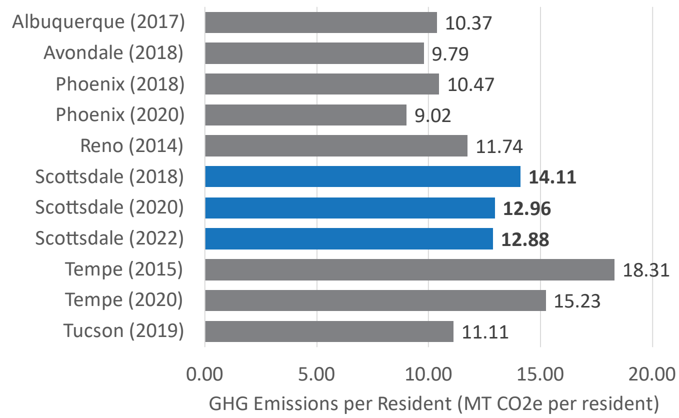

Figure 2. Comparison of Self-Reported GHG Emissions Per Capita

Finally, the project team developed the Future Energy Pathways Model for GHG inventory scenario analysis. The model can evaluate the effectiveness of different strategies, such as increasing energy efficiency, transitioning to renewable energy sources, and the adoption of electric vehicles in the transportation sector. The goal of the model is to aid City of Scottsdale decision-makers identify the most impactful and feasible options for Scottsdale, informing the city's strategy and helping prioritize its actions.

Scottsdale City-Wide GHG Emissions Inventory Findings

City-wide GHG emissions decreased by 233,837 MT CO_2e (7.1%) between 2018 and 2022 (Figure 3). Stationary energy and waste sector GHG emissions decreased 231,438 MT CO_2e (11.6%) and 5,029 MT CO_2e (10.6%), respectively. Transportation emissions increased 2,630 MT CO_2e (0.2%) between 2018 and 2022. Stationary energy emissions include all buildings and facilities within Scottsdale. Transportation emissions include on-road vehicle use to, from, and within the City of Scottsdale, but not freeway through traffic, and aviation emissions include emissions at the Scottsdale Airpark. Waste emissions include all waste & wastewater generated within the city and treated outside city boundaries.

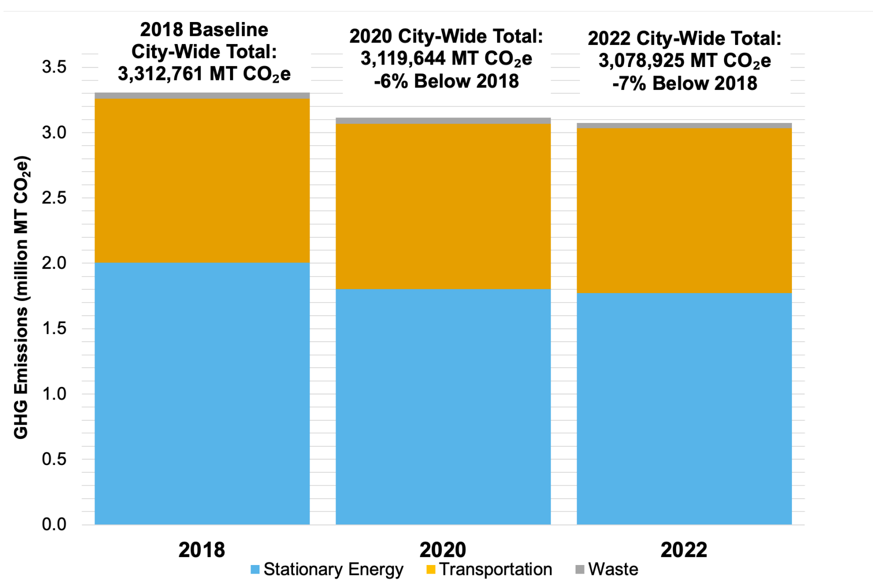

Figure 3. Scottsdale city-wide GHG emissions between 2018 and 2022.

City-wide GHG emissions trends (Table 1) for the stationary energy, transportation, and waste sectors follow regional trends.

- Stationary energy, which includes electricity consumption, decreased due to APS and SRP shifting to less carbon-intensive electricity sources.
- Transportation activity, as measured by vehicle miles, increased between 2018 and 2022. However, the associated GHG emissions increase was muted because the fuel efficiency of the average vehicle on-the-road also increased, though at a slower pace.[1]
- Waste GHG emissions decreased due to the harvest and sale of biogas at the 91st Avenue Wastewater Treatment Plant operated by the City of Phoenix, which treated wastewater generated by the City of Scottsdale as part of the Sub-Regional Operating Group (SROG).

Table 1. City of Scottsdale City-Wide Emissions by GHG Emissions Sector Along with Key City Indicators

GHG Emissions	2018	2020	2022	% Change
Stationary Energy	2,003,360	1,802,937	1,771,922	**-11.6%**
Transportation	1,256,931	1,264,986	1,259,561	**0.2%**
Waste	47,314	46,563	42,286	**-10.6%**
IPPU (Refrigerant Use)	5,156	5,156	5,156	**0%**
Total Emissions	**3,312,761**	**3,119,644**	**3,078,925**	**-7.1%**

City Indicator	2018	2020	2022	% Change
Resident Population*	234,495	240,361	238,685	**1.8%**
Estimated Scottsdale GDP ($1M US 2012)	31,142	32,742	34,992	**12.4%**
Tourism (million visitors)	10.8	8.2	NE	**NE**
Incorporated Area (sq. mi.)	184.5	184.5	184.5	**0%**
Distributed Solar Generation (MWh)	90,999	114,804	151,349	**66%**

NE – Not Estimated

**The population data in Table 1 were the best available during the inventory and report process. Future GHG inventories should revisit population data to ensure the most up-to-date estimates are utilized.*

According to population and economic activity data provided by Scottsdale, between 2018 and 2022, Scottsdale underwent a period of growth: population grew by approximately 1.8% and economic activity increased by approximately 12.4%. Accordingly, GHG emissions per capita fell roughly 8.7%[2] from 14.1 to 12.9 MT CO_2e per capita, and economic productivity per GHG emitted increased from $9.42 to $11.36 GDP (2012 constant dollars) generated per kg CO_2e emitted. Together, these findings show that Scottsdale can grow while lessening its impact on the climate (Figure 4).

[1] GHG emissions totals here vary slightly from preliminary totals reported to the Scottsdale Environmental Advisory Committee. The source of the variation results from updating emissions factors to reflect the estimated GHG intensity (GHG emissions per VMT) of vehicles on the road during the inventory year.

[2] Minor differences in calculated percent changes are due to rounding.

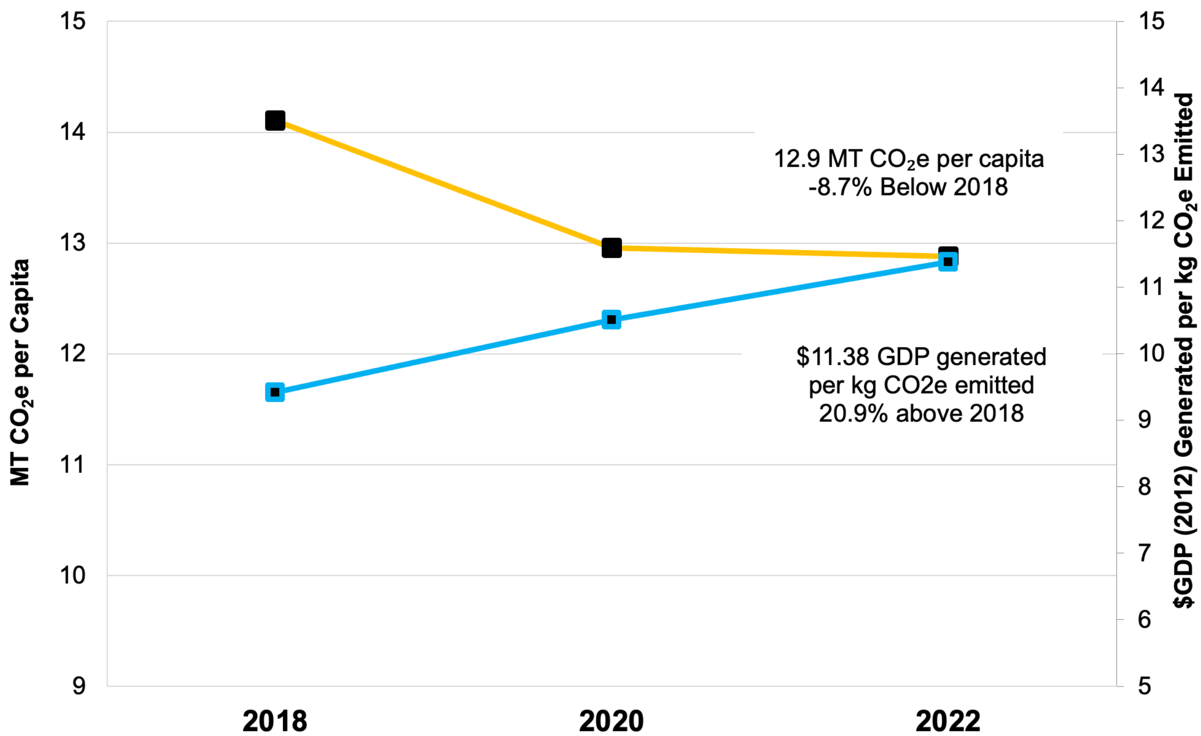

Figure 4. Change in GHG emissions performance metrics between 2018 and 2022.

GHG emissions forecasts show that significant GHG emissions decreases are achievable through proactive policies on energy efficiency, renewable energy adoption, and increased adoption of electric vehicles by residents and for fleets. GHG emission reductions policies set by APS and SRP will also help reduce Scottsdale's GHG emissions.

1. City-Wide GHG Inventory Methodology

1.1. Greenhouse Gas Protocol (GPC) GHG Emissions Scopes and Sectors

The GPC provides a city-induced framework for tabulating city-wide GHG emissions. The city-induced framework is designed to attribute GHG emissions to activities taking place within the boundary of a city. For the purposes of a GHG emissions inventory, GHG emissions are categorized into three scopes (Figure 5). Scope 1 includes direct emissions within a city boundary – e.g., natural gas combustion or fuel consumption by vehicles. Scope 2 emissions are indirect GHG emissions from grid-supplied energy, such as electricity use and other purchased utilities like district cooling and heating. Scope 3 emissions are all other indirect GHG emissions induced by city activity, such as transmission and distribution loss associated with electricity consumption; waste and wastewater generated within city boundaries but disposed of or treated outside the city boundary; and the out-of-boundary portion of transport that originates or terminates in a city.

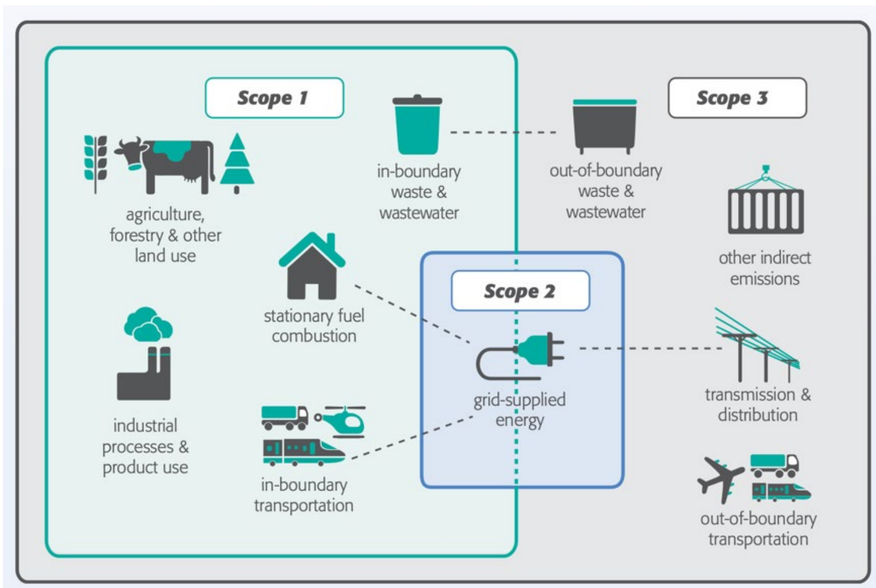

Figure 5. GHG emissions scopes. Source [GHG Protocol for Cities](#).

GHG emissions are categorized into three broad sectors: stationary energy, transportation, and waste. Stationary energy emissions occur from energy consumption at immobile buildings and facilities. Transportation emissions are related to any type of vehicle that moves. Waste emissions include all waste activities, from landfilling, recycling, the treatment of wastewater, composting organic waste, and other waste operations. Accordingly, the City of Scottsdale's GHG emissions can also be summarized by both Scope and Sector (Table 2). City-wide, Scope 2 stationary energy use, which is comprised of all net electricity consumption in the city, is the largest source of GHG emissions. Scope 1 transportation emissions, which are almost entirely comprised by on-road activities, such as personal vehicle use, light-duty and heavy-duty trucks, and other vehicles, is the second largest source of GHG emissions city-wide.

The GPC contains two levels of GHG emission reporting as part its city-induced framework: BASIC and BASIC+. The City of Scottsdale city-wide GHG emissions inventory adheres to the BASIC reporting level. The BASIC reporting level includes Scope 1 and Scope 2 emissions from Stationary Energy and Transportation sectors plus Scope 1 and Scope 3 Waste sector emissions. BASIC+ reporting builds on BASIC requirements by adding Scope 3 Stationary Energy and Transportation emissions – notably, electricity grid transmission and distribution loss; transboundary transportation – and industrial processes and product use (IPPU) GHG emissions; and agriculture, forestry, and other land use (AFOLU) GHG emissions. The additional activities included in BASIC+ reporting entail intricate and demanding data collection. While BASIC+ adds comprehensiveness, BASIC reporting allows greater comparability across cities. For these reasons, BASIC reporting was pursued for the initial city-wide GHG emissions inventory effort. However, GHG emissions from BASIC+ activities readily calculated from BASIC-level data collection are reported in Appendix A, but are not included in city-wide totals per GPC guidelines.

At the BASIC reporting level, GHG emissions occur from stationary energy and transportation activities that are induced by Scottsdale and occur within its boundary in addition to waste and wastewater activities regardless of location (Table 2). However, per the GPC, a BASIC GHG inventory does not include all emissions that occur within the city boundary; only those induced by the city. Notably, this affects the transportation sector. First, GHG emissions from on-road transportation trips fully within Scottsdale and the portion of trips to/from Scottsdale (i.e., induced by Scottsdale) within the city boundary are inventoried. Therefore, for a trip between Phoenix and Scottsdale only the portion within Scottsdale is included in Scottsdale's inventory because the Phoenix portion of the trip is Phoenix's inventory. Second, since the GPC is a city-induced framework, GHG emissions associated with travel through Scottsdale are outside the inventory boundary. Therefore, travel between Phoenix and Tempe on the Loop 101 is outside of the inventory boundary. Although these GHG emissions occur within the city, the activities are not induced by the city, and occur within the city because of freeway planning. These GHG emissions are in the inventories of the cities that induced the trip – i.e., Phoenix and Tempe.

