Tucson Water
One Water 2100 Master Plan

Technical Memorandum
GREENHOUSE GAS INVENTORY

FINAL | SEPTEMBER 2021

TUCSON WATER
A proud part of the City of Tucson

One Water 2100 Master Plan

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1 Introduction

1.1 Purpose of Memo

This Greenhouse Gas (GHG) Inventory Technical Memo provides an inventory of Tucson Water (TW) GHG emissions for 2018, an overview of previous GHG inventories, and a trend analysis comparing the GHG inventories for TW from prior years to 2018. The Inventory Management Plan (IMP) includes a summary of data sources, emission factors, and detailed assumptions. These efforts play a crucial role in the upcoming City of Tucson (City) Climate Action and Adaptation Plan by establishing a more detailed GHG emission benchmark for TW to use to guide its efforts to support the City's goal of becoming carbon neutral by the year 2030 (City of Tucson 2020, Resolution No. 23222).

This is the first inventory to fully disaggregate accounting of TW GHG emissions by scope as defined by the World Resource Institute (WRI) in their GHG protocol (WRI 2004, 2011). The WRI definitions and methods are referenced as the basis for the ICLEI (International Council for Local Environmental Initiatives) Government Operations Protocol for GHG Accounting (ICLEI 2010). ICLEI is known by their acronym and is a global organization active in over 100 countries and working with more than 2500 local and regional governments. The ICLEI Protocol utilizes the WRI Protocol as a foundation and constructs a tailored methodology for use by local governments. This ICLEI Protocol is the international best practice in GHG emissions quantification for cities and was applied by HDR to perform this TW GHG inventory for 2018. Prior City GHG inventories were conducted by the Pima County Association of Governments (PAG) using ICLEI methods and provided limited reporting of TW's emissions by category or scope.

This GHG inventory will establish a baseline for TW's plan to contribute future utility emissions reductions to meet the City's carbon neutral goals. An additional purpose of this GHG inventory is to begin to develop the capacity to report GHG emissions as a City, annually.

The 2018 GHG inventory was developed in collaboration with TW representatives, with technical assistance provided by HDR. The IMP is included (Appendix A) to provide a framework for future TW GHG inventories.

1.2 Background on Tucson Water Supply

TW has delivered water to city of Tucson residents as a municipally owned and operated water utility since 1901. Until 1992, groundwater was the primary source of potable water supplied to customers. In 1992 TW initiated receipt of water diverted from the Colorado River via the Central Arizona Project (CAP). In 2001, rather than delivering CAP water direct to customer taps, the utility began to use CAP water to recharge the regional groundwater table via the Southern and Central Avra Valley Storage and Recovery Projects (named the Clearwater Program). The majority of potable water delivered to customers is now Colorado River water delivered via the CAP, as shown below in Figure 1-1 (TW 2004, 2008, 2012).

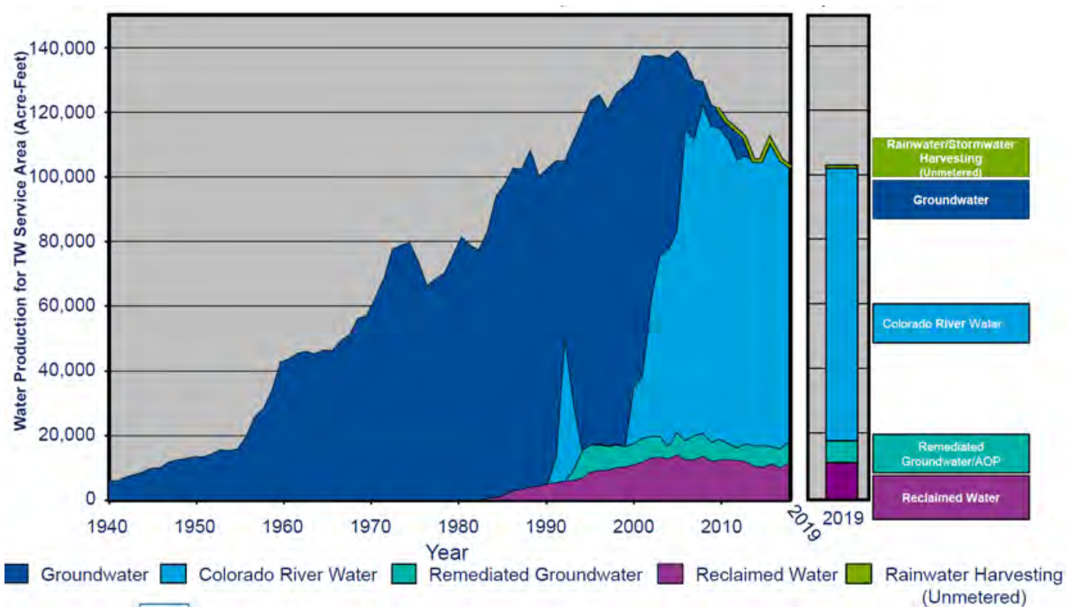

Figure 1-1. Tucson Water Production History for 1940–2019 (Source: TW 2021).

TW began receiving a partial allotment of water from CAP in 1992. Initially the CAP water was treated and then added to the distribution system, but that created issues in the service lines. Tucson Water began their recharge and recovery process in the early 2000s to avoid this problem. As the volume of recovered CAP water increased, energy use increased to move that water. The transition to CAP water as the primary potable water source in the service areas enables TW to keep as much water in the ground as possible to recharge the regional groundwater table.

TW also recycles non-potable water from reclaimed sources to use for irrigation, dust control, firefighting, industrial uses, and supporting wildlife habitat. When demand for reclaimed water is low, this water is recharged at the Sweetwater Recharge Facility, the Santa Cruz River Heritage Project, and the South Houghton Area Recharge Project.

2 2018 GHG Inventory

The 2018 (calendar year) TW GHG inventory estimates emissions using the *Local Government Operations Protocol for the Quantification and Reporting of Greenhouse Gas Emissions Inventories* (ICLEI 2010), which is based upon definitions and methods in the WRI GHG Gas Protocol. This ICELI Protocol is an accepted international standard used to quantify and report GHG emissions from local governments. This inventory will enable TW to contribute their 2018 emissions to a City GHG inventory conducted in accordance with these internationally recognized GHG accounting and reporting principles.

In summarizing these emissions, efforts were taken to apply the WRI-defined principles of GHG accounting (2004), relevance, completeness, consistency, transparency, and accuracy. Emissions sources are described below, and in more detail in the IMP provided in Appendix A.

2.1 2018 TW Emissions by Scope

Calendar Year (CY) 2018 TW emissions of GHGs by source are provided in Figure 2-2. Table 2-1 categorizes source emissions by scope. For the definition of Scopes, the ICLEI protocol refers to the WRI *Greenhouse Gas Protocol Corporate Accounting and Reporting Standard* (2004). Identifying emissions by scope helps organizations understand which emissions they have the most control over to reduce.

Categorizing GHG emissions by scope provides detail on which emissions are direct emissions from the utility (Scope 1) or indirect emissions associated with utility operations but not under operational control of TW (Scope 2 and 3). A visualization of emissions scopes is provided below in Figure 2-1. TW emits Scope 1 emissions from their own activities, such as operation of utility-owned equipment, while Scope 2 and 3, indirect emissions, are either the emissions associated with TW purchased electricity (Scope 2), or other emissions from activities of external organizations such as energy used to deliver Colorado River water through the CAP system (Scope 3). Quantifying Scope 1 and 2 emissions helps TW understand what emissions they have control over to meet their emissions reduction goals.

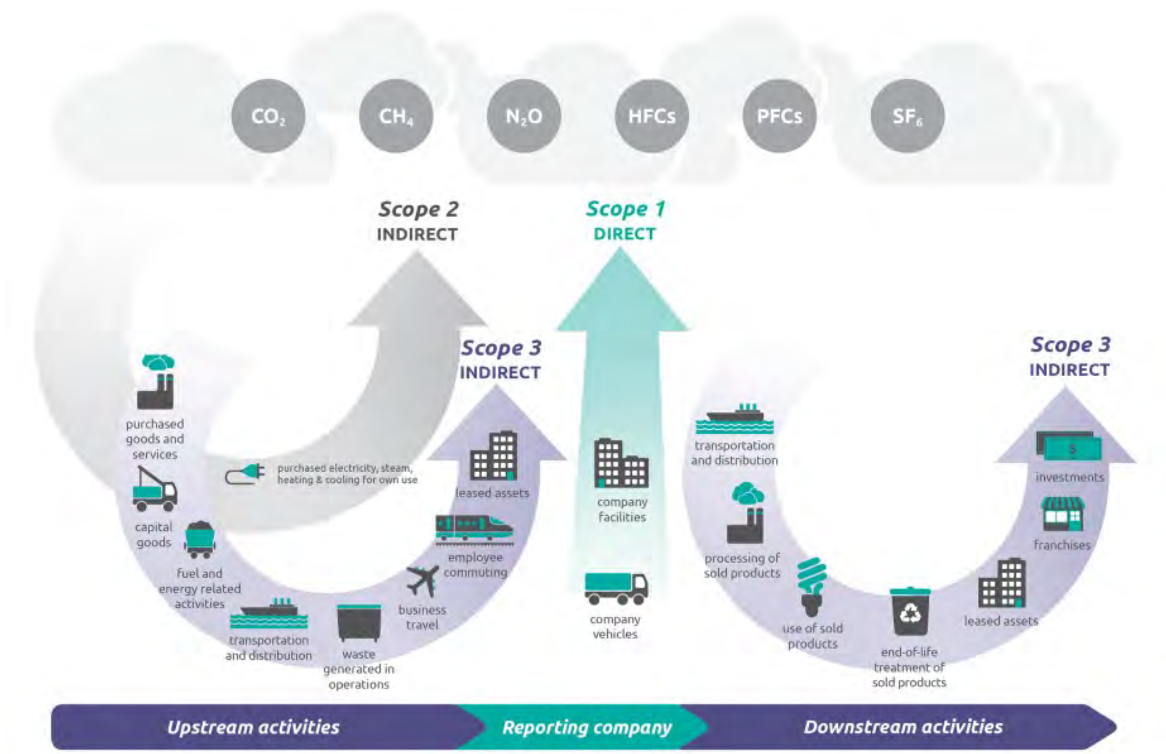

Figure 2-1. Scopes of GHG Emissions as Defined in the WRI/WBCSD Corporate Value Chain (Scope 3) Accounting and Reporting Standard (Source: WRI 2011)

While ICLEI encourages local governments to identify and measure Scope 3 sources to the extent possible, many of these emissions categories are optional, and only employee commute emissions are required following the ICLEI Reporting Standard (the ICLEI protocol details how local governments can report their emissions in Part IV and Appendix C of the protocol). Given the limited requirements to Scope 3 reporting, local governments are encouraged to focus on Scope 3 emissions that are relevant to their GHG programs and goals. Further details on scopes, emissions sources, and categories detailed in Table 2-1 are provided in the IMP (Appendix A).