Table 2. Scottsdale city-wide BASIC GHG emissions by Scope and Sector

Sector		GHG Emissions (MT CO_2e)			
		Scope 1	Scope 2	Scope 3	Total BASIC Emissions
Stationary Energy	Energy Use	264,403	1,507,519	NE	1,771,922
	Energy Generation	NO			
Transportation		1,259,561	IE	NE	1,259,561
Waste	Generated in the city	NO		42,286	42,286
	Generated outside the city	NO			
Industrial Produces and Product Use		NE			NE
Agriculture, Forestry, and Other Land Use		NE			NE
Total*		**1,523,964**	**1,507,519**	**42,286**	**3,073,768**
Emissions Required for BASIC/BASIC+ Reporting Level			BASIC	BASIC+	Territorial

IE – Included Elsewhere, NO – Not Occurring, NE – Not Estimated

**The city of Scottsdale has opted to include refrigerant use in city-wide GHG emissions totals, which is a BASIC+ emissions category.*

1.2. City-Wide GHG Emissions Inventory Boundary

The City of Scottsdale city-wide GHG emissions inventory was conducted according to the GPC BASIC reporting level. As such, the following inventory boundary conditions were observed.

- Scope 1 and Scope 2 stationary energy GHG emissions cover all buildings and facilities within the Scottsdale city boundary. Scope 3 Stationary energy GHG emissions, which occur primarily from the transmission and distribution loss associated with electricity consumption, were estimated from Scope 2 stationary energy emissions, and follow the same boundary condition.
- Transportation sector GHG emissions include on-road transportation and aviation emissions. On-road transportation GHG emissions were estimated from vehicle miles traveled (VMT) data modeled for the City of Scottsdale by the Maricopa Association of Governments (MAG) for trips

within, to, and from Scottsdale. Notably, per guidance in the GHG Protocol for Cities, the GHG emissions associated with trips that travel through Scottsdale – for example, a trip traveling through, but not stopping in, Scottsdale on a freeway – is not included within the boundary of this inventory. Scope 1 on-road transportation emissions encompass all trips within Scottsdale plus 50% of 'to' trips and 50% of 'from' trips. Scope 3 on-road transportation emissions encompass 50% of 'to' trips and 50% of 'from' trips.[3]

- Waste sector emissions encompass all municipal solid waste and wastewater generated by Scottsdale. Since the City of Scottsdale neither owns nor operates a landfill, solid waste emissions are classified as Scope 3. Scottsdale does operate water reclamation facilities for treating wastewater but does not treat solids in wastewater (which are the sources of emissions from wastewater). Wastewater solids are treated at the City of Phoenix 91st Avenue wastewater treatment plant, so wastewater treatment process GHG emissions are categorized as Scope 3.
- Industrial Processes and Product Use GHG emissions were estimated for air conditioning refrigerant recharge by the City of Scottsdale. These emissions are classified as Scope 1.
- There were no agriculture, forestry, and land use (AFOLU) GHG emissions estimated for this inventory.

1.3. Baseline Year

The baseline year selected for the city-wide City of Scottsdale GHG inventory is calendar year 2018. While some data were collected for calendar year 2016 as part of the GHG inventory process, there were significant data gaps for that year. Through the data collection process, the inventory team found calendar year 2018 was the earliest comprehensive dataset that could be collected for a GHG inventory without significant data gaps.

2. Stationary Energy Sector Findings

2.1. Natural Gas

2.1.1 Natural Gas GHG Emissions

In 2022, city-wide natural gas combustion totaled 49.8 million therms, representing a 2.6% increase over baseline consumption in 2018 (Table 3). Correspondingly, GHG emissions from the combustion of natural gas totaled 264,403 metric tons (MT) CO_2e, a 2.6% increase over baseline 2018 emissions of 238,329 MT CO_2e. GHG emissions presented in Section 2.1 are included in a BASIC inventory (Appendix A).

Table 3. Natural Gas Usage and GHG Emissions by Stationary Energy Subsector

Natural Gas Usage GHG Emissions (therms)	**2018**	**2020**	**2022**
Residential Buildings	23,866,423	29,084,332	29,060,112
Commercial & institutional buildings and facilities	24,230,749	19,272,191	20,547,256
Manufacturing industries and construction	425,322	214,510	172,456
Total	**48,522,494**	**48,571,033**	**49,779,824**

Natural Gas Usage GHG Emissions (MT CO_2e)	**2018**	**2020**	**2022**
Residential Buildings	126,765	154,480	154,351
Commercial and institutional buildings and facilities	128,700	102,363	109,136
Manufacturing industries and construction	2,259	1,139	916
Total	**257,725**	**257,983**	**264,403**

[3] VMT used for this report are in line with other reported VMT totals for Scottsdale and that MAG can model VMT for just city-maintained streets. VMT for this analysis includes Scottsdale-maintained streets in addition to freeway trips that originate or terminate in Scottsdale.

In 2022, residential customers accounted for 59% of natural gas combustion, and the resulting GHG emissions. Non-residential customers, which includes commercial and institutional/industrial accounts, totaled 41% and <1% of city-wide combustion, respectively.

Natural gas combustion, and the associated GHG emissions, by residential customers has increased from approximately 49% of total combustion in 2018 to approximately 59% of total combustion in 2022 (Figure 6). Meanwhile, natural gas combustion by commercial and institutional (C&I) customers decreased from approximately 49% of total combustion in 2018 to approximately 41% of total combustion in 2022. It is likely that the decrease in natural gas combustion by C&I customers was precipitated by pandemic-era restrictions since C&I natural gas decreased significantly between 2018 and 2020 and has since increased between 2020 and 2022.

Compressed natural gas (CNG) consumption for transportation activities are reported as transportation sector GHG emissions, not stationary energy GHG emissions.

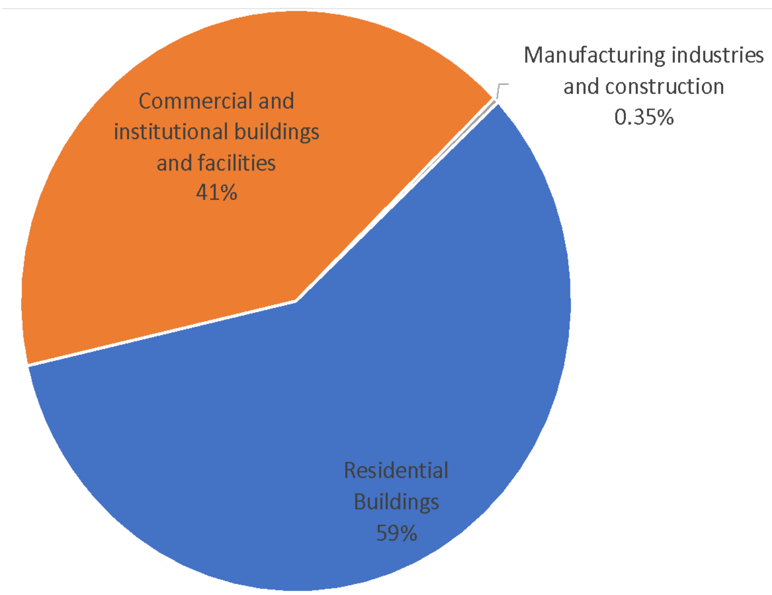

Figure 6. Proportion of Natural Gas Combustion GHG Emissions by Customer Class.

2.1.2 Natural Gas Data Sources and Methods

Natural gas data were obtained from Southwest Gas for 2016, 2018, 2020, and 2022. Southwest Gas is the only natural gas utility within the City of Scottsdale. For city-wide data, natural gas combustion data were requested by zip code and customer class. Scottsdale contains zip codes that are within the city boundary and zip codes that are partially within the Scottsdale city boundary with a portion in a different jurisdiction. For zip codes that are only partially within the Scottsdale city boundary, the data request specified that consumption be tallied only for addresses within the Scottsdale city boundary. Southwest Gas was able to comply with the data request specifications and provided monthly data for the years requested.

Once natural gas data were obtained, GHG emissions were calculated using the activity data approach[4], where natural gas combustion was multiplied by CO_2, CH_4, and N_2O emissions factors. CH_4 and N_2O emissions were converted to carbon dioxide equivalents (CO_2e) using IPCC AR5 global warming potential (GWPs) factors. Emissions factor data for natural gas were obtained for each inventory year from the EPA Emissions Factor Hub (Table 4).

Table 4. Natural Gas GHG Emissions Factors

Natural Gas GHG Emissions Factors	CO_2	CH_4	N_2O
Metric ton GHG emitted per therms natural gas combusted	0.00531	1.00E-07	1.00E-08

2.2. Electricity Consumption

2.2.1 Electricity GHG Emissions

City-wide net electricity consumption remained relatively constant between 2018 and 2022, increasing 10,623 MWh (0.3%) over the inventory time period. However, GHG emissions from electricity dropped 238,116 MT CO_2e, or 13.6% below 2018 baseline, largely due to changes in GHG intensity of the electricity Scottsdale consumes. City-wide electricity consumption includes data collected from Arizona Public Service (APS) and Salt River Project (SRP), the electricity utilities that provide service within the city boundary. APS provides approximately 80% of the electricity consumed in Scottsdale. Raw data were available from APS for all inventory years, while SRP only provided data for year 2020-2022; 2018 usage was estimated using a model built from cooling degree days, which is an indicator for the need to use air conditioning (the major driver of electricity consumption in Scottsdale). GHG emissions presented in Section 2.2 are included in a BASIC inventory (Appendix A).

Similar to natural gas usage, residential accounts consumed the majority (54%) of electricity across the City of Scottsdale in 2022, with C&I accounts consuming 45%. Consumption by industrial and agricultural customers comprised the remaining 1% of usage. The proportion of city-wide electricity consumed by residential customers spiked in 2020 (55%) and shows signs of subsiding to pre-pandemic (2018) levels. In 2018, electricity usage was more evenly weighted between residential and C&I customers, which were 52% and 47% of total consumption, respectively.

Several factors led to the steep decrease in GHG emissions associated with electricity consumption.

- First, the 2019 closure of the coal-fired Navajo Generating Station operated by SRP and the subsequent replacement of that electricity source with natural gas and renewable sources significantly decreased the GHG intensity of electricity purchased by City of Scottsdale residents and businesses.
- Second, solar energy generation by Scottsdale residents and business increased significantly between 2018 and 2022. Within the APS service territory, residential solar generation increased 88% and non-residential solar generation increased by 13%. Solar increases in SRP service

[4] The activity data approach utilizes the general equation: $GHG\ Emissions_i = Activity\ Data \times Emissions\ Factor_i$, where *I* is a GHG such as a CO_2, CH_4, and N_2O; activity data is quantitative measure of an activity that generates GHG emissions, such as natural gas combustion or electricity consumption; and emissions factor is a relative measure of the GHG emissions per unit of that activity. Emissions are then normalized to carbon dioxide equivalent emissions (CO_2e) using a global warming potential (GWP) factor for comparison across GHGs: $GHG\ Emissions_{CO_2e} = GHG\ Emissions_i \times GWP_i$, where *I* is a GHG such as a CO_2, CH_4, and N_2O and GWP is the GWP for that GHG. GWPs are updated dynamic and updated by the Intergovernmental Panel on Climate Change. The GWP standard values used in this report are the Fifth Assessment Report (AR5) GWP factors of 28 for CH_4 and 265 for N_2O.

territory were 174% for residential and 40% for commercial over the same period. As of 2022, 3.9% of all electricity consumption in Scottsdale was from rooftop solar, a 63% increase from 2018 levels.

- Finally, between 2018 and 2022, city-wide purchased electricity increased 0.3% while behind-the-meter distributed solar generation increased 66%. Combined, city-wide electricity consumption increased 1.9%. These dynamics along with changes in the regional electricity generation sources led to a significant reduction (13.6%) in GHG emissions from purchased electricity (Table 5).

Table 5. City of Scottsdale Electricity Consumption and Market-based GHG Emissions

Electricity Consumption (MWh)	**2018**	**2020**	**2022**
Residential Buildings	1,922,027	2,087,848	2,000,233
Residential Solar Generation (Not used for GHG calculation)	*58,564*	*80,371*	*113,653*
Commercial and institutional (C&I) buildings and facilities	1,746,744	1,645,150	1,688,152
C&I Solar Generation (Not used for GHG calculation)	*32,435*	*34,434*	*37,695*
Manufacturing industries and construction	41,806	36,003	32,530
Agriculture, forestry, and fishing activities	1,732	2,065	2,027
Total Billed Electricity Consumption for GHG Emission Calculation	**3,712,310**	**3,771,065**	**3,722,941**
Total Distributed Solar Generation	*90,999*	*114,805*	*151,349*
Total Electricity Consumption	**3,803,309**	**3,885,870**	**3,874,290**

GHG Emissions (MT CO_2e)	**2018**	**2020**	**2022**
Residential Buildings	908,089	856,202	810,420
Commercial and institutional buildings and facilities	818,477	673,662	683,403
Manufacturing industries and construction	18,310	14,273	12,893
Agriculture, forestry, and fishing activities	759	818	803
Total	**1,745,635**	**1,544,955**	**1,507,519**

2.2.2 Electricity Data Sources and Methods

Activity Data

Electricity consumption data were obtained from APS and SRP, the two electricity utilities that provide services through the City of Scottsdale. City-wide data were requested for calendar years 2016, 2018, 2020, and 2022 by zip code and customer class. Electricity consumption by zip code is shown in Figure 7. However, due to the incompleteness of 2016 data, 2018 was determined to be best year to serve as a baseline. Zip codes that are darker blue consume more electricity. There is a 1:1 relationship between electricity consumption and GHG emissions.

Electricity consumption totals used for GHG emissions calculated are metered, or billed, electricity consumption delivered by the electric utility. This total does not include 'behind-the-meter' or distributed solar generation (listed as an informational item in Table 5). Therefore, total (gross) electricity consumption in Scottsdale is higher than reported utility data once 'behind-the-meter' solar electricity generation is taken into account. However, for the purposes of GHG emissions accounting, only metered (net) electricity consumption is necessary because it is associated with utility-scale power plants that emit greenhouse gases to generate electricity, rather than carbon-free residential solar development.

Salt River Project Activity Data Backcasting

City-wide data provided by SRP were limited to three years (2020-2022) and were only reported for residential and non-residential electricity consumption. Since 2018 serves as the baseline year, SRP electricity consumption was backcasted for the 2018-2019 period.

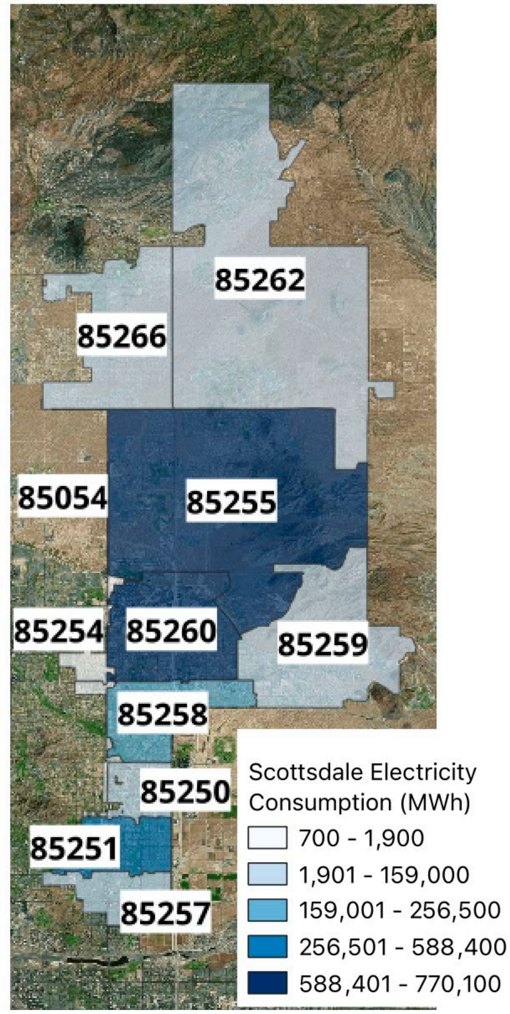

Figure 7. Total net electricity use in Scottsdale by zip Code.

A backcasting methodology was developed by regressing 2020-2022 SRP data against three indicator variables for air conditioning use, assuming electricity consumption in the Phoenix metro area is related to AC usage/temperature. The primary indicator used in this method was annual cooling degree days (CDDs), which is an indicator of AC demand based on the mean daily temperature compared to a baseline temperature above which it assumed people use AC. For example, if the baseline temperature is seventy-five and the mean daily temperature is eighty, that day has a measure of 5 degree-days. Using the same method, any days during a year with a mean temperature above 75 are assigned a CDD value based on the example calculation. CDDs are then summed over the year to get an indicator of how hot the year is with respect to the baseline temperature. In addition, two variations of the CDD metric were also used as indicator variables: CDD departure from normal, which is an indicator of AC usage compared to a typical year; and CDD departure from the previous year, which is a measure of year-over-year variability in AC demand. SRP electricity consumption from 2018-2019 were modeled with the three indicators and the results were averaged. All three methods produced comparable results. However, the method worked better for predicting residential electricity consumption (r^2 between 0.88-1) than commercial electricity consumption (r^2 between 0.01-0.19). SRP commercial electricity consumption is approximately 8% of total electricity consumption in Scottsdale. One challenge to modeling commercial electricity usage in Scottsdale was 2020 and 2021 were significant departures from normal for this sector due to the pandemic.

Electricity GHG Emissions Factor Data

Electricity consumption GHG emissions were calculated according to dual reporting requirements. Dual reporting requirements recommend that organizations calculate electricity-related GHG emissions using both location-based, regional electricity GHG emissions factors and market-based GHG emissions factors specific to their utility, which considers the mix of electricity generation sold by the utility. Location-based regional electricity GHG emissions were obtained from the EPA's Emissions & Generation Resource Integrated Database (eGRID) for calendar year 2021. The City of Scottsdale is located within the Arizona-New Mexico subregion of the U.S. electric grid for estimating GHG emissions using EPA eGRID.

For market-based calculations, the GHG inventory utilizes APS- and SRP-specific GHG emissions factors. An APS-specific GHG emissions factor was obtained from APS's GHG emissions factor reporting to the Edison Electricity Institute's (EEI) Electric Company Carbon Emissions and Electricity Mix Reporting Database. To "support corporate customers in their sustainability reporting efforts, EEI developed a database that provides carbon dioxide emission intensity rates and resource mix information, accounting for renewable energy certificates, for delivered electricity by electric distribution company." An SRP-specific GHG emissions factor was obtained from the SRP website GHG emissions reporting.

After obtaining the GHG emission factors, electricity GHG emissions were calculated using the standard activity data approach, where electricity consumption was multiplied by CO_2, CH_4, N_2O, CO_2e emissions factors. CH_4 and N_2O emissions were converted to carbon dioxide equivalents (CO_2e) using IPCC AR5 global warming potential (GWPs) factors. Market-based electricity GHG emissions are reported for the City of Scottsdale's GHG emissions. When both types of emissions factor data are available, the Corporate Standard and Scope 2 Guidance for calculating electricity consumption GHG Emissions recommends calculating emissions using both market-based and location-based approaches, but only reporting the market-based GHG emissions in an organization's GHG emissions total because it represents the GHG emissions associated with a utility's unique generation mix. This approach is called 'dual reporting' of electricity GHG emissions and was employed in this GHG inventory.

As shown in Table 6, the market-based approach is the more conservative approach to calculating Scottsdale's GHG emissions associated with electricity generation. In other words, the market-based approach results in a higher estimate of electricity GHG emissions than the location-based approach. The self-reported GHG emissions factors for APS and SRP are higher than the Arizona-New Mexico regional GHG emissions factors reported in eGRID, which is used for the location-based approach.

Table 6. The Observed Difference Between GHG Market-Based (Table 5) and Location-Based Estimation Methods

Market-Based GHG Emissions (MT CO_2e)	**2018**	**2020**	**2022**
Residential Buildings	908,089	856,202	810,420
Commercial and institutional buildings and facilities	818,477	673,662	683,403
Manufacturing industries and construction	18,310	14,273	12,893
Agriculture, forestry, and fishing activities	759	818	803
Total	**1,745,635**	**1,544,955**	**1,507,519**

Location-Based GHG Emissions (MT CO_2e)	**2018**	**2020**	**2022**
Residential Buildings	895,728	804,962	746,671
Commercial and institutional buildings and facilities	814,041	634,281	630,173
Manufacturing industries and construction	19,483	13,881	12,143
Agriculture, forestry, and fishing activities	807	796	757
Total	**1,730,059**	**1,453,920**	**1,389,744**

Δ Between Market-Based and Location-Based Methods	**15,576**	**91,035**	**117,775**

2.3. Electricity Transmission and Distribution Loss

2.3.1 T&D Loss GHG Emissions

As electricity moves from the point of generation to consumption, transmission, and distribution (T&D) losses occur within the electric grid. T&D loss can be thought of as an overhead rate on electricity consumption. If the T&D loss rate is 5%, for 100 kWh consumption 105 kWh had to be generated.

Electricity loss during the transmission and distribution of electricity varies from year to year. It is approximated from electricity consumption (
Table 7). As a Scope 3 emissions, it is an indirect GHG emissions out of the control of the City of Scottsdale or any Scottsdale-based electricity consumer.

Table 7. Transmissions and Distribution (T&D) Loss for City-wide Electricity Consumption

T&D Loss Rate	Unit	2018	2020	2022
T&D Loss Rate	%	3.6	4.2	3.8

T&D Loss	Unit	2018	2020	2022
City-wide	MWh	134,183	157,803	141,838

T&D Loss GHG Emissions	Unit	2018	2020	2022
City-wide	MT CO_2e	63,097	64,650	57,434

2.3.2 T&D Loss Data Sources

State-level T&D loss rates were calculated from methods published by the Energy Information Agency (EIA) and 2021 data obtained for Arizona from the EIA on the supply and disposition of electricity. GHG emissions associated with electricity lost during T&D were then calculated using the approach described for calculated Scope 2 electricity consumption GHG emissions.

3. Transportation Sector Findings

3.1. On-Road Vehicles

3.1.1. On-Road Vehicle GHG Emissions

City-wide on-road transportation GHG emissions were calculated from the vehicle miles traveled (VMT) induced by Scottsdale's economic activity. VMT were modeled by the Maricopa Association of Governments (MAG) as part of their transportation demand modeling efforts to support regional transportation planning.

VMT data provided by MAG are summarized in terms of directionality – trips to, from, and within Scottsdale – and vehicle class. Vehicle classes include light duty cars and trucks summarized as (1) single occupancy vehicles and (2) carpool miles; (3) light trucks; (4) medium-duty trucks; and (5) heavy-duty trucks. Per the GPC, on-road vehicle GHG emissions derived from transportation demand models have both Scope 1 and Scope 3 emissions. Scope 1 emissions include trips within Scottsdale and 50% of the distance of trips to and from Scottsdale. Scope 3 emissions include the other half of the total distance of trips to and from Scottsdale. Notably, trips traveling through Scottsdale are not included in the GHG emissions inventory accounting protocol. A future inventory could tabulate and report these GHG emissions as an informational item.

GHG emissions were calculated using year-specific VMT emissions factors (EFs) obtained from Table 8 of EPA Emissions Factor Hub. VMT EFs are provided by vehicle class: passenger cars, including cars, SUVs with a wheelbase <121 inches, minivans, and small pickup trucks; light-duty trucks, which includes full-size pickup trucks and vans, and SUVs with a wheelbase >121 inches; and medium- and heavy-duty trucks. In order to align VMT data with VMT EFs, SOVs and HOVs were assigned the passenger car vehicle class. All other MAG vehicle classes (light trucks and medium- and heavy-duty trucks) mapped directly to EPA Emissions Factor Hub VMT emissions factors.

In 2022, city-wide VMT totaled 5.11 billion VMT, where 0.80 billion VMT were within Scottsdale, 2.16 billion VMT started in Scottsdale, and 2.14 VMT billion ended in Scottsdale. Per the GPC guidelines, 2.96 billion VMT – VMT within Scottsdale plus 50% of trips starting and ending in Scottsdale – were counted toward Scope 1 on-road transportation GHG emissions calculations and the remaining 2.15 billion were counted as Scope 3 on-road transportation GHG emissions calculations (Figure 8). City-wide VMT in 2022 had an estimated increase of 6% over 2018 levels.

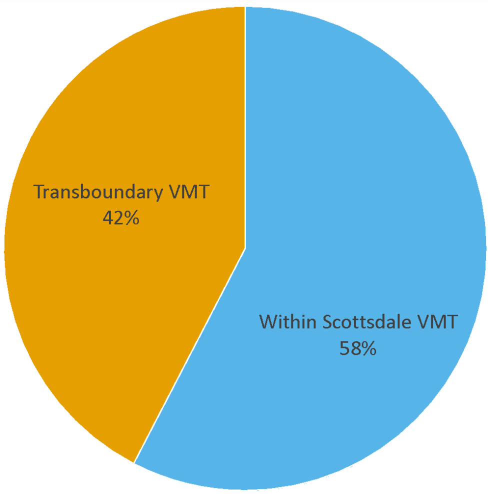

Figure 8. The percent distribution of VMT induced by Scottsdale between miles driven within Scottsdale and outside of Scottsdale.

GHG emissions were estimated from VMT using the activity data approach and emissions factors from the EPA Emissions Factor Hub. Specifically, Table 8 from the EPA Emissions Factor Hub[5] was used because it summarizes on-road GHG emissions factors in the U.S. by vehicle type and GHG per VMT derived from the EPA national GHG emissions inventory. Additionally, these emissions factors are specific to inventory year, providing insight on year-over-year efficiency increases. Where clarifying data were available for a specific fuel type – for example, CNG consumption by the City of Scottsdale – these miles were subtracted from the MAG total and tabulated separately.

In 2022, the total GHG emissions associated with City of Scottsdale on-road transportation total 2.24 million MT CO_2e, a roughly 0.5% increase above 2018 levels. Of the total, 1.26 million MT CO_2e were associated with Scope 1 on-road GHG emissions and 0.98 million MT CO_2e were associated with Scope 3 on-road GHG emissions (Figure 9)[6]. GHG emissions from on-road transportation increased 0.2% between 2018 and 2022. Meanwhile, over the same period, MAG modeled a 6% increase in VMT associated with on-road transportation in Scottsdale. On-road transportation GHG emissions remained stable despite the significant increase in VMT due to increases in average on-road vehicle fuel efficiency (Table 8 of the EPA Emissions Factor Hub). Further, data available from the Arizona Department of Transportation shows gasoline fuel sales, the largest contributor of transportation GHG emissions, only increased 0.6% over the same period, supporting the finding of a modest increase in GHG emissions from on-road

[5] Table 8 is entitled, "Scope 3 Category 4: Upstream Transportation and Distribution and Category 9: Downstream Transportation and Distribution."

[6] GHG emissions totals here vary slightly from preliminary totals reported to the Scottsdale Environmental Advisory Committee. The source of the variation results from updating emissions factors to reflect the estimated GHG intensity (GHG emissions per VMT) of vehicles on the road during the inventory year.

transportation. Since fuel sales are a county-level indicator, they provide a high-level trends of Phoenix metropolitan area gasoline consumption between 2018-2022.

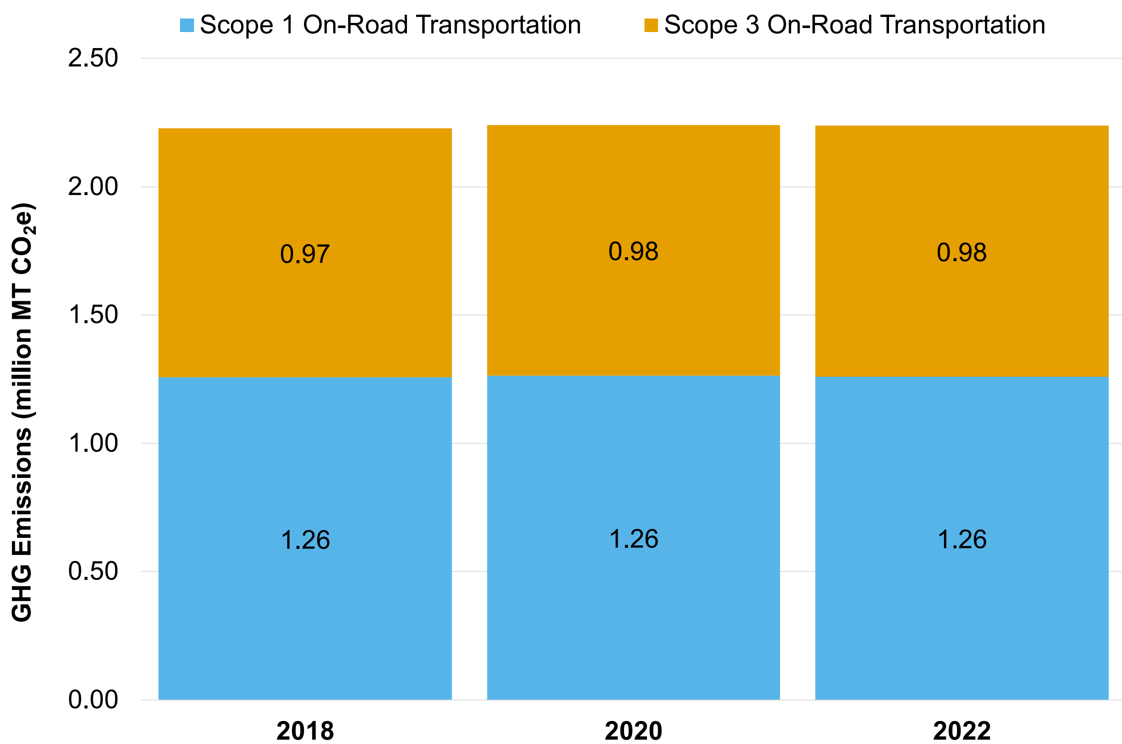

Figure 9. City-wide Scope 1 and 3 On-Road Transportation GHG Emissions

3.1.2 On-Road Vehicle Data Sources

City-wide vehicle miles traveled data were obtained from the Maricopa Association of Governments (MAG). MAG models county-wide VMT as part of their role for producing transportation demand models to support compliance with Federal air quality regulations. The MAG transportation model accounts for changes in telecommuting pre- and post-pandemic. Pre-pandemic telecommuting rates were modeled at 6% and post-pandemic telecommuting rates were modeled at 18%. MAG provided data for calendar years 2016, 2018, 2020, and 2022. Full documentation of the assumptions and modeling approaches for MAG's transportation demand model can be found in the model documentation.