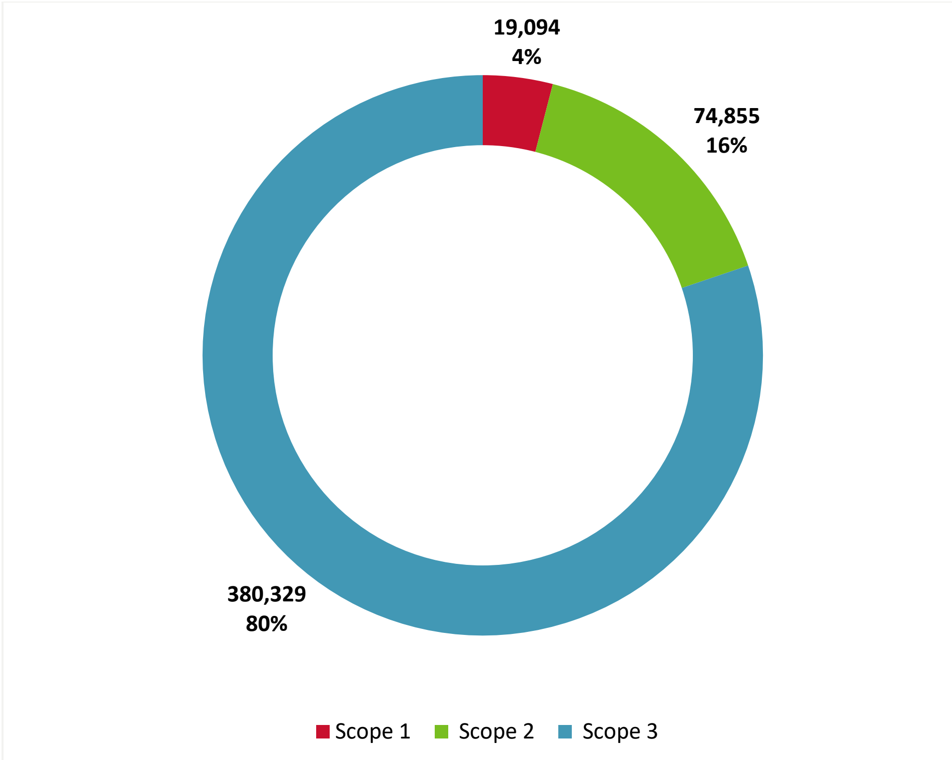

Figure 2-2. TW Emissions by Scope (MT CO_2e), 2018.

Emissions sources for each of the scopes are visualized in Figure 2-3 and quantified in Table 2-1. The following emissions sources were identified for this inventory:

Natural Gas (Scope 1)

- Emissions from natural gas provided by Southwest Gas (SWG) that is used by pumps, furnaces at TW offices, and equipment to extract, convey, treat, and deliver potable or reclaimed water.

Vehicle Fleet (Scope 1)

- Emissions from fuel used in TW-owned on-road and off-road vehicles and equipment.

Refrigerants (Scope 1)

- Emissions from replaced refrigerants that leaked from TW equipment (replaced fleet refrigerants not included).

TW Grid Supplied Electricity (Scope 2)

- Although TW uses some self-generated renewable (solar) electricity (0.5 percent of total electricity use) and purchases hydropower from Hoover Dam through the Arizona Power Authority (APA) (1.5 percent of total electricity use), the majority of the electricity used to deliver water is provided by Tucson Electric Power (TEP) and Trico Electric Cooperative (Trico), which comes from diversified non-renewable and renewable generation sources. In addition to this, a limited amount of hydroelectric power each year is provided to TW by the Bureau of Indian Affairs – San Carlos Irrigation Project to serve a remote site with a metered well and booster pump. Note the WAPA Hoover Dam power is delivered on Trico infrastructure and is accounted for as carbon-free in the emissions figure below (Figure 2-3).

CAP Grid Supplied Electricity (Scope 3)

- CAP operates a series of pump stations that deliver the City of Tucson allotment of Colorado River water to TW; although CAP owns and operates the pump stations that deliver the allotment, the utility tracks the emissions from electricity use associated with their operation.

Transmission and Distribution Loss (Scope 3)

- Emissions from the grid losses of TW purchased power.

TW Waste (Scope 3)

- Emissions associated with the generation of TW waste and recycling.

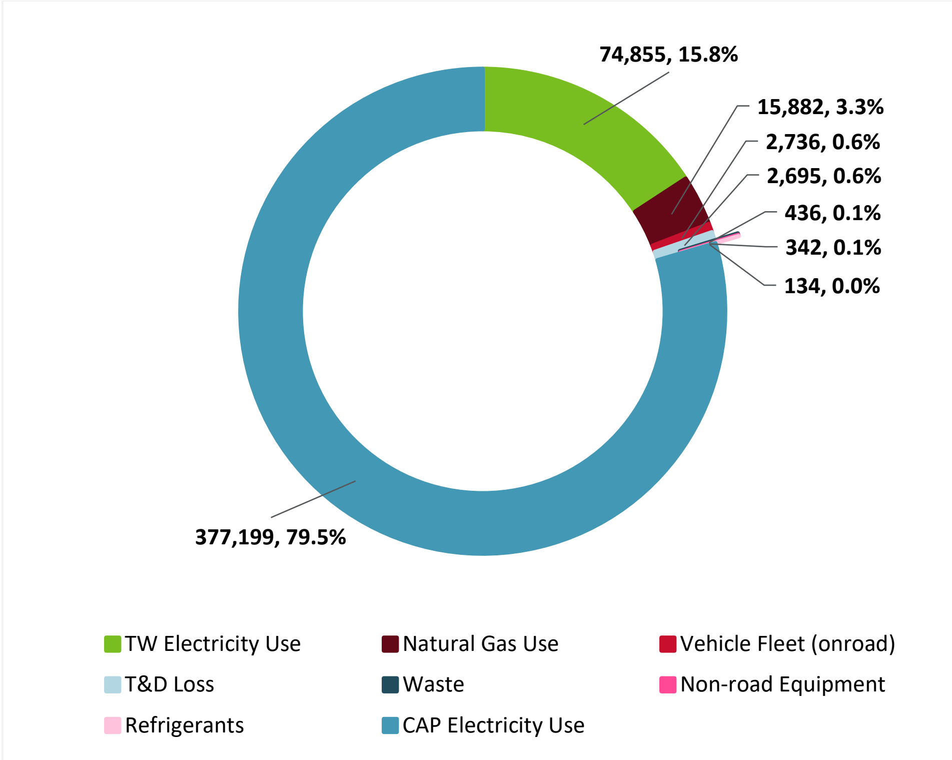

Figure 2-3. TW Emissions by Source (MT CO_2e), 2018.

Two emissions sources outside of the boundary of previous inventories completed by PAG for TW, fugitive emissions from refrigerants and transmission/distribution losses associated with TW consumed electricity, are also identified in Figure 2-3.

Table 2-1. 2018 TW GHG Emissions by Source and Scope.

Emissions Source	ICLEI Emissions Category	2018 Emissions (MT CO_2e)
Scope 1		
Natural Gas Use	Stationary Combustion	15,882
Vehicle Fleet (on-road)	Mobile Combustion	2,736
Vehicle Fleet (off-road)	Mobile Combustion	342
Refrigerants	Fugitive Emissions	139
Total Scope 1 Emissions		**19,100**
Scope 2		
TW Electricity Use	Purchased Electricity	74,855
Total Scope 2 Emissions		**74,855**

Emissions Source	ICLEI Emissions Category	2018 Emissions ($MT\ CO_2e$)
Scope 3[a]		
CAP Electricity Use to Transport Water to TW	Upstream Transportation of Materials and Fuels	377,199
Transmission and Distribution Losses from Consumed Electricity (AZ)	Transmission and Distribution Losses from Consumed Electricity	2,695
TW Waste	Waste Related Scope 3	436
Total Scope 3 Emissions		**380,329**
Subtotal		**474,278**

a) Employee commute is a recommended category of Scope 3 GHG emissions to include per the ICLEI (2010) protocol. TW employee commute data could not be disaggregated from the City commute survey, so it is not reported.

As shown above in Figure 2-3, the majority (80 percent) of TW 2018 emissions are Scope 3 emissions from the upstream electricity use associated with CAP (TW's water supply), while the remaining 20 percent are emissions from electricity and natural gas use, refrigerants, and the vehicle fleet.

2.2 Comparative Review of Select Capital Goods (Scope 3)

TW requested a comparative review of the relative climate impacts of select purchased capital goods within the TW supply chain. Chemicals and pipes, two major types of capital goods important to operation of a water supply agency, were the focus of this analysis. This comparative review is intended to help inform TW of the implications of their existing choices of materials purchases and could inform future purchasing decisions.

Given this review is comparative by material type, the GHG emissions associated with the 2018 purchase of pipes and chemicals were not calculated for the 2018 inventory. In a typical inventory, the GHG associated with capital goods would be based on the dollar spend annually for each category and calculated using WRI methods with relevant industry average GHG emission factors (i.e. emissions per dollar spent). WRI's recommended standard method is to use an Extended Input-Output (EEIO) model.

Life Cycle Assessment for Purchased and Capital Goods

This analysis relies upon a different calculational approach than is used in standard practice for a GHG inventory. For this comparison, Life Cycle Analysis (LCA) was used. LCA is an ISO 14040 normalized method for the assessment of products and systems from cradle-to-grave, which begins with raw materials extracted from the earth, and continues with product development, manufacturing, and disposal. LCA allows comparison between different materials or processes providing the same service or function.

The resulting metric is intended for use to understand the relative merits of alternative material types for pipes and for chemicals purchased by TW. This comparison is to represent the GHG or climate impact (using either embedded energy or embedded carbon) of alternative materials. As expected, embodied carbon can vary widely by electricity and fuel used during the life cycle. The embodied energy represents the energy consumed regardless of the source or carbon content. LCA includes:

- Cradle-to-Gate: Raw material production and transportation; pipe or chemical production
- Pipe or chemical transportation and installation
- Pipe or chemical use phase (including maintenance, repair and replacement)
- Pipe or chemical end-of-life phase
- Cradle-to-Grave in an LCA includes all of the above

HDR prepared a relative comparison of the life cycle attributes representing GHG as associated with each of chemicals and types of pipes based upon CY 2018 data for TW purchases. Data collected by TW for water supply pipe (by type, diameter size and total linear feet) and chemicals purchases for CY 2018 are summarized in the IMP in Appendix A, Section 7.4. The predominant types of pipe purchased by TW in 2018 are first, polyvinyl chloride (PVC), and second, ductile iron (DI). Lesser amounts of pipe types purchased were cement, high-density polyethylene (HDPE), copper, and steel. Water treatment chemicals purchased by TW in 2018 included ammonia, chlorine, hydrogen peroxide, sodium bisulfate and sulfuric acid. After 2018, chlorine is no longer purchased, and sodium hypochlorite is used instead.

Pipes

Based upon the review of available analyses of alternative pipe materials, credible results based upon standard LCA methods (WRI and ISO standards for products) were limited but available in one peer-reviewed report (Sustainable Solutions Corp. (SSC) 2017). These SSC results cover three of TW's pipe materials (HDPE, PVC and DI) and indicate that over the life cycle, cradle-to-grave (100-yr life cycle), PVC pipe material for 8-inch pipes (for DR18) have the lowest embodied energy followed by DI and HDPE. Over the life cycle PVC pipe material for 8-inch pipes (for DR25) have the lowest embodied energy followed by HDPE and DI. For 24-inch pipe material, the cradle-to-grave rank order of the embodied energy starting with the lowest, were prestressed concrete cylinder pipe (PCCP), PVC, DI, and HDPE. The results above include replacement of HDPE, DI and PCCP pressure pipes during the 100-year system design life. Even without replacement, these pipe materials still have greater total embodied energy over 100 years than PVC pipe.

Water Treatment Chemicals

Of the five chemicals TW continues to purchase on an annual basis, the largest quantities in rank order are sodium hypochlorite, sulfuric acid, hydrogen peroxide, ammonia, and sodium bisulfate.

There are LCA data gaps for the water industry in several processes, equipment, and chemicals commonly used in water treatment that are not specifically included in existing LCA databases (WEF 2013). Unfortunately, these data gaps for production of specific bulk chemicals have not recently been addressed.

An LCA (Cradle-to-Gate) for eleven typical water treatment chemicals was completed by WEF and indicating Global Warming Factors in grams CO_2 eq / kg. Of those chemicals, sodium hypochlorite and sulfuric acid were purchased by TW and are shown in italics in the table below. Based on an analysis using the WESTweb tool, a factor for chlorine was identified and is included below (WESTweb 2018). Thus, climate LCA factors are available for only these two of the five water treatment chemicals purchased by TW going forward beyond 2018.

With the available data, below in rank order, is a numerical comparison of the relative LCA carbon intensity of alternative types of water treatment chemicals. Sodium hypochlorite is about ½ as carbon intense as chlorine; so its use in replacement of chlorine post CY 2018 yields a GHG reduction. Chlorine's Global Warming Factor is significantly higher than sodium hypochlorite and sulfuric acid. However, a comparison to other TW chemical purchases of hydrogen peroxide, ammonia and sodium bisulfate is not possible without additional LCA factors.

Table 2-2. Comparison of Global Warming Factors for Water Treatment Chemicals

Water Treatment Chemical	Global Warming Factor ($g\ CO_2eq$ / kg)
Ammonium sulfate	2,370
Chlorine (from WESTweb)*	1,357
Phosphoric acid, 85% in H_2O	1,210
Hydrochloric acid	1,170
Sodium hydroxide, 50% in H_2O	*1,010*
Quicklime, milled, packed	982
Sodium hypochlorite, 15% in H_2O	763
Hydrochloric acid, 30% in H_2O	735
Iron (III) chloride, 40% in H_2O	617
Aluminum sulfate, powder (Alum)	458
Sulfuric acid, liquid	86

* Listed for comparison
Source: WEF 2013. WESTweb 2018.

3 Prior PAG Inventory Reports and Data

3.1 Review of PAG 1990–2017 Emissions Sources and Inventory Boundaries

Prior to this 2018 inventory, PAG completed three regional GHG inventories that included the emissions from TW as a component of a larger regional GHG inventory. These inventories estimated emissions using the *Local Government Operations Protocol for the Quantification and Reporting of Greenhouse Gas Emissions Inventories* (ICLEI 2010), which is the same protocol used to estimate 2018 emissions above. As the process was being refined by PAG, different reporting strategies and emissions factors with regards to TW emissions were used in these inventories, which affected comparability year over year when reviewing TW total emissions. These differences are summarized in Table 3-1.

Table 3-1. Inventory Years, Publication Dates of PAG Inventories, and differences.

PAG Inventory Publication Date	Regional GHG Inventory Years	PAG GHG Inventory Differences
October 2014	1990-2012	• Used separate emissions factors for TEP and Trico Electricity. • CAP emissions *not* reported in TW total emissions. • Potable and reclaimed water emissions reported *separate (and by utility)*.
February 2017	2012-2014	• Assumed Trico emissions factor is the *same* as TEP. • CAP emissions *are* reported in TW total emissions. • Potable and reclaimed water emissions reported *separate.*
June 2019	2012-2017	• Assumed Trico emissions factor is the *same* as TEP. • CAP emissions *are* reported in TW total emissions. • Potable and reclaimed water emissions reported *together (as shown in* Table 2-1*).*

Source: PAG 2014, 2017, 2019.

Each of PAG's regional GHG inventories were aggregated from three subsets, one each for the Tucson Community (City Community), Pima County Government Operations (County Government), and the City of Tucson Operations (City Government). The City Government subset inventory included emissions associated with the operation of TW.

3.2 Review of PAG Tucson Water GHG Inventories 1990–2017

The result of the three regional inventories that estimated TW GHG emissions to date are summarized in Table 3-2. GHG emissions are summarized by HDR in the format reported in the most recent inventory (PAG 2019).

Table 3-2. PAG Estimated TW GHG Emissions per calendar year (2000–2017)

Emissions ($MT\ CO_2e$)	2000[a]	2005[a]	2010[a]	2012[d]	2013[d]	2014[d]	2015[d]	2016[d]	2017[d]
TW Grid Supplied Electricity[b]	101,622	104,467	103,270	103,427	98,588	95,578	90,113	91,705	77,628
TW Fossil Fuel Usage (Natural Gas Use)	12,720	24,599	22,552	24,636	22,029	14,968	11,995	11,306	21,856
CAP Grid Supplied Electricity[c]	29,218	184,061	253,521	390,220	377,493	387,402	412,461	418,268	342,686
Tucson Water Subtotal	**143,560**	**313,127**	**385,343**	**518,283**	**498,110**	**497,948**	**514,569**	**521,279**	**442,170**

a. Emissions were aggregated for 2000, 2005, 2010 to match the three categories of the most recent 2012–2017 PAG inventory (published 2019).
b. As detailed in Table 3-1 the methodology in the 1990–2012 PAG Inventory (PAG 2014) used separate EFs to estimate electricity use emissions from Trico and TEP.
c. CAP emissions were not included in the total for TW in the 1990–2012 PAG Inventory but are included in this table.
d. Emissions as shown in the 2012–2017 PAG Inventory (PAG 2019).

3.3 Review of PAG Emissions Sources (1990–2017)

TW Grid Supplied Electricity

- Emissions associated with TW consumed electricity provided by TEP and TRICO.

TW Fossil Fuel Usage

- Emissions from natural gas consumed by TW. Provided by SWG. Fossil fuel usage from the TW fleet or during employee commute is not included in this metric, as these categories were not disaggregated specific to the utility in previous inventories (PAG 2014, 2017, 2019).

CAP Grid Supplied Electricity

- Emissions from electricity associated with CAP transmission of water to TW.

In addition to these emissions sources, City waste emissions were reported in previous PAG inventories (PAG 2014, 2017, 2019), but were not disaggregated specific to the utility and therefore are not reported here.

4 Emissions Trends

4.1 2018 TW GHG Emissions Using PAG Categories

For comparison with previous years, GHG emissions for 2018 are summarized in Table 4-1 using the emissions sources and boundaries delineated in the most recent PAG inventory (2019). This omits some of the emissions sources identified in Section 2, but is helpful for comparing emissions to prior years.

2018 GHG Inventory Using PAG (2019) Boundaries

Table 4-1. 2018 TW GHG Emissions.

Emissions Source	2018 Emissions (MT CO_2e)	2018 Energy Use (MMBtu)
TW Grid Supplied Electricity	74,855	412,575
TW Fossil Fuel Usage (Natural Gas Use)	15,882	299,018
CAP Grid Supplied Electricity	377,199	1,200,045
TW Subtotal	**467,936**	**1,911,638**

Using the boundaries from previous inventories, the majority (80 percent) of TW's 2018 emissions are associated with the CAP, while the remaining emissions (20 percent) are emissions from TW natural gas or electricity use.