GHG emissions were calculated from VMT using the activity data approach, where VMT data were multiplied by CO_2, CH_4, N_2O, CO_2e emissions factors. CH_4 and N_2O emissions were converted to carbon dioxide equivalents (CO_2e) using IPCC AR5 global warming potential (GWPs) factors.

Emissions factor data for light-, medium-, and heavy-duty trucks were obtained for each inventory year from the EPA Emissions Factor Hub for shown in Table 8.

Table 8. On-Road Vehicle GHG Emissions Factors Obtained from the EPA Emissions Factor Hub

Vehicle Type	Year	CO_2 Factor (kg / unit)	CH_4 Factor (g / unit)	N_2O Factor (g / unit)	Units
Medium- and Heavy-Duty Truck	2022	1.387	0.013	0.038	vehicle-mile
Passenger Car	2022	0.313	0.008	0.007	vehicle-mile
Light-Duty Truck	2022	0.467	0.013	0.012	vehicle-mile
Medium- and Heavy-Duty Truck	2020	1.387	0.013	0.033	vehicle-mile
Passenger Car	2020	0.335	0.009	0.008	vehicle-mile
Light-Duty Truck	2020	0.461	0.012	0.010	vehicle-mile
Medium- and Heavy-Duty Truck	2018	1.467	0.014	0.010	vehicle-mile
Passenger Car	2018	0.343	0.019	0.011	vehicle-mile
Light-Duty Truck	2018	0.472	0.019	0.018	vehicle-mile

Electric Vehicles

Until better data is available from the utilities, electricity consumption by EVs at home and commercial EV charging stations are included in Scope 2 stationary energy Electricity Consumption.

3.2. Aviation

3.2.1. Aviation GHG Emissions

Aviation GHG emissions in the City of Scottsdale primarily occur from landing and takeoff operations (LTOs) at the Scottsdale Airpark. Flight operations at the Scottsdale Airpark include private jets, fixed wing aircraft and helicopters, and service primarily domestic locations. At the Airpark, Jet Fuel A is the primary source of GHG emissions, accounting for approximately 98% of aviation emissions (Table 9). GHG emissions at the Airpark are considered a Scope 3 emission per the Greenhouse Gas Protocol for Cities. GHG emissions presented in Section 3.1 are not included in a BASIC inventory (Appendix A). Aviation emissions are reported here for informational and transparency purposes.

Table 9. GHG Emissions at the Scottsdale Airpark

Fuel	Unit	2018	2020	2022
Aviation Gasoline (AvGas)	MT CO_2e	2,804	3,294	3,066
Jet Fuel A	MT CO_2e	105,960	120,458	162,909

The initial GHG emissions estimation for the Airpark summarizes emission by fuel type. Additional data collection is required to further classify and refine these totals. Further efforts would work to classify helicopter operations that takeoff and land within Scottsdale versus those that either takeoff or land in Scottsdale; quantify the fraction of Airpark emissions from landing and takeoff operations that occur within the city; quantify the portion of emissions that occur at Phoenix Sky Harbor airport from Scottsdale residents. For that reason, the total gallons of aviation gasoline and Jet Fuel A consumption are used for GHG emissions estimation to provide a first-order estimation that accounts for scoping and data limitations. Per the GPC guidance, these limitations could be overcome through other data collection means, such as a survey of helicopter operators within Scottsdale and a survey of travel activity of Scottsdale at Phoenix Sky Harbor Airport.

3.2.2. Aviation Data Sources

Jet Fuel A and aviation gasoline (AvGas) consumption at the Scottsdale Airpark were obtained from the City of Scottsdale. Data obtained for the Scottsdale Airpark show an increase in flight activity, indicated by increased fuel usage between 2018-2022 (Table 10).

Table 10. Fuel Usage at the Scottsdale Airpark

Fuel	Unit	2018	2020	2022
Aviation Gasoline (AvGas)	gallons	337,390	396,383	368,987
Jet Fuel A	gallons	10,867,707	12,354,709	16,708,587

Aviation GHG emissions were calculated using the activity data approach. Fuel consumption was multiplied by CO_2, CH_4, N_2O, CO_2e emissions factors. CH_4 and N_2O emissions were converted to carbon dioxide equivalents (CO_2e) using IPCC AR5 global warming potential (GWPs) factors. Emissions factor data were obtained for each inventory year from the EPA Emissions Factor Hub.

4. Waste Sector Findings

4.1. Solid Waste Disposal

4.1.1. Solid Waste GHG Emissions

Over the inventory period, both solid waste generation and the resulting GHG emissions remained relatively constant. Section 4.1.1 covers GHG emissions from the landfill and not from hauling waste to the landfill, which are included in Section 3. Solid waste totals in this initial inventory effort only include solid waste picked up by the City of Scottsdale and deposited at the Salt River Landfill, since data from private haulers are not available. Solid waste GHG emissions tend to be a function of population and landfill operations. Residential (refuse) solid waste generation increased by approximately 1.7% between 2018-2022 over the same period, as did the associated GHG emissions over the same period (Table 11). GHG emissions presented in Section 4.1.1 are included in a BASIC inventory (Appendix A).

Table 11. City of Scottsdale Solid Waste Disposal GHG Emissions

Municipal Solid Waste Collection (short tons)	2018	2020	2022
Residential (Refuse)	62,370	69,052	63,439
Recycle	24,389	25,414	23,635
Brush	18,479	23,347	20,768
Green Waste	633	82	14
Commercial	20,502	16,969	18,151
Roll-Off	3,147	3,133	3,237
Total	**129,520**	**137,997**	**129,244**

GHG Emissions (MT CO_2e)	2018	2020	2022
Residential (Refuse)	20,859	23,094	21,217
Recycle	--	--	--
Brush	6,180	7,808	6,946
Green Waste[1]	--	--	--
Commercial	6,857	5,675	6,071
Roll-Off	1,053	1,048	1,083
Total	**34,949**	**37,626**	**35,316**

[1]Green waste GHG emissions were not estimated because they were deemed de minimus.

4.1.2. Solid Waste Data Sources & Methods

The City of Scottsdale provided annual solid waste collections data in tons for residential (refuse), recycling, brush, green waste, commercial, and roll-off waste streams. GHG emissions from landfilling were estimated for the residential (refuse), brush, green waste, commercial, and roll-off waste streams. According to the data provided by the city of Scottsdale, solid waste collected within the city limit was deposited in Salt River Landfill. Generally, recycling is excluded from solid waste GHG emissions because the materials are diverted from the landfill.

Using this assumption, a landfill-specific GHG emissions factor for the Salt River Landfill was obtained from the EPA Facility Level Information on Greenhouse gases Tool (FLIGHT). The landfill-specific GHG emissions factor was calculated using methane emissions data and waste-in-place data collected for the period between 2011-2021 for Salt River Landfill from EPA FLIGHT. The ten-year average Salt River Landfill GHG emissions factor was then multiplied by total amount of waste generated by Residential (Refuse), Brush, Green Waste, Commercial, and Roll-Off and deposited in the Salt River Landfill.

A ten-year average was developed as a general emissions factor to characterize the landfill operations. A ten-year average was chosen for several reasons:

- First, waste deposited in an inventory year may not begin to generate methane until the next calendar year, so a ten-year average provides a summary estimate of methane emitted per ton of waste deposited at the landfill.
- Second, other cities deposit waste in the landfill, so the emission factor is used to estimate Scottsdale's contribution to methane generated at the landfill.
- Third, averaging over ten years dampens year-to-year variability from environmental or operational conditions. For example, years with more rainfall may exhibit greater than average methane generation, and drier years less. Also, years where the landfill gas capture system is offline for significant maintenance may exhibit increased methane emissions.
- Finally, an alternative source of GHG emissions factors for waste degradation in landfills is the EPA Center for Corporate Climate Leadership's GHG Emissions Factor Hub. These emissions factors reflect a typical U.S. landfill and likely overestimates GHG emissions from located in the hot, arid conditions in the Phoenix metropolitan area.

4.2. Wastewater Treatment

4.2.1. Wastewater Treatment GHG Emissions

Wastewater produced by the City of Scottsdale is treated both within the city boundary and at the City of Phoenix 91st Avenue Wastewater Treatment Plant (WWTP). However, City of Scottsdale WWTPs only treat liquid waste and do not treat solids in the wastewater stream; wastewater with solids is sent for treatment at the 91st Avenue WWTP. Since wastewater emissions per the GPC only includes the GHG emissions from the breakdown of waste, Scottsdale wastewater emissions for the purposes of this report only occur at the 91st Avenue WWTP. GHG emissions from natural gas combustion and the electricity consumption at Scottsdale owned and operated WWTPs are included in stationary energy GHG emissions. GHG emissions presented in Section 4.2.1 are included in a BASIC inventory (Appendix A).

City of Scottsdale wastewater treatment GHG emissions are calculated using a prorated share of GHG emissions occurring at the 91st Ave WWTP (Table 12). Scottsdale's portion of GHG emissions at the WWTP decreased dramatically due to on-site actions that resulted in the construction of a system to capture and sale methane generated through the wastewater treatment process.

Table 12. City of Scottsdale Wastewater Treatment Emissions

Wastewater Treatment (million gallons)	**2018**	**2020**	**2022**
Net Outflows to SROG	3,650	3,077	2,399
Total	**3,650**	**3,077**	**2,399**

GHG Emissions (MT CO_2e)	**2018**	**2020**	**2022**
Net Outflows to SROG	12,365	8,938	6,970
Total	**12,365**	**8,938**	**6,970**

4.2.2 Data Sources & Methods

For wastewater treatment, there is no difference between city-wide and city-operations data. The City of Scottsdale operates two wastewater treatment plants (WWTP), but neither treat solids contained in wastewater. Solids treatment is responsible for the generation of methane and nitrous oxide emissions. Therefore, methane and nitrous oxide emissions were not estimated for the Scottsdale WWTPs. Scottsdale WWTP emit GHGs through combustion of natural gas and consumption of electricity, which have been included in Scope 1 and Scope 2 emissions calculations.

Scottsdale wastewater solids are sent to the City of Phoenix 91st Avenue Wastewater Treatment Plant as part of their partnership in the Sub Regional Operating Group (SROG) that is responsible for the wastewater treatment plant. The City of Scottsdale provided weekly flow data on deliveries to the 91st Avenue WWTP. Scottsdale flows to the 91st Avenue WWTP were multiplied by a GHG emissions intensity factor for the 91st Ave WWTP published by the City of Phoenix. The 91st Ave WWTP GHG emissions intensity factor includes all GHG emissions at the facility, including on-site natural gas combustion, electricity consumption, methane emissions from wastewater treatment, in addition to nitrous oxide emissions from wastewater treatment and discharge to the environment. Since the years of the Phoenix government operations GHG emissions inventory do not all align with the Scottsdale GHG inventory years, the closest years were used for the Scottsdale inventory. For example, the 2015 Phoenix inventory was used for Scottsdale's 2016 inventory and the 2020 Phoenix inventory was used for the 2020 and 2022 Scottsdale inventory since there is not yet a 2022 Phoenix inventory. Therefore, Scottsdale wastewater emissions are inclusive of all emissions sources resulting from treatment.

5. Industrial Processes and Product Use (IPPU)

5.1. Refrigerant Loss

5.1.1. Refrigerant Loss GHG Emissions Findings

Currently, the city-wide inventory only contains refrigerant losses for known City of Scottsdale purchases of R-22, R-410A, and R-134A refrigerants for recharging HVAC units. Per the data received from the City of Scottsdale, purchasing, and therefore recharge, levels were identical across the inventory years (Table 13). These were the only data obtained related to IPPU emissions. Since the Scottsdale GHG inventory is reported at the BASIC reporting level, these emissions are included for informational and transparency purposes (Appendix A).

Table 13. City of Scottsdale Refrigerant Usage 2018-2022

Refrigerant	Purchased Amount (jugs)	Purchase Amount (weight)	GHG Emissions (MT CO_2e)
Type R-22	66	1,980	1,626
Type R-410A	87	2,175	3,453
Type R-134A	4	120	78

5.1.2 Refrigerant Loss Data Sources

Data on fugitive emissions from refrigerant leaks/losses were only available for City of Scottsdale heating, ventilation, and air conditioning (HVAC) units. The City of Scottsdale activity data were reported for both city-wide and city-operations and utilized for GHG emissions calculating. It is expected that city-wide emissions from refrigerant losses/leaks are greater than the reported total. Emissions factor data for refrigerants were obtained for each inventory year from the EPA Emissions Factor Hub (Table 14).

Table 14. Refrigerant GWPs

Refrigerant	GWP
Type R-22	1,810
Type R-410A	3,500
Type R-134A	1,430

6. Municipal Operations GHG Inventory

6.1. Municipal Operations GHG Inventory Findings

Between 2018 and 2022, Scottsdale's municipal operations GHG emissions decreased roughly 10% from 203,564 MT CO_2e to 181,584 MT CO_2e. The municipal operations GHG emissions inventory was conducted according to the Local Government Operations Protocol, the established standard for conducting municipal operations GHG emissions inventories. While GHG emissions from municipal operations are included in the city-wide total (Sections 2-5), the municipal operations inventory provides specific detail identifying and quantifying the GHG emissions related to municipal operations. GHG emissions reported in Section 6 are reported using a separate inventory protocol and encompass an organizational boundary – Scottsdale municipal operations – rather than a geographic boundary – activities within the Scottsdale city boundary.