4.2 TW Emissions to Date (1990–2018)

Given this is the first inventory completed for TW to include disaggregation by scope of GHG emissions, there are no previous years' data available for comparison to all the emissions sources identified in Table 2-1. To examine trends, Figure 4-1 compares 2018 emissions to previous PAG results by grouping emissions sources using the PAG methodology detailed in Section 3.

Using the boundaries (inventory methodology) defined by PAG, emissions increased between the years of 2017 and 2018 by 6 percent and have varied by about 15 percent since 2012. Detailed information for comparison with previous PAG inventories is provided below in Table 4-2.

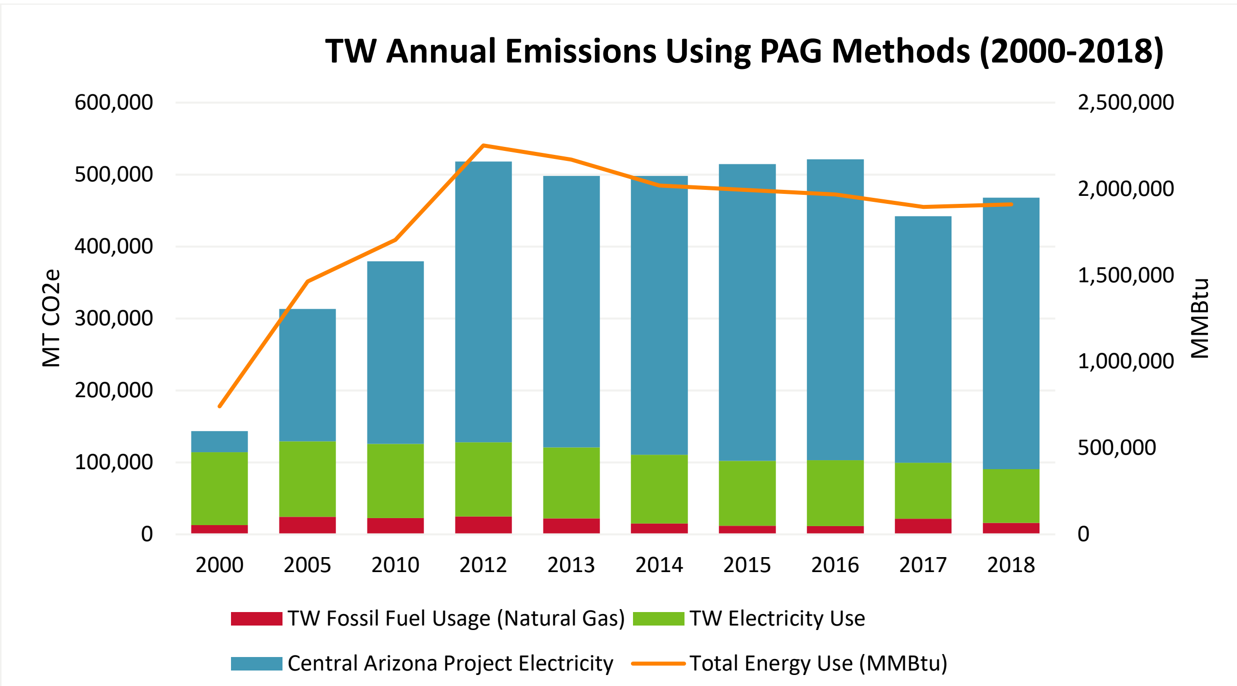

Figure 4-1. TW Annual Emissions and trends from 2000–-2018. Note, to be comparable with previous inventory this figure estimates 2018 emissions using the PAG methodology.

In future years with the refined data collection process described in the IMP (Appendix A), trends in GHG emissions could be tracked by scope to show progress toward TW's emissions reductions goals.

City of Tucson Carbon Reduction Targets

The City of Tucson has a goal of carbon neutrality in operations by the year 2030 (Tucson City Council Resolution No. 23222). The Tucson City Council declared this goal in a Climate Emergency Declaration adopted in September 2020.

Table 4-2. TW GHG Emissions 2000–2018 (Using PAG Format Since Previous Years Unavailable By Scope).

Emissions (MT CO_2e)	2000[a]	2005[a]	2010[a]	2012[d]	2013[d]	2014[d]	2015[d]	2016[d]	2017[d]	2018[e]
TW Grid Supplied Electricity	101,622	104,467	103,270	103,427	98,588	95,578	90,113	91,705	77,628	74,855
TW Fossil Fuel Usage (Natural Gas Use)	12,720	24,599	22,552	24,636	22,029	14,968	11,995	11,306	21,856	15,882
CAP Grid Supplied Electricity	29,218	184,061	253,521	390,220	377,493	387,402	412,461	418,268	342,686	377,199
Tucson Water Annual GHG Subtotal	**143,560**	**313,127**	**385,343**	**518,283**	**498,110**	**497,948**	**514,569**	**521,279**	**442,170**	**467,936**

a. Emissions were combined for 2000, 2005, 2010 to match the format of the most recent 2012–2017 PAG inventory (published 2019).
b. As detailed in Table 2-1 the methodology in the 1990–2012 PAG Inventory (PAG 2014) used separate EFs to estimate electricity use emissions from Trico and TEP.
c. CAP emissions were not included in the total for TW in the 1990–2012 PAG Inventory.
d. Emissions as shown in the 2012–2017 PAG Inventory (PAG 2019).
e. Only comparable emissions sources listed representing about 98.5% of reported emissions by scope; see Table 2-1 for complete 2018 GHG inventory.

Anticipated Carbon Intensity Reductions from Electric Utilities

To meet statewide mandates (ACC 2021) and stakeholder concerns, both TEP and Trico plan to incorporate more renewable energy into their future generation portfolio (TEP 2020, TRICO 2019). The current Arizona standard is a mandate of 15 percent renewable energy supply from regulated utilities by 2025, which Trico has already met and TEP is planning to exceed by 2030, detailed in Table 4-3. This will result in a reduction of the carbon intensity of energy provided to TW in the future. A breakdown of Scope 1 and 2 energy sources is shown in Figure 4-2.

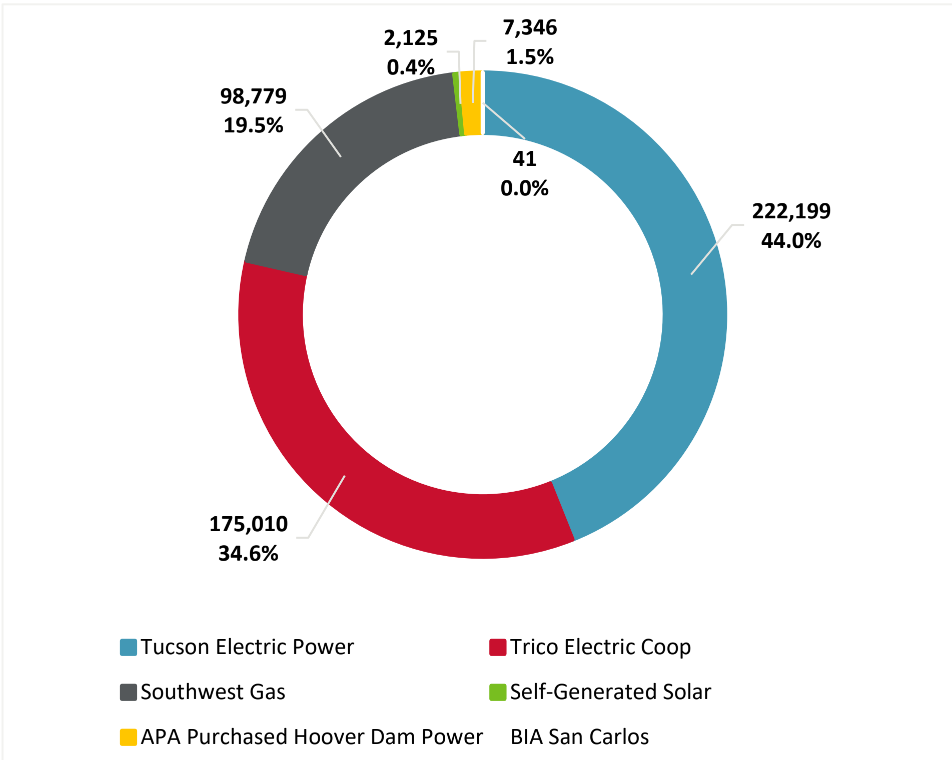

Figure 4-2. TW 2018 Electricity and Natural Gas Use (MMBtu)

As detailed in the figure, 80 percent of the Scope 1 and 2 energy demand for TW are provided by Trico and TEP. The current and future renewable portfolio targets for these two companies are provided in Table 4-3.

Table 4-3. TEP and TRICO Existing and Future Generation Capacity

Electricity Generation Capacity[a]	2018 TEP	2030 TEP Goal	2018 TRICO	2030 TRICO[b] Goal
Coal	34%	13%	38%	n/a
Natural Gas	56%	42%	40%	n/a

Electricity Generation Capacity[a]	2018 TEP	2030 TEP Goal	2018 TRICO	2030 TRICO[b] Goal
Renewables	10%	45%	16%	n/a
Hydropower	0%	0%	6%	n/a

a. Assuming 2020 generation detailed by TEP 2020, Trico 2021 is similar to 2018 generation.
b. Meets existing Arizona RPS standard of 15 percent by 2025, but future standards could require additional incorporation of renewables.

As Trico and TEP incorporate more renewables into their portfolios the carbon intensity of energy provided to TW will decrease. In addition, it is anticipated that CAP GHG emissions will decrease following the replacement of high carbon emitting electricity with the decommissioning of the coal-fired Navajo Generating Station in November 2019 (CAP 2020). Further carbon reduction or mitigation options for TW to reduce emissions to achieve the City's 2030 goal will be discussed in future technical memos referring to this baseline document.

5 Summary

Although TW has completed GHG inventories back to 2000, previous inventory years emissions are not categorized by scope, as recommended by the ICLEI Local Governments Reporting Standard (Appendix C of ICLEI 2010). The information to complete an inventory by scope to internationally recognized reporting and accounting principles has been provided in this technical memo, along with an additional IMP (Appendix A) to provide guidance to replicate an inventory by scope in future years.

To compare this inventory to previous years, a retrospective analysis would be required to categorize historical emissions by scope to keep the existing TW baseline, or the 2018 GHG Inventory in this memo could be established as a new baseline to identify clear GHG mitigation options to reach the utility's goal of carbon neutrality by 2030.

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Appendix A. Inventory Management Plan

Contents

Tables

Figures

1 Introduction

An Inventory Management Plan is provided in this section to provide an overview of the methodology, data sources, emission factors, and assumptions used to complete the 2018 Tucson Water (TW) Greenhouse Gas (GHG) Inventory. Questions regarding the 2018 TW GHG Inventory or Inventory Management Plan should be directed to:

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2 Boundary Conditions

2.1 Organization Boundary

TW GHG Inventory emissions are reported by calendar year (CY). The TW GHG inventory boundary follows an operational control approach, which encompass all activities where TW has direct control of day-to-day decision making, which is generally within the TW water service area boundary shown below in Figure 1.

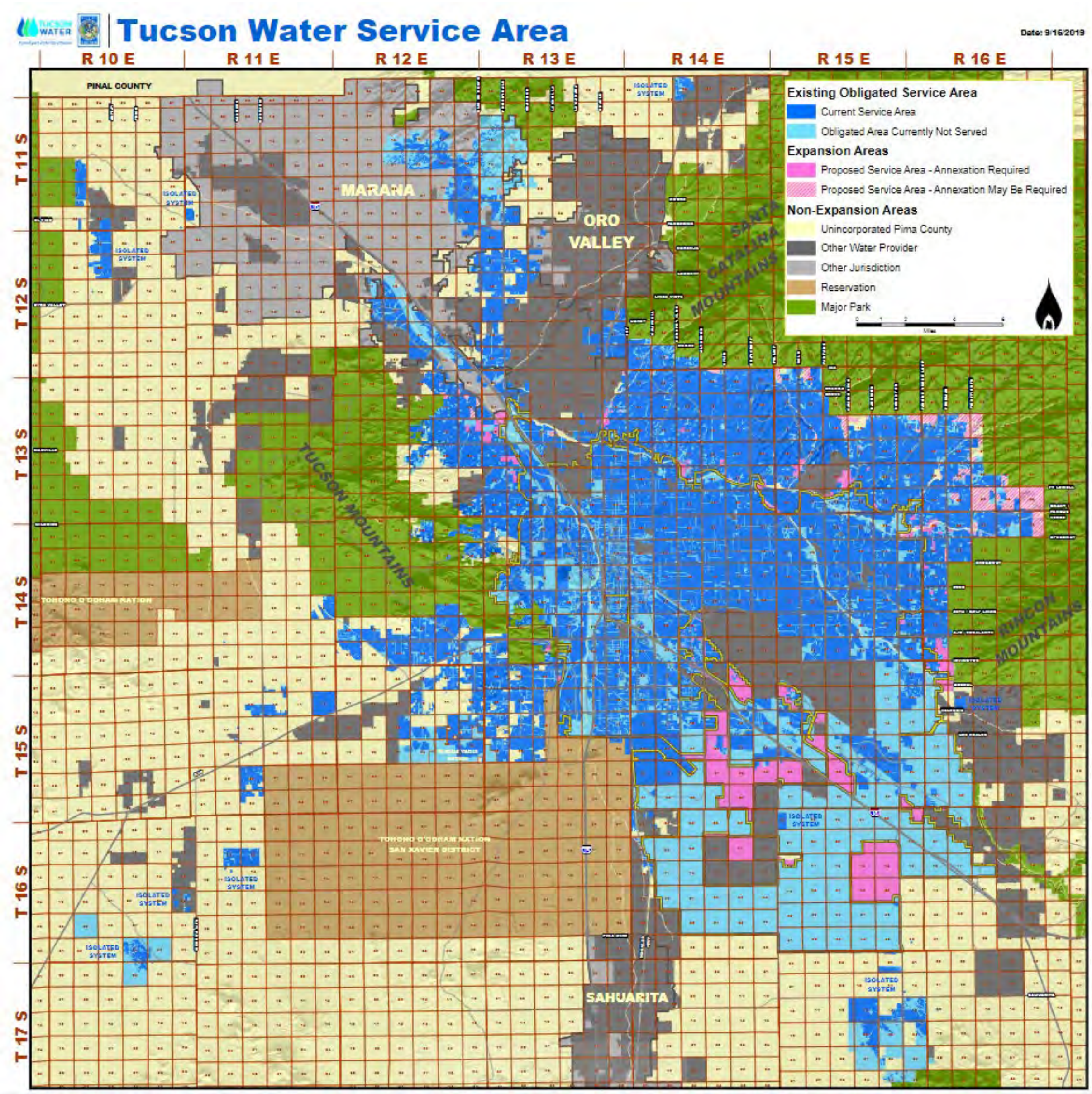

Figure 1: Map of Tucson Water Service Area by Township, Section, and Range.

This includes areas where the utility has full authority to affect change and introduce and implement operating policies that affect GHG emissions, including:

- Treatment Plants
- Pump Stations
- Booster Pumps
- Wells
- Administrative Offices
- Vehicles Used in Operations

- Generated Waste
- Purchased Goods and Services

TW reviewed potential emission sources for all six major GHGs as identified by the United States Environmental Protection Agency (EPA 2020a). Relevant GHGs are detailed in Table 1.

Table 1. Relevance of EPA Identified GHGs to TW Operations.

EPA Identified GHG[1]	Relevance to TW Operations
Carbon dioxide (CO_2)	*Relevant.* Produced from the combustion of fossil fuels.
Methane (CH_4)	
Nitrous oxide (N_2O)	
Hydrofluorocarbons (HFCs) and Perfluorocarbons (PFCs)	*Relevant.* Fluorinated gas emissions are often the result of leaking refrigerants. Refrigerants are used in TW administrative and operations buildings, such as well houses. The TW vehicle fleet also uses refrigerants.
Sulfur hexafluoride (SF_6)	*Not Relevant.* SF_6 is primarily used by the electric power industry to insulate high-voltage circuit breakers.[1]
Nitrogen trifluoride (NF_3)	*Not Relevant.* NF_3 is used in a relatively small number of industrial processes, primarily produced in the manufacture of semiconductors and LCD panels, and certain types of solar panels and chemical lasers.[2]

1. EPA 2020a
2. WRI 2013

Within the organizational boundary of the TW GHG Inventory emissions sources were identified for CO_2, CH_4, N_2O, and from fluorinated gases (refrigerants). The TW GHG Inventory uses International Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) of global warming potential for CH_4 and N_2O to be consistent with 2020 EPA guidance (EPA 2020b).

2.2 Operational Boundary

The TW inventory follows the Local Government Operations Protocol for the Quantification and Reporting of Greenhouse Gas Emissions Inventories (ICLEI 2010), with emissions reported in accordance with the World Resource Institute (WRI) Greenhouse Gas Protocol Corporate Accounting and Reporting Standard (WRI 2004 and 2011) where appropriate. Note that the ICELI protocol refers users to the WRI standard for the definition of scopes and methods.

Previous TW GHG boundaries detailed in the 2012–2017 Pima County Association of Governments (PAG) Regional GHG Inventory TW did not disaggregate which City of Tucson emissions are attributed to TW from facilities, fleet, public lighting, district energy, water, or employee commuting. In addition to this, TW emissions were not categorized by scope. The 2018 inventory categorizes emissions by scope and includes additional relevant emissions sources that can be disaggregated from City of Tucson data. For comparison with previous years, emissions are also provided using the boundary from PAG inventories. Note that TW did not have full control of the PAG inventory and assumptions for the utility's emissions.

The WRI Standard categorizes direct and indirect emissions as Scope 1, 2, and 3. Direct emissions are Scope 1 emissions, while Scope 2 and 3 emissions are indirect. A visual of this information by category is shown in Figure 2. Direct emissions are emissions that an organization emits from their own activities, such as operation of utility-owned equipment, while indirect emissions are emissions from activities of external organizations, such as generation of electricity or energy used to move water by the Central Arizona Project (CAP).

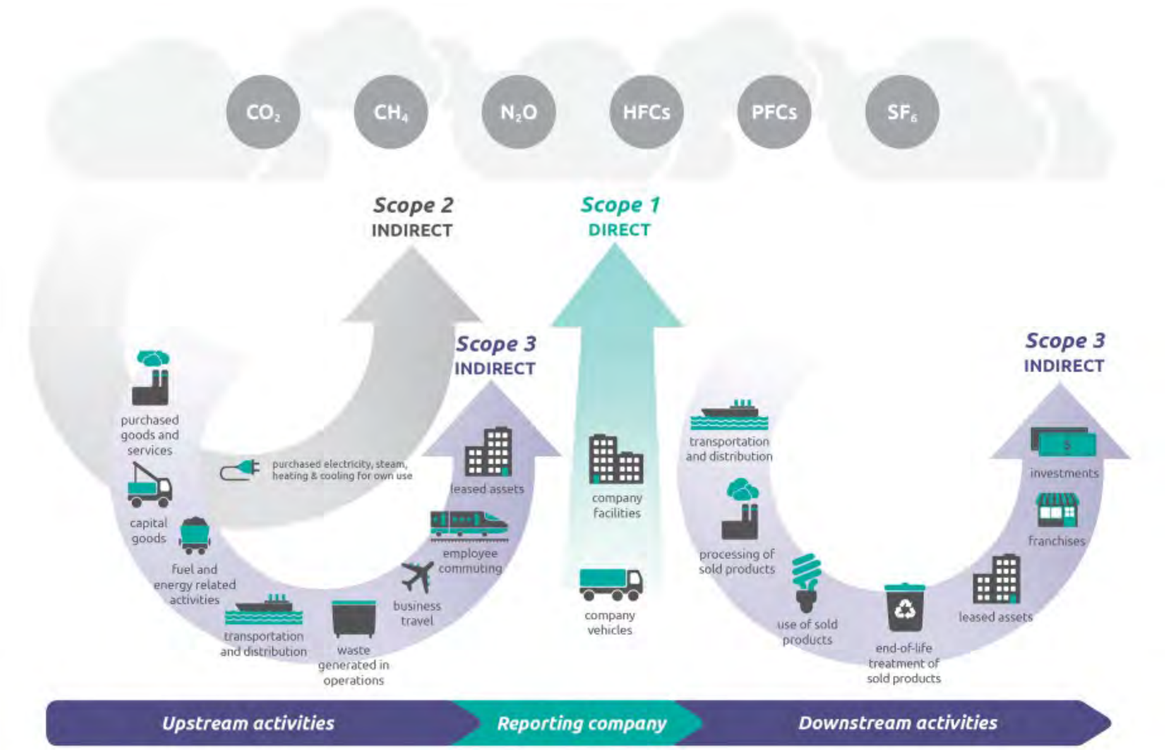

Figure 2. Scopes of GHG Emissions as Defined in the WRI/WBCSD Corporate Value Chain (Scope 3) Accounting and Reporting Standard (Source: WRI 2011)

Relevant TW emissions categories and sources by scope are detailed in Table 2.