GHG emissions from municipal operations included the stationary energy use from all Scottsdale buildings and facilities, fleet, refrigerant loss, employee commute, electricity transmission and distribution loss, and out-sourced activities like solid waste disposal and wastewater treatment. GHG emissions from these activities are categorized into three scopes: Scope 1, Scope 2, and Scope 3.

- Scope 1 includes direct emissions from city owned or operated assets – e.g., natural gas combustion at buildings in heating, ventilation, and air conditioning (HVAC) units or boilers and fuel consumption by vehicles.
- Scope 2 emissions are indirect GHG emissions from grid-supplied energy, such as electricity use and other purchased utilities like district cooling and heating. For the City of Scottsdale, Scope 2 was limited to purchased electricity.
- Scope 3 emissions are all other indirect GHG emissions. For example, employee commute, electricity transmission and distribution loss, and out-sourced activities like solid waste disposal and wastewater treatment.

GHG emissions from municipal operations changed significantly between 2018 and 2022 (Table 15). First, and notably, the COVID-19 pandemic had an impact on Scottsdale's GHG emissions. There is a decrease and then increase in GHG emissions moving between 2018 and 2020 and then 2020 and 2022. The change in life brought by the pandemic in 2020 caused considerable changes to the City of Scottsdale's GHG emissions. While other indicators of GHG emissions from municipal operations remained relatively constant between 2018-2020, electricity consumption during the COVID-19 pandemic had the most dramatic influence on emissions. Scottsdale's electricity consumption decreased 29% between 2018 and 2020 and then increased 38% between 2020 and 2022. Overall municipal operations GHG emissions followed the same pattern.

Scottsdale's municipal operations GHG inventory is dominated by electricity consumption. In 2022, electricity consumption comprised approximately 62% of the city's GHG inventory. Of City of Scottsdale electricity consumption, addresses associated with the city's water and wastewater treatment plants consumed the most electricity. After electricity consumption, solid waste and the vehicle fleet are the next largest emitters of GHGs from municipal operations, comprising 19% and 6.6% of total, respectively.

Several factors led to the change in municipal operations GHG emissions between 2018 and 2022.

- Though a smaller emitting activity, GHG emissions from the on-site combustion of natural gas increased approximately 15% between 2018 and 2022. This emitting activity does not include CNG consumption by the Scottsdale fleet, which is included in the Vehicle Fleet emitting activity.

- GHG emissions from the Vehicle Fleet remained relatively flat between 2018 and 2020.
- Electricity-related GHG emissions fell significantly for a couple reasons. First, the SRP-operated Navajo Generating Station (NGS) closed in 2019. Second, NGS was a significant source of GHG emissions in SRP electricity generation portfolio and replaced with less GHG-intensive electricity sources.
- As described in Section 5.2, biogas flaring at the 91st Ave WWTP was rerouted into a new project that provides renewable natural gas into the regional natural gas pipeline.

Table 15. Overview of City of Scottsdale GHG Emissions from City Operations

Scope 1 Emissions Type	GHG Emissions (MT CO_2e)			% Change
	2018	2020	2022	
Natural Gas Combustion	3,114	2,989	3,585	15.1%
Vehicle Fleet	11,974	11,435	11,905	-0.6%
Refrigerant Loss	5,156	5,156	5,156	0.0%
Total	**37,375**	**36,171**	**37,708**	**0.9%**

Scope 2 Emissions Type	GHG Emissions (MT CO_2e)			% Change
	2018	2020	2022	
Electricity Consumption	129,577	81,913	112,107	-13.5%
Total	**129,577**	**81,913**	**112,107**	**-13.5%**

Scope 3 Emissions Type	GHG Emissions (MT CO_2e)			% Change
	2018	2020	2022	
Solid Waste	34,949	37,626	35,316	1.0%
Wastewater	12,365	8,938	6,970	-43.6%
Employee Commute	1,746	2,269	2,274	30.3%
T&D Loss	4,684	3,428	4,271	-8.8%
Total	**53,743**	**52,260**	**48,831**	**-9.1%**

Overall Total (MT CO_2e)	**203,564**	**153,753**	**181,584**	**-10.8%**

6.2. Municipal Operations GHG Inventory Boundary

For the municipal operations GHG emissions inventory, the following inventory boundary conditions were observed.

- Scope 1 and Scope 2 Stationary energy sector GHG emissions cover all buildings owned and/or operated by the City of Scottsdale. Scope 3 stationary energy GHG emissions (for transmission & distribution losses) were estimated from Scope 2 stationary energy emissions and follow the same boundary condition.
- Transportation sector GHG emissions include on-road transportation by the City of Scottsdale fleet and employee commuting. Scottsdale fleet GHG emissions were classified as Scope 1. Employee commute GHG emissions were classified as Scope 3.
- Since the City of Scottsdale neither owns nor operates a landfill or a wastewater treatment plant that processes solids in wastewater, these emissions are estimated as Scope 3 GHG emissions.
- Fugitive emissions within municipal operations GHG inventories typically include emissions from wastewater treatment plants and municipal solid waste landfills owned or operated by the city. However, while Scottsdale does operate wastewater treatment facilities, they do not treat solids in the wastewater stream; solids are sent to the city of Phoenix 91st Avenue wastewater treatment plant (WWTP). Per the municipal operations inventory guidance, fugitive emissions at

wastewater treatment plants occur from the treatment of solids, so Scottsdale's WWTPs do not produce fugitive emissions. Therefore, the only fugitive emissions tabulated were from refrigerant leaks from municipal-owned heating ventilation and air conditioning (HVAC) units. Data on fugitive emissions from refrigerant leaks/losses were available for City of Scottsdale HVAC units. The City of Scottsdale reported the purchase of R-22, R-410A, and R-134A refrigerants for recharging HVAC units. These emissions were classified as a Scope 1 fugitive emission.

6.3. Municipal Operations GHG Inventory Baseline Year

The baseline year for the City of Scottsdale municipal operations GHG emissions inventory was set to 2018 to align with the community inventory.

6.4. Stationary Energy Findings

6.4.1. GHG Emissions from Natural Gas Combustion

Natural gas combustion for municipal operations increased approximately 15% between 2018 and 2022 (Table 16). Stationary energy natural gas combustion only includes buildings and facilities use, which was approximately 57% of total municipal operations natural gas usage. Approximately 43% of natural gas usage by the City of Scottsdale was for CNG vehicles, which is reported in the transportation section. Of natural gas usage for municipal operations, approximately 81% of usage occurs in three zip codes: 85260 (38%), 85251 (22%), and 85257 (21%). Large facilities like Westworld and the City of Scottsdale's aquatic and sports recreation centers were the largest users of natural gas.

Table 16. City of Scottsdale Natural Gas Usage for City Operations

Natural Gas Combustion	Units	2018	2020	2022
Natural Gas Combustion	therms	586,207	562,691	675,004
Natural Gas Greenhouse Gas Emissions	MT CO_2e	3,114	2,989	3,585

Natural Gas Data and Methods

Southwest Gas is the only natural gas utility within the City of Scottsdale. For the municipal operations inventory, data were requested for natural gas combustion for City of Scottsdale accounts at the address level. Southwest Gas was able to comply with the data request specifications and provided monthly data for the years requested. For detailed methods on calculating GHG emissions from on-site natural gas combustion, please refer to section 2.1.2 Natural Gas Data Sources and Methods.

6.4.2. GHG Emissions from Electricity Consumption

Between 2018 and 2022, net electricity consumption of municipal operations decreased by 2.1% from 286,007 MWh to 280,021 MWh (Table 17). Over the same period, the GHG intensity of the electricity consumed by the City of Scottsdale has reduced significantly. Over the same 2018 to 2022 time period, GHG emissions from electricity consumption for city-operation decreased 13.5%, or 17,469 MT CO_2e.

Table 17. Electricity Consumption for City of Scottsdale Operations

Electricity Consumption	Units	2018	2020	2022
Municipal Operations Electricity Consumption	MWh	286,007	202,165	280,021
Municipal Operations Greenhouse Gas Emissions	MT CO_2e	129,577	81,913	112,107

Electricity Data & Methods

Electricity consumption data were obtained from APS and SRP, the two electricity utilities that provide services through the City of Scottsdale. Municipal operations electricity consumption data were requested for City of Scottsdale accounts at the address-level for calendar years 2018, 2020, and 2022. Both APS and SRP were able to comply with this data request.

In 2022, approximately 91% of electricity consumed by the City of Scottsdale was in the APS service territory. Further, most of the overall municipal operations electricity consumption (55%) occurred in the 85255 zip-code where the Scottsdale Water Campus is located. The Scottsdale Water Campus, which houses a water reclamation facility, is the largest electricity consumer among municipal electricity consumers. It should be noted that electricity data provided by the utilities was metered (billed) electricity consumption, or net electricity consumption. The metered electricity data does not include 'behind-the-meter' solar. Scottsdale does have solar installed on city buildings.

Electricity GHG Emissions Factor Data

For detailed information on electricity GHG emissions factors used and the dual reporting method in the City of Scottsdale GHG inventories please to section 2.2.2 Electricity Data Sources and Methods.

When location-based and market-based electricity emissions factor data are available, the Corporate Standard and Scope 2 Guidance for calculating electricity consumption GHG Emissions mandates calculating emissions using both market-based and location-based approaches, but only reporting the market-based GHG emissions in an organization's GHG emissions total because it represents the GHG emissions associated with a utility's unique generation mix. While this mandate is not mentioned in the Local Government Operations Protocol, it was followed here to provide conformity with the approach in the city-wide GHG emissions inventory. This approach is called 'dual reporting' of electricity GHG emissions and was employed in this GHG inventory (Table 18).

Table 18. Difference Electricity GHG Emissions Between Market-Based and Location-Based Estimation Methods for Municipal Operations

Electricity Consumption	Unit	2018	2020	2022
Electricity Consumption - Market Based	MT CO_2e	129,577	81,913	112,107
Electricity Consumption - Location Based	MT CO_2e	133,289	77,944	104,529
Δ Between Market-Based and Location-Based Methods		**-3,712**	**3,969**	**7,578**

6.4.3. GHG Emissions from Electricity Transmission and Distribution Loss

As electricity moves from the point of generation to consumption, transmission, and distribution (T&D) losses occur within the electric grid. T&D loss can be thought of as an overhead rate on electricity consumption. If the T&D loss rate is 5%, for 100 kWh consumption 105 kWh had to be generated. Electricity loss during the transmission and distribution of electricity varies from year to year (Table 19). It is approximated from electricity consumption. It is an indirect GHG emissions out of the control of the City of Scottsdale or any Scottsdale-based electricity consumer, and therefore categorized as a Scope 3 emission.

Table 19. Transmissions and Distribution Loss for Municipal Operations Electricity Consumption

T&D Loss Rate	**Unit**	**2018**	**2020**	**2022**
T&D Loss Rate	%	3.6	4.2	3.8
T&D Loss	**Unit**	**2018**	**2020**	**2022**
Municipal Operations	MWh	10,338	8,460	10,668
T&D Loss GHG Emissions	**Unit**	**2018**	**2020**	**2022**
Municipal Operations	MT CO_2e	4,684	3,428	4,271

Data Sources

For detailed information electricity GHG emissions factors used in the City of Scottsdale GHG inventories please to 2.3.2 T&D Loss Data Sources. City of Scottsdale Solid Waste Disposal GHG Emissions

6.5. City Fleet Findings

6.5.1. GHG Emissions from On-Road Vehicles

GHG emissions from the City of Scottsdale fleet are shown in Figure 10. Unleaded gasoline fuel use is the largest source of GHG emissions and has increased since 2018. Diesel fuel consumption, and the associated GHG emissions, was roughly equivalent to gasoline in 2018, but has decreased as a percentage of fleet fuel usage between 2018-2022. Usage of CNG as a fleet fuel, and the associated GHG emissions, increased between 2018-2022, but the associated emissions are still less than diesel emissions. The Scottsdale fleet reported E85 ethanol (a blended biofuel of 85% ethanol and 15% gasoline) in 2018 and 2020 but began phasing out usage of that fuel after 2020.

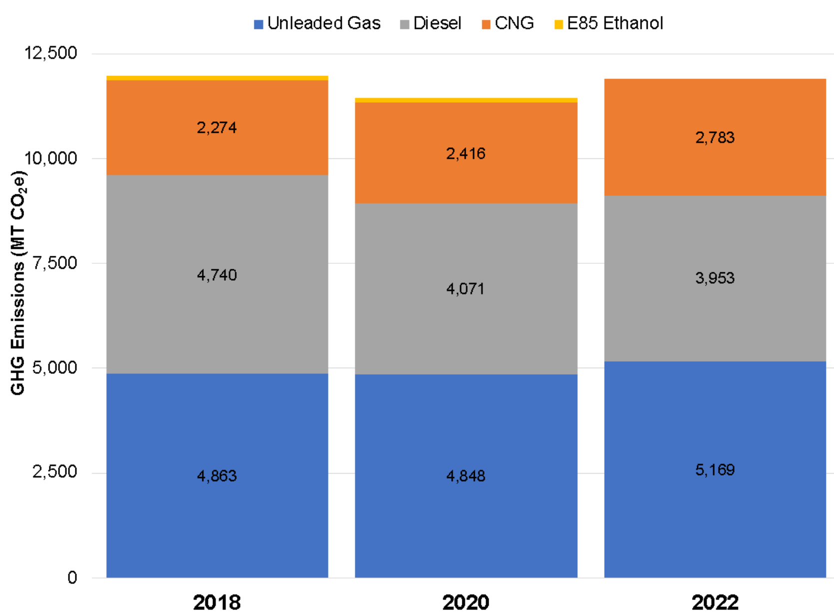

Figure 10. City of Scottsdale Fleet GHG Emissions by Fuel Type

Data Sources

For the municipal operations GHG emissions inventory, emissions from fuel consumed by the city fleet are a Scope 1 GHG emission. City of Scottsdale provided fleet data by fuel type and vehicle for calendar years 2018, 2020, and 2022. Fleet data contains information on vehicle miles driven by each fleet vehicle and fuel type in addition to monthly fuel consumption and costs by fuel type. Fuel consumption data by vehicle, which would enable for vehicle-level calculation of GHG emissions and fleet efficiency analysis, were not available.

6.6. Employee Commute Findings

6.6.1. GHG Emissions from Employee Commute

Employee commute data showed an increase in total miles driven by Scottsdale employees between 2018 and 2022. Notably, between 2018 and 2022, the reported employee commute trip distance increased, which in turn, caused an increase of annual employee commute miles and resulting GHG emissions (Table 20).

Table 20. Employee Commuting Miles and GHG Emissions

Employee Commute Indicators	**2018**	**2020**	**2022**	**% Change**
Commute Miles	5,053,796	6,724,900	7,210,517	43%
Commute Miles Per Trip	17.34	19.59	20.07	16%
Employee Commute Emissions	**2018**	**2020**	**2022**	**% Change**
GHG Emissions (MT CO_2e)	1,746	2,269	2,274	30.3%

Data Sources

For the municipal operations GHG inventory, employee commute is Scope 3 Transportation GHG emissions. City of Scottsdale employee commute data were obtained from summaries of Scottsdale's reporting to the Maricopa County Trip Reduction Program (TRP). TRP data contains information on average employee commute miles driven per week for each Scottsdale worksite.

GHG emissions factors for city-wide on-road transportation are used to calculate GHG emissions from City of Scottsdale employee commuting. For a detailed description of the on-road transportation GHG emissions factors, please refer to section

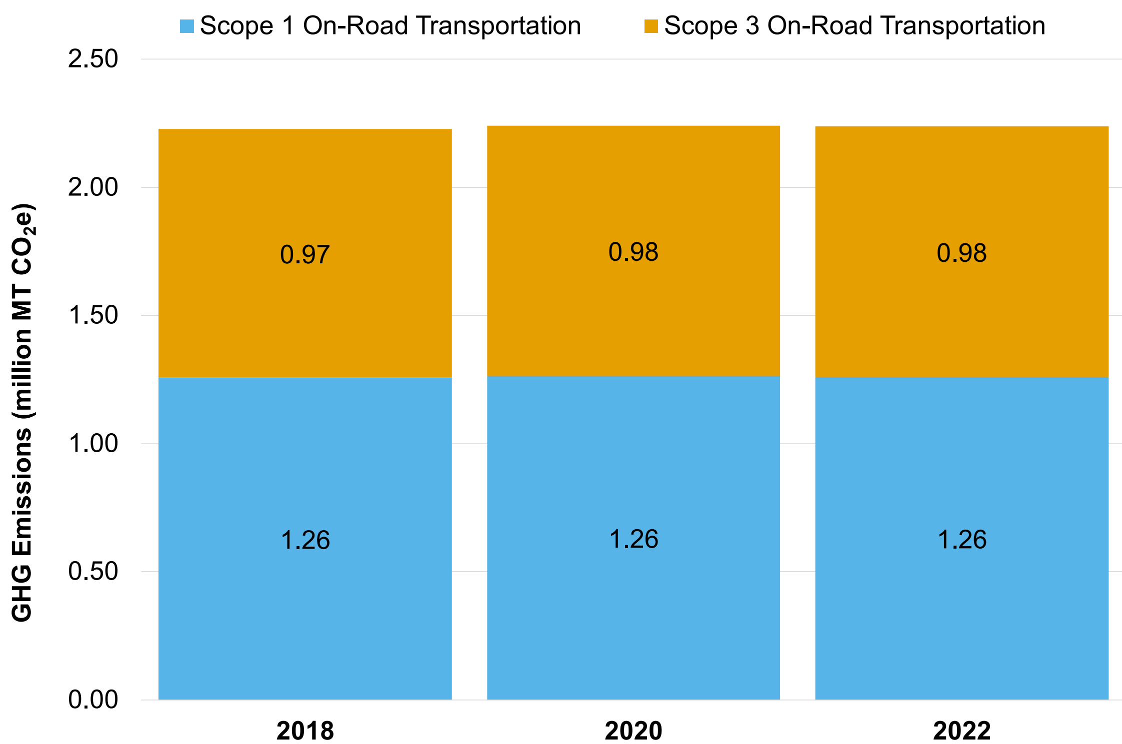

Figure 9. City-wide Scope 1 and 3 On-Road Transportation GHG Emissions

3.1.2 On-Road Vehicle Data Sources.

6.7. Solid Waste Disposal Findings

6.7.1. GHG Emissions from Solid Waste

For a full explanation of findings, please refer to section Solid Waste GHG Emissions. Results in Table 21 are reproduced as they are part of both the city-wide and municipal operations inventories.

Table 21. City of Scottsdale Solid Waste Disposal GHG Emissions

Municipal Solid Waste Collection (short tons)	2018	2020	2022
Residential (Refuse)	62,370	69,052	63,439
Recycle	24,389	25,414	23,635
Brush	18,479	23,347	20,768
Green Waste	633	82	14
Commercial	20,502	16,969	18,151
Roll-Off	3,147	3,133	3,237
Total	**129,520**	**137,997**	**129,244**

GHG Emissions (MT CO_2e)	2018	2020	2022
Residential (Refuse)	20,859	23,094	21,217
Recycle	--	--	--
Brush	6,180	7,808	6,946
Green Waste	--	--	--
Commercial	6,857	5,675	6,071
Roll-Off	1,053	1,048	1,083
Total	**34,949**	**37,626**	**35,316**

Solid Waste Data Sources & Methods

For a full explanation of data sources and methods please refer to section Solid Waste Data Sources & Methods. Results are reproduced in this section as they are part of both the city-wide and municipal operations inventories.

6.8. Wastewater Treatment Findings

6.8.1. GHG Emissions from Wastewater Treatment

For a full explanation of findings please refer to section Wastewater Treatment GHG Emissions. Results in Table 22 are reproduced in this section as they are part of both the city-wide and municipal operations inventories.

Table 22. City of Scottsdale Wastewater Treatment Emissions

Wastewater Treatment	2018	2020	2022
Net Outflows to SROG (million gallons)	3,650	3,077	2,399
Total	**3,650**	**3,077**	**2,399**

GHG Emissions	2018	2020	2022
Net Outflows to SROG (MT CO_2e)	12,365	8,938	6,970
Total	**12,365**	**8,938**	**6,970**

Data Sources & Methods

For a full explanation of data sources and methods please refer to section 4.2.2 Data Sources & Methods. Results are reproduced in this section as they are part of both the city-wide and municipal operations inventories.

6.9. Fugitive Emissions from Refrigerant Losses Findings

6.9.1. GHG Emissions from Refrigerant Loss

For a full explanation of findings please refer to section Refrigerant Loss GHG Emissions Findings. Results in Table 23 are reproduced as they are in both city-wide and municipal operations inventories.

Table 23. City of Scottsdale Refrigerant Usage 2018-2022

Refrigerant	Purchased Amount (jugs)	Purchase Amount (weight)	GHG Emissions (MT CO_2e)
Type R-22	66	1,980	1,626
Type R-410A	87	2,175	3,453
Type R-134A	4	120	78

Refrigerant Loss Data Sources

The City of Scottsdale activity data were reported for the municipal operations GHG inventory, but also utilized in the city-wide GHG emissions inventory because they were the only data available city-wide. Emissions factor data for refrigerants were obtained for each inventory year from the EPA Emissions Factor Hub (Table 24).

Table 24. Refrigerant GWPs

Refrigerant	GWP
Type R-22	1,810
Type R-410A	3,500
Type R-134A	1,430

7. Future Energy Pathways Model

7.1. Background

The primary objective of this model is to analyze current trends at the community, state, and national levels and use this information to estimate future community-level GHG emissions in Scottsdale. By doing so, it seeks to anticipate the trajectories these trends are likely to follow, and the potential impacts of modifications to various variables on future GHG emissions. The model is built on the foundation of the city-wide GHG inventory developed for Scottsdale incorporated with other sources to help estimate future energy pathways. By incorporating this local data, the model can provide insights which are tailored specifically to Scottsdale's unique circumstances.

Using the data in the GHG inventory, this model then utilizes a range of forecasting methods to project current data into the future, considering potential changes in demographics, technology, policy, and economic factors. Included in this model are detailed assumptions, each reflecting rigorous research and expert predictions. The model also allows for sensitivity analysis, providing the flexibility to examine how changes in these assumptions might impact outcomes. This feature enhances the robustness of the results by acknowledging the inherent uncertainties in long-term forecasting. The model projections extend out to the year 2050, providing a long-term perspective that is crucial for strategic planning.

This model also allows for scenario analysis, examining a variety of potential pathways to reducing GHG emissions. It can evaluate the effectiveness of different strategies, such as increasing energy efficiency, transitioning to renewable energy sources, and changes in the transportation sector. The goal is to identify the most impactful and feasible options for Scottsdale, informing the city's strategy and helping prioritize its actions.

As a forecasting and planning tool, this model serves as an indicator of potential outcomes. It is important to understand that the model's projections are estimations. These are relatively straightforward estimations designed to illustrate trends rather than provide exact predictions. To maintain simplicity and clarity, the model concentrates on the most significant sources of city-wide emissions. Some smaller sources of emissions such as aviation fuels and refrigerants, which collectively represent only a minor portion (2.8%), are not explicitly included in the model.

Given the inherently unpredictable nature of technological advancements, policy changes and a myriad of other factors that influence future conditions, the model's results should be viewed as directional indicators rather than absolute certainties, more offering a compass rather than a map. The future is uncertain, and the model's results need to be interpreted with this in mind.

7.2. Model Method

For this report five distinct scenarios were modeled to highlight different possible futures. The first, "Baseline" simply extends current trends into the future, serving as a control scenario to compare to the others. The subsequent scenarios — "Renewable Energy Development," "Energy Efficiency," and "EV Growth" — each focus on a specific variable corresponding to their respective titles, enhancing it beyond the baseline model to illustrate its potential impact on emissions. The final scenario, or the All-of-the-Above, combines the maximum potential of all variables, highlighting the potential cumulative effect of these factors on emission reduction.

This forecasting model is built on several basic assumptions, then those interact with other variables to generate forecasted activity data, which in turn is utilized to calculate the corresponding emissions.

The emissions are calculated for six different sources into the future, two sources from each Scope 1, Scope 2, and Scope 3 categories.

- Scope 1, or direct emissions, sources calculated are emissions from natural gas and mobile emissions from vehicles with internal combustion engines (ICE). Scope 1 on-road transportation emissions encompass all trips within Scottsdale plus 50% of trips to Scottsdale and 50% of trips from Scottsdale as calculated in the GHG Inventory.
- Scope 2 addresses indirect emissions from purchased electricity, which is divided into APS emissions and SRP emissions. This differentiation considers the different reach and emissions intensity of each utility provider.
- Lastly, the Scope 3 emissions are mobile emissions from internal combustion engines (ICE), comprising 50% of trips to Scottsdale and 50% of trips from Scottsdale as calculated in the GHG inventory. This category also comprises 'Other' emissions which includes solid waste and wastewater.

In the following sections, the details behind each scenario will be examined. For each, a description will be provided, a discussion on the specific variables at play and then the results. Before the scenarios are explored, however, the assumptions and variables which underpin the entire model will be outlined. Following the scenario discussion, there will be a detailed description of the calculation methods, and sources.

7.2.1. Model Assumptions

This model incorporates several foundational assumptions. These assumptions, which are constant across all scenarios, provide the context on which the model is built. Included are expected changes in climate, advances in vehicle technology and predicted changes in the electrical grid.

Cooling Degree Days (CDD): Scottsdale's average annual temperature continues to rise, aligning with the International Energy Agency's projection of cooling degree days (CDD) – the days where air conditioning is necessary – growing by 50% by 2050. The model uses CDD because there is a high correlation between the number of CDD and the total annual electricity consumption within the city.

ICE Efficiency Increase: This assumption relates to the expected efficiency of internal combustion engines from the present day until 2050. According to NREL, the expected increase is 32%-37%. The median of a 34.5% efficiency increases by 2050 is used across all scenarios, forecasted linearly from a baseline of 0% in 2022.

EV Efficiency Increase: As of 2022 the average kWh per mile for EV's is .346. This can be expected to become more efficient as technology improves over time. The best models on the market currently use .238 kWh/mile. This assumption linearly models from a baseline of today's average of .346 kWh/mile to an average in 2050 that matches today's best models at .238 kWh/mile.

Utility Emission Factors: The emission factors used in this model come from each of the utility's sustainability plans. In January 2020, APS set a goal to supply 100% clean, carbon-free electricity to customers by 2050. This goal includes a 2030 milestone of achieving a resource mix that is 65% clean energy, with 45% of the generation portfolio originating from renewable energy. SRP aims to decrease the amount of CO_2 emitted per megawatt-hour (MWh) by 65% from 2005 levels by 2035 and by 90% by 2050.

Population Growth: The initial population in 2022 is set at 238,68 in alignment with the numbers used in Scottsdale's GHG Inventory. To maintain consistency across the modeled scenarios, population growth calculations were used from Scottsdale's General Plan 2035 (pg. 21 & 129) which estimates a population of 316,700 in 2055. For the purposes of this model, the population growth calculated for the scenarios follows a linear trend based on these figures from 2022 to 2050. Although not explicitly applied in the following scenarios, the model is capable of forecasting different population trends (High, Medium, and Low) for the purposes of sensitivity analysis using the Maricopa County projections available from the AZ Commerce Authority.

7.2.2. Model Variables

The model and scenarios are built around three primary variables, each adjustable to simulate various scenarios. These variables interact with the model's assumptions to generate activity data, which in turn is utilized to calculate the corresponding emissions projections. In the model itself there are more adjustment options than recorded in this report, which allows for sensitivity analysis.

Solar Growth: This variable uses permit data from "2022 Scottsdale Solar Trends 12-30-22" Slides 5-7 which was compiled by Anthony Floyd and assumes an 'Average PV Generation" of 16,427 kWh per permit per year. The Baseline scenario uses a linear regression forecasted to 2050 based on the permit data indicating that 32% of households will have solar by 2050. The enhanced, or High scenario, aligns more closely to current trends from both Scottsdale's own permit data and data from APS, which show an almost exponential increase. This adjustment ends up with 57% of households having solar by 2050.

EV Growth: This Variable represents the anticipated growth of electric vehicles in the transportation sector. The growth rates are sourced from NREL's Scenario Calculator for electrification. This calculator offers three rates: Business as Usual (BAU), which is used in this report as the Baseline scenario; Medium, which can be used in the model but is not used in this report; and High, which is used in the Electric Vehicle Growth scenario.

Energy Efficiency Increase: This variable serves as a multiplier, affecting natural gas and electricity use across the board. It signifies an increase in per capita energy efficiency stemming from several factors such as improved building codes, enhanced appliance efficiency, and other technological advancements. It is recorded as a percentage, with the Baseline scenario continuing present day efficiency, and the Energy Efficient Scenario using a 15% increase of this value by 2035.

7.3. Modeled Scenario Results

In the succeeding sections, the details behind each scenario will be examined. For each, a description will be provided, a discussion on the specific variables at play and then the results. In the accompanying charts for each scenario, Scope 1 emissions are blue colors, Scope 2 are green colors and Scope 3 are indicated in orange.