Table 2. TW Emissions Sources, Scopes

2018 Emissions Source	Scope	Emissions Source[1]	2018 Activity Data
Natural Gas Use	1	Stationary Combustion	299,018 MMBtu[2]
TW Vehicle Fleet (on-road)	1	Mobile Combustion	33,592 Gallons Diesel[3] 271,514 Gallons Gasoline[3] 180 Gallons Ethanol[3]
TW Vehicle Fleet (off-road)	1	Mobile Combustion	31,598 Gallons Diesel[3] 1 Gallon Gasoline[3]
Refrigerants	1	Fugitive Emissions	77 Pounds R22 8 Pounds R407C 7 Pounds R410A 50 Pounds R422B
Electricity Use (TW Operations)	2	Purchased Electricity	116,416 MWh[2,5]
Upstream (CAP) Water	3	Upstream Transportation of Materials and Fuels	351,713 MWh[4]
Waste from Operations	3	Waste Generated in Operations	665 Short Tons Landfilled[6] 188 Short Tons Recycled[6]
T&D Loss from Purchased Electricity	3	Utility T&D Loss	2,695 MWh5[5,7]

1. ICELI 2010
2. Values provided by Tucson Water from the EnergyCAP system, for electricity only includes carbon emitting electricity use
3. Value provided from City of Tucson Fleet Services
4. Electricity to deliver the water provided from the Central Arizona Project
5. Only includes purchased electricity from TEP, Trico. Bureau of Indian Affairs (BIA) electricity is delivered by the Western Area Power Administration (WAPA). According to WAPA's electricity customer list (2021a). WAPA provides predominantly hydropower generation at federal facilities and purchases power as needed (2021b). For CY 2018 the split as reported by WAPA is 93% (hydro) to 7% other sources (2021b). Thus, since the BIA power is predominantly hydro, and BIA electricity is 0.01% percent of TW's electricity use, these emissions are considered *de minimis* (See IMP for definition of term). A calculation of the GHG emissions associated for WAPA purchased power was not included.
6. Value provided from Environmental and General Services Department
7. 3.6% Transmission and Distribution Energy Loss reported for Arizona in 2018 (EIA 2020)

3 Reporting Principles

The TW GHG inventory is developed in accordance with the ICELI Local Government Operations Protocol for the Quantification and Reporting of Greenhouse Gas Emissions Inventories. ICLEI relies upon and refers to the scopes and methods defined in the WRI Greenhouse Gas Protocol Corporate Accounting and Reporting Standard (Corporate Standard), and the WRI Corporate Value Chain (Scope 3) Accounting and Reporting Standard.

Development of the GHG inventory is based on the following core GHG accounting and reporting principles (defined in WRI 2004):

Relevance. Developing a GHG inventory that appropriately reflects TW's GHG emissions.

Completeness. Accounting for and reporting on all GHG emission sources and activities within the inventory boundary, with clear disclosure and justification for exclusions.

Consistency. Using consistent methodologies to allow for meaningful comparisons of emissions over time. Documenting changes to the data, boundary, or other relevant factors.

Transparency. Addressing emission sources in a factual and coherent manner, supported by clear documentation of source data, assumptions, and calculation methodologies.

Accuracy. Applying best practices to systematically estimate GHG emissions as accurate as reasonable and minimize uncertainties as far as practicable.

4 GHG Emissions Sources and Factors

Emissions factors for each identified emissions source and quantification methodologies are detailed in Table 3.

Table 3. TW Emissions Source, Factors, and Quantification Methodology.

2018 Emissions Source (Unit)	Emissions Factor (GHGs / Unit)	Quantification Methodology[1]
Scope 1		
Combustion of Natural Gas –Operations (MMBtu)	53.1 kg CO_2e 1.00 g CH_4 0.10 g N_2O	$MT\ CO_2e = Natural\ Gas\ Use * EPA\ EF_{CO_2,N_2O,CH_4} * GWP_{N2O,CH4} * Unit\ Conversion$
On-Road Vehicle Fleet (Gallons)	10.21 kg CO_2 (Diesel) 8.78 kg CO_2 (Gasoline) 5.75 kg CO_2 (Ethanol) Different CH_4 and N_20 per make/model	$MT\ CO_2e = Total\ Fuel\ Use * EPA\ EF_{CO_2,N_2O,CH_4} * GWP_{N2O,CH4} * Unit\ Conversion$
Off-Road Vehicle Fleet (Gallons)		
Refrigerants (Pounds)	1870 CO_2e (R22) 1774 CO_2e (R407C) 2088 CO_2e (R410A) 2526 CO_2e (R422b)	$MT\ CO_2e = Refridgerant\ Weight\ (lbs) * GWP * Unit\ Conversion$
Scope 2		
Electricity Use – Operations (MWh)	0.643 tons CO_2e	$MT\ CO_2e = TEP\ EF_{CO_2,N_2O,CH_4} * mWh\ Purchased * GWP_{N2O,CH4} * Unit\ Conversion$
Scope 3		
Upstream (CAP) Water (MWh)	1.072 CO_2e[2]	$MT\ CO_2e = Navajo\ Generating\ Station\ EF_{CO_2,} * mWh\ Purchased * Unit\ Conversion$

Waste from Operations (Short Tons)	0.63 Metric Tons CO_2e / Short Tons (Municipal Solid Waste) 0.09 Metric Tons CO_2e / Short Tons (Mixed Recycling)	$MT\ CO_2e = (EPA\ EF * Short\ Tons\ Municpal\ Solid\ Waste\ or\ Mixed\ Recycling)$
T&D Loss From Purchased Electricity (MWh)	3.6% of TW-consumed electricity from utilities	$MT\ CO_2e = TEP\ EF_{CO_2,N_2O,CH_4} * mWh\ Purchased * GWP_{N2O,CH4} * EIA\ EF * Unit\ Conversion$

1. EPA emissions factors detailed in EPA 2020b. Global Warming Potential (GWP) values are from theAR4.
2. Emissions factor estimated from EIA energy use and EPA emissions Data (EIA 2020, EPA 2020a)

5 Scope 1 Emissions Sources

5.1 Stationary Combustion

Definition

The ICELI *Local Government Operations Protocol for the Quantification and Reporting of Greenhouse Gas Emissions Inventories* Standard (2010) defines stationary combustion as fuel used to "produce electricity, steam, heat or power using equipment in a fixed location." Stationary combustion for TW is limited to combustion of natural gas to heat offices or operate equipment. Depending on use emissions are categorized within either the ICELI defined Water Delivery or Buildings categories. The WRI *Greenhouse Gas Protocol Corporate Accounting and Reporting Standard* (2004) defines this emissions source as Scope 1.

2018 Data Source and Analysis for Inventory

Natural gas use was estimated using utility bills from Southwest Gas (SWG) for CY 2018. This information was collected from the Tucson Utility Management System (which uses EnergyCAP software) and provided to HDR as a spreadsheet. This included all the natural gas used to heat occupied office space. To estimate emissions per MMBtu an emissions factor was used from the 2020 EPA guidance for GHG inventories (EPA 2020b).

Since the EnergyCAP data were aggregated, additional information was required to apportion natural gas use between office space and water delivery. For future city-wide inventories it is recommended this apportionment be completed to help disaggregate GHG emissions in the ICELI defined categories.

5.2 Mobile Combustion

Definition

The ICELI standard (2010) defines mobile combustion as "fuels in fleet transportation sources (e.g., cars, trucks, marine vessels, and planes) and emissions from off-road equipment such as in construction, agriculture and forestry." Emissions are categories such as "on-road" or "off-road," where "on-road" fleet vehicles are those such as sedans, pickup trucks, dump trucks that see a majority of street use and “off-road” vehicles are other mobile equipment such as small engine components and construction equipment.

Mobile combustion for TW is limited to fuel use for City-owned fleet and non-road equipment for the ICELI defined Water Delivery and Vehicle Fleet emissions categories. The WRI standard (2004) defines this emissions source as Scope 1.

2018 Data Source and Analysis for Inventory

On-road vehicle fleet fuel usage was provided to HDR in an Excel spreadsheet from the City Fleet Services department. A separate spreadsheet was provided with make/model information and the two datasets were related to one another by HDR. After joining the spreadsheets, gallons of fuel for diesel, gasoline, and ethanol were totaled. Based on discussion with TW staff, it is assumed that DRP (undefined diesel) fuel has an equivalent emissions profile to diesel fuel, allowing these fuels to be totaled together. Note: after combining these data, some vehicles were determined to be off-road after the make/model was discovered. To estimate GHG emissions per gallon of fuel consumed, EPA emissions factors for gasoline, diesel, and ethanol were used (EPA 2020b).

To estimate indirect CH_4 and N_2O emissions for the on-road vehicle fleet EPA emissions factors based on mileage data depending on the vehicle make/model were used (EPA 2020b). This was completed for 70 percent of the vehicles in the data provided; for the other 30 percent of vehicles, the make/model could not be determined from the data provided. To estimate the emissions, the weighted average of the made/model of the rest of the on-road vehicle fleet was applied to these vehicles. It is assumed the indirect emissions associated with this assumption would only result in a small (less than 10 metric tons) difference if these data were available and is thus below the TW *de-minimus* threshold (the minimum threshold to require further analysis, defined by the ICELI to be <5 percent of total emissions). A complete spreadsheet with fuel usage and vehicle make/model could avoid the need to make this assumption in future reporting years.