7.3.1 Baseline Scenario

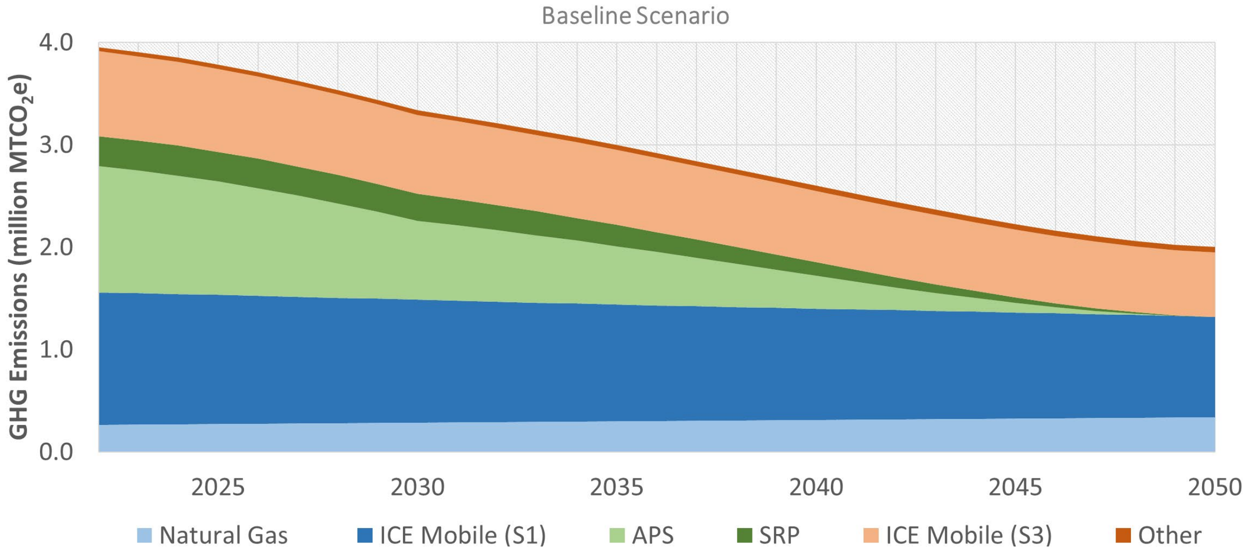

Figure 11. Scottsdale City-Wide Trajectory Under the Baseline Scenario

The Baseline scenario provides a reference point, illustrating an estimated future trajectory if current trends continue without significant interventions and changes (Figure 11). This is essentially assuming 'business as usual' or maintaining the status quo. This scenario serves as a benchmark that all the other scenarios will be compared to, highlighting the impacts of different interventions on emission levels.

In this Baseline scenario, the most conservative estimates for key variables are used. For Renewable Energy development (the variable called Solar Growth in the model), a projection of about 32% of household adoption of renewable energy systems by 2050 is modeled which reflects a natural, gradual increase in solar adoption. The Energy Efficiency variable mirrors its current rate into the future, staying constant without any substantial enhancement. The Electric Vehicle adoption variable uses the National Renewable Energy Laboratory's (NREL) most conservative forecast, which estimates 8% and 11% of the vehicles on the road are electric by 2035 and 2050, respectively.

Taking a look at this status quo scenario, total emissions are estimated to decrease by approximately 50% by the year 2050. This decrease is primarily driven by the projected improvements in the electricity sector as the utility providers increasingly adopt cleaner energy sources. This predicted decrease in utility emissions intensity will be the case throughout each pathway as it is a base assumption and is clearly seen in Figure 11. These emissions will be minimal or nonexistent in 2050 with the current utility pledges. As for other emission sources, a slight rise in natural gas emissions is anticipated due to population growth, while internal combustion engine (ICE) vehicle emissions are expected to decrease slightly in both Scope 1 and 3 due to projected increases in vehicle efficiency.

7.3.2 Renewable Energy Development

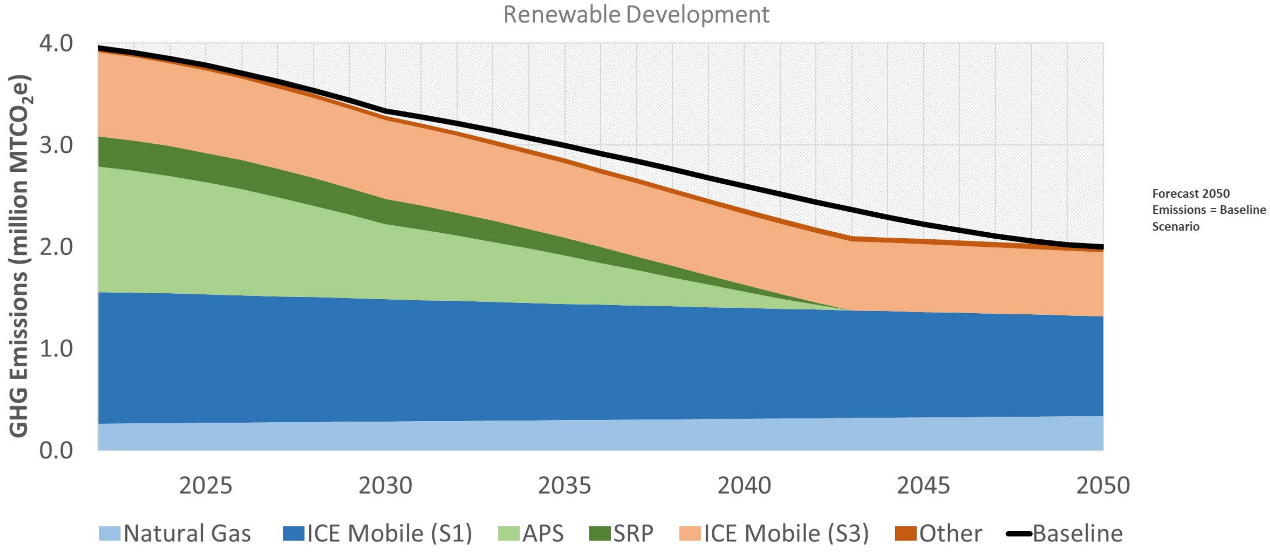

Figure 12. Scottsdale City-Wide Trajectory Under the Renewable Energy Development Scenario

In the Renewable Energy scenario, an increased adoption and installation of community renewable energy sources is considered. The model suggests that with increased uptake of renewable energy systems, emissions from purchased electricity could be substantially reduced years ahead of the Baseline scenario's 2050 estimation and in a way that allow residents and businesses to reduce their energy costs.

This scenario assumes that 57% of households will install solar units by 2050, which is a significant leap from the Baseline scenario's 32%, more than doubling total adoption. The drivers behind this shift could be a blend of utility incentives, federal and local policies and market forces favoring renewable energy sources (i.e., the cost of distributed solar decreases). It should be noted that this increase in adoption does not include potential commercial or municipal solar installations. As a result, greater or a more rapid adaptation of renewable energy could further expedite the attainment of reduced emissions from electricity. Furthermore, significant benefits are associated with renewable energy investments including stable, predictable, low-cost electricity, generation of local jobs, and avoidance of future costs linked to carbon emissions.

The variables for Energy Efficiency and Electric Vehicle adoption remain unchanged from the Baseline scenario. Therefore, emissions stemming from Scope 1 sources (natural gas and ICE vehicles), along with the Scope 3 emissions from ICE vehicles and others are not directly impacted by renewable energy growth and are estimated in this scenario similarly to the Baseline scenario.

By 2050, total emissions in this scenario align with the Baseline scenario's emissions with no difference between the two. The reason for this is because in both scenarios, Scope 2, which is linked to utilities, is reduced to zero. However, with renewable development increases, this reduction is achieved sooner (Figure 12). Despite this expedited reduction, the final emissions outcome is the same as in the baseline scenario, which shows that although renewable development accelerates progress, it does not necessarily change the result on its own. This underscores the importance of using renewable energy development in conjunction with other measures for a more integrated approach to reducing emissions.

7.3.3 Energy Efficiency Scenario

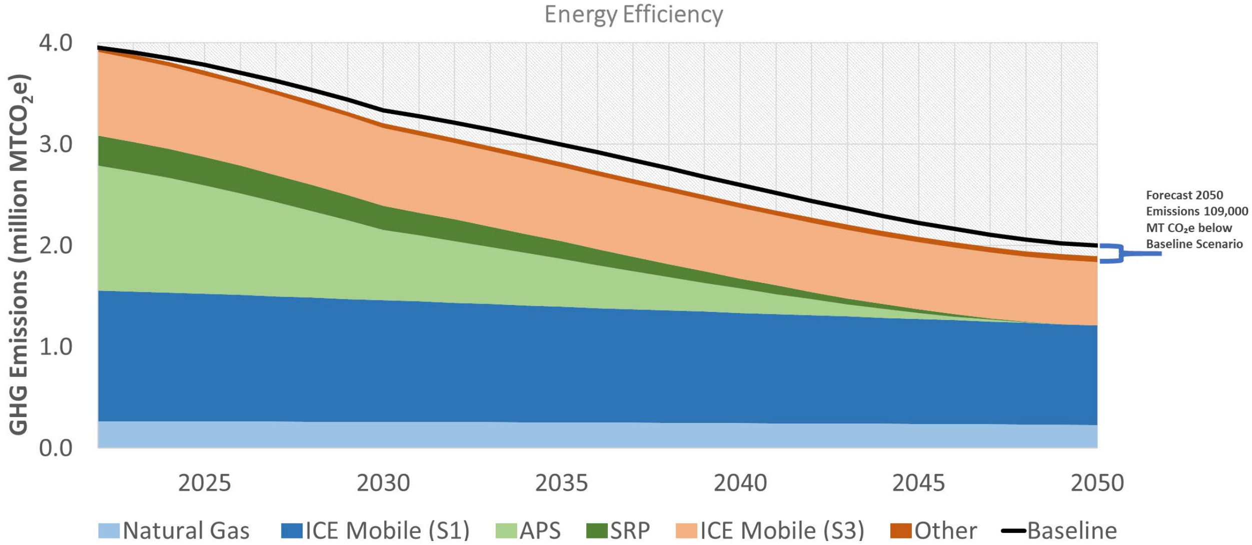

Figure 13. Scottsdale GHG Emissions Trajectory the Energy Efficiency Scenario

In the Energy Efficiency scenario, an enhancement in the efficiency of community energy usage is hypothesized. The scenario estimates a 15% increase in energy efficiency by 2035, with this trend continuing until 2050. This could be achieved through the implementation of stricter building codes, usage of more efficient appliances, improved windows, insulation, and other measures. An increase in energy efficiency reduces the energy required to perform identical tasks, thereby decreasing overall emissions. As has been shown in studies such as the landmark McKinsey & Company study, energy efficiency measures typically offer a high ratio of emission reduction per dollar spent as compared to other reduction methods and a positive return on investment. Moreover, energy efficiency measures lay a solid foundation for a transition of households and businesses to renewable energy by reducing the energy demand for operational needs.

The energy efficiency variable is enhanced in this scenario from a static factor in the Baseline to 15% increase in efficiency by 2035. The Electric Vehicle Adoption and Renewable Energy variables remain consistent at their baseline levels.

The Energy Efficiency scenario results in a modest decrease in total emissions by 2050 of about 109,000 MT of emissions as compared to Baseline, with a notable reduction in natural gas emissions (Figure 13). Most of any decrease in total emissions due to energy efficiency increase is counteracted by the increase in Mobile emissions. It is worth highlighting that energy efficiency is the only variable in this model which results in decreased natural gas emission by 2050. This suggests that while energy efficiency improvements alone may not drastically reduce emissions, they can play a significant role when combined with other strategies. Given their economic viability and significant returns, energy efficiency improvements can be a useful part of a broader emissions reduction strategy.

7.3.4 Electric Vehicle Adoption Scenario

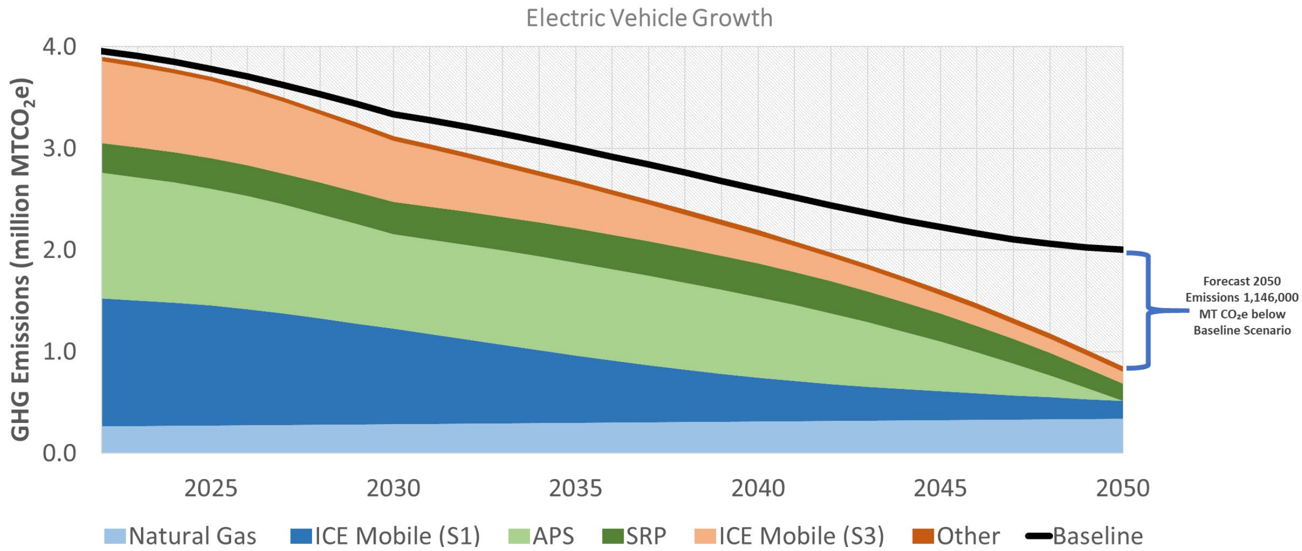

Figure 14. Scottsdale GHG Emissions Trajectory Under the Electric Vehicle Adoption Scenario

The EV Growth scenario investigates the impact of amplified adoption of electric vehicles (EVs). With their zero tailpipe emissions, EVs can play a pivotal role in reducing greenhouse gas emissions. This transition also has additional community and individual benefits. For one, the shift to EVs promises lower operational and maintenance costs due to few moving parts and no oil changes. Furthermore, the efficiency of electric drivetrains significantly surpasses that of internal combustion engines, leading to reduced energy consumption per mile traveled, leading to further cost savings. On top of the economic benefits, increased EV adoption will contribute to improved air quality due to the reduction of pollutants which contribute to smog and poor air quality.

The EV adoption variable here is enhanced according to NREL's high projection, which estimates the 39% and 85% of vehicles on the road will be electric by 2035 and 2050, respectively. This is a dramatic increase in EV usage as compared to the Baseline scenario. In this scenario, the Energy Efficiency and Renewable Energy variables remain at their Baseline levels.

The results of this scenario suggest a significant reduction in emissions from 2022 levels with nearly a one-third decrease by 2035 and a three-quarters decrease by 2050 (Figure 14). This level of reduction results in less than half of the Baseline emissions by 2050. It is important to note that this shift towards EVs would initially increase electricity consumption. However, as the electricity supply becomes cleaner over time, emissions from this increased electricity usage would also decline. Thus, while the transition to EVs may initially require more electricity, the net effect, particularly when paired with renewable energy sources, can lead to substantial emissions reductions.

7.3.5 The All-of-the-Above Scenario

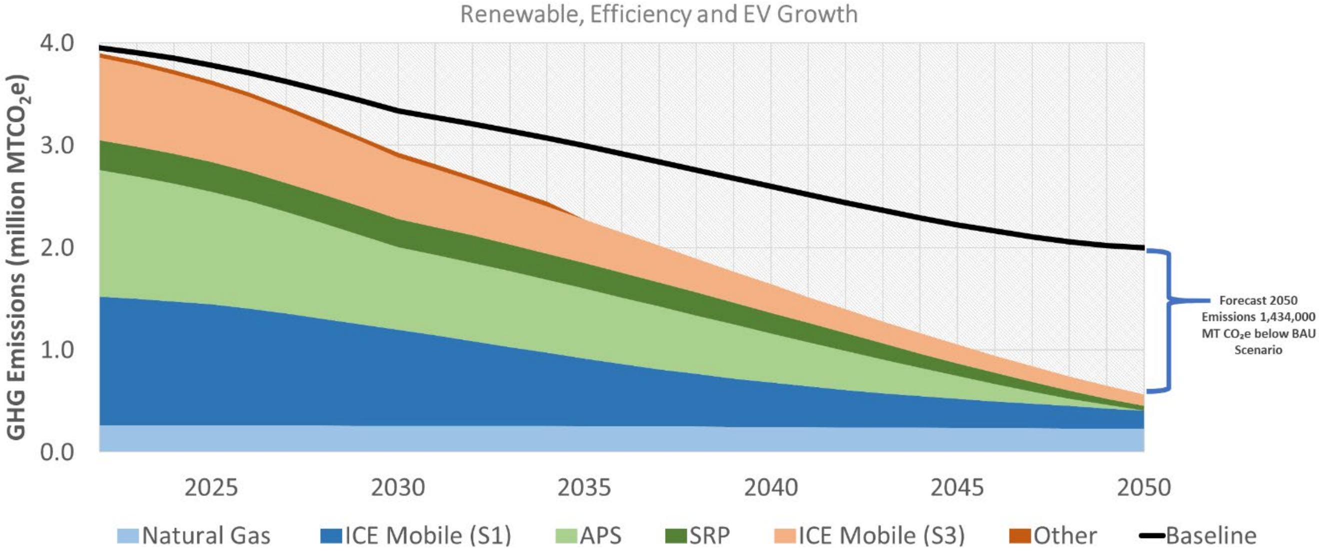

Figure 15. Scottsdale GHG Emissions Trajectory Under the All of the Above Scenario.

The All-of-the-Above Scenario represents a comprehensive approach to emission reduction, where all the identified strategies are used together. This scenario not only aims to reduce emissions but also promotes sustainable growth by harnessing the additional economic and other benefits that these strategies provide. Implementing renewable energy, energy efficiency measures, and electric vehicle adoption together can lead to job creation, improved air quality, and a stable, low-cost electricity supply. These benefits extend beyond environmental protection, generating savings for consumers, businesses, and the city, all while contributing to a cleaner, healthier, and more economically prosperous future.

In this scenario, all the key variables - Energy Efficiency, Renewable Energy Development, and Electric Vehicle adoption – are enhanced beyond their baseline levels. This scenario shows the potential of combined action, where each variable is maximized, working in synergy to drive down emissions.

This combined approach's results are striking. By 2050, emissions could be entirely minimized, reaching levels 85% below those of 2022 and about three-quarters of the projected Baseline emissions for 2050 (Figure 15). The primary sources of remaining emissions are expected to be natural gas usage and vehicles that have not transitioned to electric. These findings display the importance of a comprehensive approach in emission reduction measures. While each strategy contributes to emission reduction on its own, their combined impact as shown in this scenario shows the potential for substantial reductions.

7.4. Model Calculation Description

The activity data in the model is calculated by starting with 2022 numbers from the GHG inventory, combined with the assumptions and variables to create the modeled data through 2050. The descriptions here use the table column names in the Microsoft Excel model.

Scope 1: Natural Gas & Mobile Emissions

- For stationary sources, natural gas consumption is primarily influenced by population growth. As the population increases, the model assumes a parallel rise in natural gas usage. Additionally, the model's Energy Efficiency Multiplier, which accounts for advancements in energy-saving technologies and practices, also affects this calculation.

- In the mobile sector, the total miles driven are derived from the community's Vehicle Miles Traveled (VMT) data, which is expected to grow in proportion to the population. This total mileage is then divided into Electric Miles and Non-Electric Miles. Electric Miles represents the portion of the total miles driven by EVs. This is calculated by multiplying the total miles by the percentage of EVs on the road, reflecting the growth of EV adoption. The remaining Non-Electric Miles are simply the Total Miles minus the Electric Miles.
- In addition, the model also calculates the electricity consumption for EV charging within the city boundaries, termed as 'Mobile MWH'. This is based on an average kWh/mile rate determined annually, in accordance with the EV efficiency rate described in the assumptions. The primary influencing factor for this calculation is the growth rate of EV adoption.

Scope 2: Utility Emissions

- The Total Electricity Purchased is calculated from two sources: APS usage and SRP usage. APS Total and SRP Total represents the electricity purchased from APS and SRP, respectively. In the model, both figures increase in line with population growth with added Mobile MWh, and are adjusted downwards by the calculated solar generation, and, if applicable, the Energy Efficiency Multiplier used.
- The total amount of renewable electricity generated in Scottsdale, labeled as Total Renewable, is derived from the Total to Date (TTD) Permits, with each permit assumed to generate 16,427 kWh of power per year as stated in the assumptions. The Total Usage of electricity is then calculated as the sum of the Total Purchased electricity and Solar Generation. The influencing variables across these calculations include Population Growth, Energy Efficiency Multiplier, and Solar Growth.

Scope 3: Mobile & Other Emissions

- In Scope 3, the calculation for mobile miles is like that in Scope 1. The total miles driven are derived from the community's scope 3 Vehicle Miles Traveled (VMT) data, expected to increase in line with population growth. This total is then split into Electric Miles and Internal Combustion Engine (ICE) Miles. The Electric Miles, influenced by the rate of EV adoption, are subtracted from the total miles to ascertain the number of miles driven by ICE vehicles.
- The other section of the model covers waste, both solid and water. These are assumed to grow with population growth.

7.5. Model Data Sources

Table 25. Future Energy Pathways Model Variables

Model Variable	Source
Population	Scottsdale GHG Inventory 'GPC Summary Table'
Population Growth Projections	AZ Commerce Authority Population Projections for Maricopa County, Scottsdale General Plan pp. 21 & 129
Utility Emission Factors	APS & SRP Stated Goals
Cooling Degree Days (CDD)	International Energy Agency's projection
Solar Permits / Avg PV Use	"2022 Scottsdale Solar Trends 12-30-22" Slides 5-7 SUSTAINABILITY: ECOLOGY AND THE BUILT ENVIRONMENT (scottsdaleaz.gov)
EV Growth	NREL Scenario Calculator
ICE Efficiency	Decarbonizing Medium- & Heavy-Duty On-Road Vehicles: Zero-Emission Vehicles Cost Analysis
EV Efficiency	https://ecocostsavings.com/average-electric-car-kwh-per-mile/, https://ecocostsavings.com/electric-car-kwh-per-mile-list/
McKinsey Energy Efficiency	McKinsey & Company. (2009). Unlocking energy efficiency in the U.S. economy. McKinsey & Company. https://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/sustainability/pdfs/a_compelling_global_resource.ashx

8. Appendix A: Greenhouse Gas Protocol for Cities BASIC/BASIC+ Reporting

The GPC outlines two levels of reporting for city-wide inventories: BASIC and BASIC+. Both of these reporting levels are recognized and accepted by relevant entities such as the Carbon Disclosure Project (CDP), C4O Cities, and Global Covenant of Mayors (GCoM). The distinction between BASIC and BASIC+ reporting lies in the depth of information required to fulfill reporting obligations.

A BASIC community-level GHG emissions inventory serves as a fundamental representation of a city's GHG emitting activities – Stationary Energy, Transportation, and Waste sector activities– as these three core activities are present in almost all cities. BASIC-level GHG inventory reporting proves particularly suitable for initial city inventories due to its clear and straightforward data requirements and provides comparability between cities.

Building upon the BASIC reporting framework, BASIC+ reporting requires the incorporation of additional Scope 3 GHG emissions and two additional sectors: Industrial Processes and Product Use (IPPU) and Agriculture, Forestry, and Other Land Use (AFOLU). The data prerequisites for these sectors are notably more intricate and demanding and may not always be applicable to every city. IPPU and AFLOU activity data might be sensitive or confidential, posing challenges for GHG emissions reporting process. The City of Scottsdale's city-wide GHG emissions inventory adheres to the BASIC reporting level due to the challenges of inventorying all activities required for BASIC+ reporting.

To meet BASIC+ criteria, a comprehensive inventory of GHG emissions within the AFOLU and IPPU sectors would be necessary. However, including these sectors would demand substantial data collection and modeling efforts, as much of this data is not publicly available. For instance, IPPU emissions entail GHG emissions from chemical processes within city facilities (e.g., N_2O administration at hospitals and dental offices), city-wide refrigerant usage, and emissions from certain foams and aerosols in consumer goods. Meanwhile, the AFOLU sector encompasses CO_2 sequestration and emissions due to land use changes in addition to CH_4 and N_2O emissions from agricultural operations within the city. Notably, for the City of Scottsdale inventorying the AFOLU sector would require a tabulation of GHG emissions resulting from the numerous equestrian activities that occur throughout the city in addition to GHG emissions from turf management practices at the city's parks and golf courses.

The most comprehensive type of city-wide GHG emissions reporting is called 'territorial' emissions. Territorial emissions encompass BASIC/BASIC+ GHG emissions and include GHG emissions from grid-supplied energy generated within Scottsdale and waste generated outside of Scottsdale but disposed of within Scottsdale. As there is significant distributed generation of electricity via solar across Scottsdale, territorial GHG emissions from energy generation are zero. As a territorial GHG emissions inventory includes specific types of emitting activities, they may not occur for every city, as is the for Scottsdale.

GHG emissions required for BASIC+ reporting that were readily calculated from BASIC-level data collection are reported in Table A-1. It should be noted that there is a large difference between Scottsdale's BASIC and BASIC+ estimated GHG totals due to Scope 3 on-road transportation emissions. Scope 3 on-road transportation emissions are the estimated GHG emissions that occur outside of Scottsdale's boundary during a transboundary journey and, consequently, are another city's Scope 1 on-road transportation emissions. In other words, these Scottsdale's Scope 3 on-road transportation emissions are, for example, Scope 1 on-road transportation emissions for Phoenix, Tempe, or Mesa. Therefore, these GHG emissions are not reported in Scottsdale's total GHG emissions because they should be reported by other cities and cause the double counting of GHG emissions across the Phoenix metropolitan area.

Table A-1. Scottsdale city-wide GHG emissions by Scope and Sector for 2022

Sector		Total by Scope (MT CO_2e)			Total (MT CO_2e)	
		Scope 1	Scope 2	Scope 3	BASIC	BASIC+
Stationary Energy	Energy Use	264,403	1,507,519	57,434	1,771,922	1,829,356
	Energy Generation	NO				
Transportation		1,259,561	IE	1,146,827	1,259,561	2,406,388
Waste	Generated in the city	NO		42,286	42,286	42,286
	Generated outside the city	NO				
Industrial Processes and Product Use		5,156			NE	5,156
Agriculture, Forestry, and Other Land Use		NE			NE	NE
Total		**1,529,120**	**1,507,519**	**1,246,547**	**3,073,768**	**4,283,186**

IE – Included Elsewhere, NO – Not Occurring, NE – Not Estimated

Emissions Required for BASIC/BASIC+ Reporting Level: BASIC | BASIC+ | Territorial

9. Appendix B: Future Directions

The 2022 City of Scottsdale GHG inventories are an initial effort to tabulate the city's GHG emissions. As such, during the data collection and GHG emissions calculations process, areas were identified that could expanded for future inventories.

Future directions for the City of Scottsdale GHG inventory include:

- The City of Scottsdale should pursue a full accounting of electric vehicle (EV) electricity consumption. EV electricity consumption data were not available for this inventory cycle. Future inventories must account EV electricity consumption EV's will comprise a larger percentage of on-road vehicle. If EV electricity consumption data are not available, the city of Scottsdale should work with APS and SRP, and other stakeholders, to be develop approaches to estimate EV electricity consumption.
- Additionally, within the Transportation sector the City of Scottsdale could pursue a full Scope 3 GHG emissions accounting travel related to its resident and visitor population.
- The City of Scottsdale is known for equine recreation and does have agricultural farms located within its boundaries. A future GHG inventory should include GHG emissions from the Agriculture, Forestry, and Land Use (AFOLU) sector. Including AFOLU GHG emissions will enable the City of Scottsdale to reach the BASIC+ level of GHG emissions reporting.
- Scottsdale should pursue a full accounting of Scope 3 GHG emissions associated with its water system, including the energy associated with its share of both the Central Arizona Project (CAP) and Salt River Project (SRP). The City of Scottsdale receives a sizeable fraction of its water resources portfolio from the Central Arizona Project, which pumps Colorado River water from Lake Havasu to Scottsdale water treatment facilities. The CAP is the largest single electricity consumer in the State of Arizona.
- The initial Scottsdale GHG emissions inventory only captures municipal solid waste (MSW) picked up and hauled by city operations. Future GHG emissions inventories should include data from all MSW haulers.
- Similarly, refrigerant recharge emissions, which are part of the Industrial Processes and Product Use (IPPU) GHG emissions sector, should be expanded to encompass the whole city. Currently, refrigerant recharge emissions capture only city operations. The City of Scottsdale could collaborate with Maricopa County to understand and estimate IPPU GHG emissions within Scottsdale's boundary.
- Additionally, future GHG inventory efforts could consider the tabulation of a consumption-based GHG emissions inventory. Consumption-based inventories tabulate GHG emissions from the consumption of goods and services within a city utilizing methods derived from economic input-output modeling. The State of Oregon; King County, Washington; City of Seattle, WA; and New York City, NY have previously published consumption-based GHG emissions inventories.