For off-road vehicles, gallons of fuel used in 2018 was determined using with data from fuel pumps that track the dispersal of fuel, which were provided to HDR by TW. Total gallons of fuel were provided from the Fleet Services database for these categories. It is assumed that fuel dispensed from fuel truck 5900 is representative of all fuel dispersed to “off-road” vehicles. Emissions per gallon were estimated by applying the EPA defined “off-road construction/mining” emissions factor.

5.3 Fugitive Emissions

Definition

ICELI defines fugitive emissions as emissions that “…are not physically controlled but result from intentional or unintentional releases, commonly arising from the production, processing, transmission, storage, and use of fuels and other substances, often through joints, seals, packing, gaskets, etc. (e.g., HFCs from refrigeration leaks, SF_6 from electrical power distributors, and CH_4 from solid waste landfills).” Fugitive emissions for TW are limited to refrigeration leaks for the ICELI defined Water Delivery emissions category. The WRI Protocol (2004) defines this emissions source as Scope 1.

2018 Data Source and Analysis for Inventory

Refrigerants used by TW in 2018 were provided from a City-maintained database but did not include refrigerant losses from TW-owned vehicles. It is assumed that added refrigerants to TW systems are replacing refrigerants that were released to the atmosphere. An emissions factor for each refrigerant was provided from 2020 EPA data (EPA 2020b) or from the California Air Resources Board "High-GWP Refrigerants" database (2020).

6 Scope 2 Emissions Sources

6.1 Purchased Electricity

Definition

TW emissions associated with the consumption of purchased electricity are relevant to the ICELI defined Water Delivery and Buildings and Other Facilities emissions categories. The WRI standard (2004) defines this emissions source as Scope 2.

2018 Data Source and Analysis for Inventory

Annual electricity use from TW operations was estimated using utility bills provided from TEP, Trico, and the Bureau of Indian Affairs (BIA) San Carlos Irrigation District for calendar year 2018. This information was collected from the Tucson Utility Management System and provided to HDR as a separate spreadsheet for each utility in MMBtus. Data were converted to kWh and combined into one spreadsheet grouped by utility. Electricity billed was subtracted from total used to determine solar electricity generated and consumed at the Hayden Udall Treatment Plant and Reclaimed Plant.

In October of 2017 TW signed a contract with the Arizona Power Authority to purchase renewable hydroelectric power generated by the Hoover Dam until September of 2067. TW is allocated approximately 2,725,000 kWh each year. This electricity and associated T&D losses are assumed to be carbon-free in the 2018 TW inventory. This power is delivered to TW through Trico transmission and distribution infrastructure. APA invoices paid by TW for CY 2018 were provided to HDR to confirm the amount of power delivered. This power is assumed to be consumed through the Trico CAVSARP master meter in the EnergyCAP data provided to HDR (Personal Communication TW 2021). To account for this, a portion of the electricity consumed from Trico equal to the total APA purchased power consumed is assumed to be carbon free (2,153,000 kWh) in 2018.

Although additional solar energy is generated at CAVSARP from two solar arrays, TW entered two 25-year power purchase contracts (in 2011 and 2013) with Trico to sell the electricity generated along with the Renewable Energy Credit (RECs). A REC is a market-based instrument that represents the property rights to the environmental, social, and other non-power attributes of renewable electricity generation. RECs are issued for each one megawatt-hour (MWh) of electricity that is generated and delivered to the electricity grid from a renewable energy resource. RECs are the accepted legal instrument through which renewable energy generation and use claims are substantiated in the U.S. renewable energy market (EPA 2021). Since the RECs from TW's solar generation were sold to Trico, TW is unable to claim the electricity is renewable in their accounting of GHG since TW does not legally own the RECs for this solar electricity generation. The contracts for sale of the RECs to Trico expire as shown in Table 4, which provides a detailed summary of solar generation and REC ownership.

Table 4: Solar Electricity Generated and Ownership of Renewable Energy Credits (2018)

Solar Generating Facility Location	kWh Generated	kWh Solar Consumed by TW	Ownership of RECs
Hayden Udall Treatment Plant	408,134	408,134	TW
Reclaimed (Water) Plant	214,543	214,543	TW
CAVSARP 1	2,100,144	0	Trico (until 2036) TW (after 2036)
CAVSARP 2	7,354,068	0	Trico (until 2038) TW (after 2038)

An emissions factor for TEPs 2018 electricity mix was reported online by TEP to the Edison Electric Institute (EEI 2019) and utilized in this inventory. A PAG representative confirmed with Trico that the TEP emissions factor would also be appropriate for the GHG emissions from their utility generation for the CY 2018 (PAG 2021). Given that BIA electricity is only 0.01 percent of TW's electricity in 2018 (*de minimis*) and BIA's supply is purchased from Western Area Power Administration (primarily large-scale hydro), it is assumed this electricity does not emit carbon.

The utility management system data was categorized by building name and code. Further analysis is required to apportion electricity use between office space and water delivery uses. If possible, for future city-wide inventories we recommend this be completed to help categorize emissions in the ICELI defined categories (Buildings, Water Delivery). In addition to these four facilities (R_710_OTHER_PUMP-ELRIO-2, R_710_OTHER_PUMP-ELRIO-1, R_710_OTHER_WELLSITE-B-047A, R_710_OTHER_IRR_CASEPARK) attributed to streets and parks were removed from the dataset.

7 Scope 3 Emissions Sources

7.1 Upstream Transportation of Materials and Fuels

Definition

The electricity associated with the extraction and conveyance of CAP water to TW is categorized by ICELI (2010) as supply chain emissions associated with the Upstream Transportation of Materials and Fuels. The ICELI standard (2010) defines this emissions source as Scope 3 since these emissions are outside the control of TW.

2018 Data Source and Analysis for Inventory

TW began receiving a partial allotment of water from CAP in 1990, which increased in volume until the full allotment was received in recent years. As volume increased, energy use increased to convey that water. The CY 2018 electricity to deliver TW's allotment of CAP water is provided to TW from CAP. It is assumed the Navajo Generating Station (NGS) generated all of the electricity used to deliver CAP Colorado River water to TW in CY 2018. Given that NGS is being retired and CAP has begun to diversify their generation sources, it is recommended in future inventory years that CAP be requested to provide a more detailed breakdown of generation sources, and complete their own carbon intensity analysis to create an annual or monthly emissions factor (CAP 2020).

To estimate the emissions associated with this upstream electricity usage an emissions factor was created by dividing CY 2018 NGS generation in kWh reported to the EIA (2020a) by GHG emissions reported to the EPA (2020a). This estimation was validated by PAG staff to be similar to how previous emissions factors were calculated for CAP electricity (PAG 2021).

7.2 Waste Generation from Operations

Definition

The ICELI standard (2010) defines emissions local government waste that is not disposed of in a government-owned landfill as supply chain waste related Scope 3 emissions.

2018 Data Source and Analysis for Inventory

Tonnage of transactions for municipal waste and recycling collection was provided to TW from the Environmental and General Services Department. Emissions factors for municipal solid waste and mixed recyclables were applied to the tonnage of the two waste streams for 2018 (EPA 2020b). It is assumed all municipal solid waste was disposed of at Los Reales Landfill, which has a gas collection system for fugitive methane (TEP 2021).). Future data collection could include further waste characterization and more detailed tracking of disposal and/or recycling by TW of materials such as water meters, brass, copper, and insulating wire.

7.3 Transmission and Distribution Losses

Definition

The ICELI standard (2010) provides the option for governments to report the electricity lost during the transmission and distribution of electricity. For TW these emissions are categorized into the ICELI defined Water Delivery, Buildings and Other Facilities categories. The WRI standard (2011) defines this emissions source as Scope 3.

2018 Data Source and Analysis for Inventory

Transmission and distribution loss data were estimated by multiplying carbon-emitting electricity use by the average loss for the state of Arizona (EIA 2020b).

7.4 Purchased Products and Capital Goods

Definition

The ICELI standard (2010) provides the option for governments to report upstream emissions (embodied carbon) associated with the production of purchased equipment, or materials. For TW these emissions are categorized into the ICELI defined Water Delivery, Buildings, and Other Facilities categories. The WRI standard (2011) defines this emissions source as Scope 3.

Purchased products and capital goods are separated into two categories per the WRI 2011 protocol:

1. **Capital Goods:** All upstream (cradle-to-gate) emissions from the production of products not immediately consumed but used in the process of providing water to customers (pipes, mechanical equipment, office equipment, computers, vehicles, etc.).
2. **Purchased Goods:** All upstream emissions from the production of products not reported above, such as those that are immediately consumed (chemicals, batteries, other "one-time" use materials during operations).

2018 Data Source and Comparative Analysis

In a typical inventory, the GHG associated with purchased and capital goods would be based on the dollar spend annually for each category of goods and calculated using WRI methods with relevant industry average emission factors (i.e., emissions per dollar spent). WRI's recommended standard method is to use an Extended Input-Output (EEIO) model

Since this is the initial GHG inventory by scope for TW, a more comparative review of the embedded carbon or carbon intensity of selected purchased and capital goods from their supply chain is provided in this section. TW requested a focus upon purchased and capital goods, and a relative analysis of two major materials types important to their operations as a water supply agency, i.e., chemicals and pipes. Methodology for Comparative Analysis

This methodology relies upon a different calculational approach than the standard practice for a GHG inventory. For this comparison, Life Cycle Analysis (LCA) was used. LCA is an ISO 14040 normalized method for the assessment of products and systems from cradle-to-grave, which begins with raw materials extracted from the earth, and continues with product development, manufacturing, and disposal. LCA allows comparison between different materials or processes providing the same service or function. The resulting metric is for TW's use to understand the relative impacts on a climate or GHG basis of alternative material types for pipes and for chemicals, as purchased by TW.

The LCA method generates a factor for climate or GHG in embodied carbon (CO_2e), alternatively, the precursor to this is embodied energy and can be utilized. As expected, embodied carbon for a product can vary widely by electricity and fuel types used during the life cycle. The embodied energy represents the energy consumed regardless of the source or carbon content and is represented in joules (J). The boundaries for LCA are described below.

HDR prepared a relative comparison of life cycle attributes associated with each of chemicals and pipes based upon CY 2018 data for TW purchases. Data collected by TW for purchases of water supply pipe (by type, diameter size and total feet) and chemicals (by weight) for CY 2018 are summarized below in Table 5. The predominant types of pipe purchased by TW in 2018 are PVC and ductile iron, respectively. Lesser amounts of pipe types purchased were cement, HDPE, copper and steel. Water treatment chemicals purchased by TW in 2018 included ammonia, chlorine, hydrogen peroxide, sodium bisulfate and sulfuric acid.

Table 5. Water Supply Pipe and Chemicals Purchased by TW, CY 2018

Product Type Purchased (2018)		
Maintenance Pipe	**Diameter (in)**	**Length (ft)**
Cement Asbestos (CA)	12	33
Concrete Cylinder (CC)	NA	NA
Copper Pipe (CU)	2	43
Ductile Iron (DI)	4	1,879
Ductile Iron (DI)	6	8,578
Ductile Iron (DI)	8	7,813
Ductile Iron (DI)	12	1,359
Ductile Iron (DI)	16	495
Ductile Iron (DI)	24	811
High Density Polyethylene (HDPE)	4	22
Polyvinyl chloride (PVC)	2	96
Polyvinyl chloride (PVC)	4	3,924
Polyvinyl chloride (PVC)	6	24,758
Polyvinyl chloride (PVC)	8	60,122
Polyvinyl chloride (PVC)	10	26
Polyvinyl chloride (PVC)	12	16,776
Polyvinyl chloride (PVC)	16	2,325
Steel (STL)	4	28
Chemicals		**Gals/yr**

Ammonia		15,000
Chlorine		220,000
Hydrogen Peroxide		35,000
Sodium Bisulfate		7,200
Sulfuric Acid		36,000

Sources – Pipe: Bill Burris, Water Program, TW.
Chemicals: Michael Moraga, Water Quality & Operations Division;
David Villalovos, Water Plant. Both TW.

Water Supply Pipeline Material

A review of comparisons of water pipe materials yielded a small number of studies that were primarily sponsored by water pipe manufacturers. In these comparisons of pipe materials, the methodologies relied upon were non-standard, and the conclusions were highly variable from study to study, i.e., the results favored the pipe material represented by the sponsoring pipe manufacturer.

For this report, HDR selected the results of an LCA review that was:

a) based upon international standard methods referenced by the WRI;

b) utilized a calculation methodology that is based upon product evaluation methods under ISO 14040 standards that require transparency; and,

c) peer reviewed.

The study, *Life Cycle Assessment of PVC Water and Sewer Pipe and Comparative Sustainability Analysis of Pipe Materials* (Sustainable Solutions Corp. [SSC] 2017), also makes reference to the 2015 Environmental Product Declaration for PVC Pipe, which complies with ISO 14025 standards and was independently certified by global health organization NSF International.

This study reported embodied energy in MJ/100 ft pipe and that metric is a general surrogate for carbon intensity. Embodied energy is a reasonable surrogate for embodied carbon or carbon intensity, since when converted from energy to carbon, the result is primarily associated with carbon dioxide emissions from non-renewable energy. To convert embodied energy to embodied carbon would require setting a carbon emissions factor for each pipe material. The carbon emissions factor for each pipe material will vary based upon how raw material is sourced, how the pipe is manufactured, the carbon intensity of the electricity (power content label) and other fuels used during production or manufacturing.

Table 6 shows the Cradle-to-Gate phase is a relative comparison of the embodied energy of pipes by material type and diameter.

Table 6. Cradle-to-Gate Embodied Energy for Alternative Water Supply Pipe Materials (Pressure pipe category)

Comparable Products	Standard	Embodied Energy (MJ/100 ft.)
8" PVC DR18	AWWA C900	23,300
8" HDPE 4710 DR9	AWWA C906	42,600
8" DI CL51	AWWA C151	50,900
8" PVC DR25	AWWA C900	15,900
8" HDPE 4710 DR13.5	AWWA C906	29,600
8" DI CL51	AWWA C151	50,900
24" PVC DR25	AWWA C905	137,900
24" HDPE 4710 DR13.5	AWWA C906	240,800
24" DI CL51	AWWA C151 AWWA C104	206,600
24" PCCP PC200	AWWA C301	53,500

Key: DI – Ductile iron. PCCP - Prestressed concrete cylinder *pipe*. PP - Polypropylene pipes.
Source (SSC 2017)

These results indicate that for the cradle-to-gate order of ranking of the lowest embodied energy (least GHG) for either 8-inch category pipe is shown below:

1. PVC
2. HDPE
3. Ductile iron

For 24-inch pipe, the cradle-to-gate order of ranking of the lowest embodied energy (least GHG) is listed below.

1. PCCP
2. PVC
3. Ductile iron
4. HDPE

Note that in the study referenced below, steel pipe material was not included or evaluated. Thus, PVC has the lowest embodied energy at the 8-inch-diameter size. PCCP is the lowest at the 24-inch-diameter size.

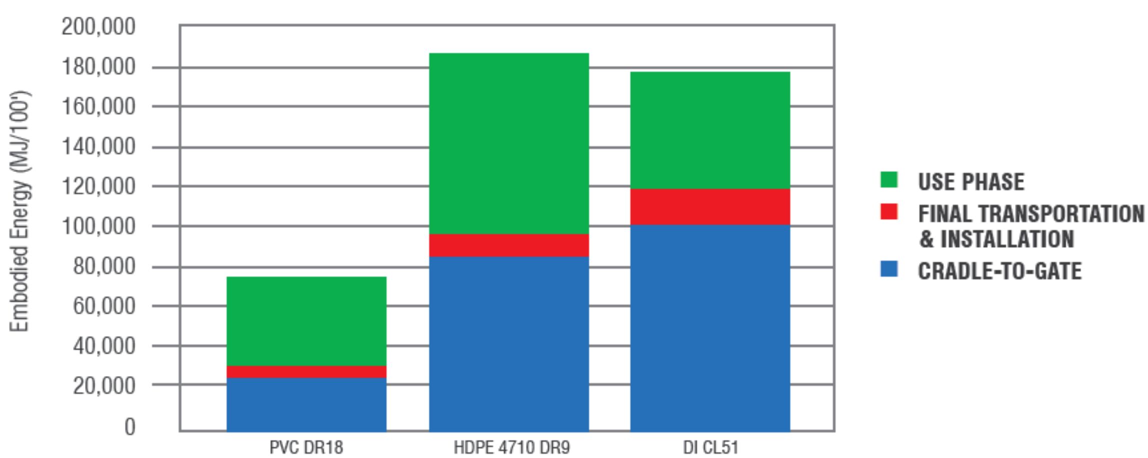

Figure 3. Total 100-year Embodied Energy for Equivalent 8″ Pressure Pipes (PVC DR18) (Source: SSC 2017)

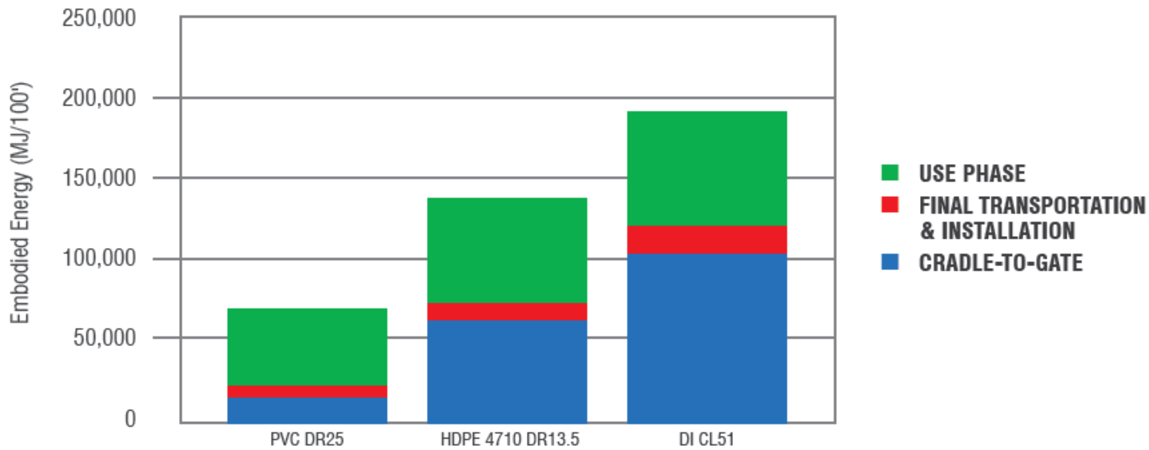

Figure 4. Total 100-year Embodied Energy for Equivalent 8″ Pressure Pipes (PVC DR25) (Embodied Energy in MJ/100 ft of pipe) (Source: SSC 2017)

For the entire life cycle, the results are different. SSC's results indicate changes from the Cradle-To-Grave energy associated with transportation (weight) and frequency of pipe replacement. These SSC results also indicate that over the life cycle, from Cradle-To-Grave, PVC pipe material for 8-inch pipes (DR18) have the lowest embodied energy followed by ductile iron and HDPE iron. Over the life cycle PVC pipe material for 8-inch pipes (DR25) have the lowest embodied energy followed by HDPE and ductile iron. For 24-inch pipe material, the cradle-to-gate rank order of the embodied energy starting with the lowest, were prestressed concrete cylinder pipe (PCCP), PVC, ductile iron and HDPE. These results are summarized in Table 7 below.

Table 7. Cradle-to-Grave Ranking of Alternative Water Pipe Material (by Embodied Energy) (Source: SCC 2017)

Diameter Size/Product	Rank	Pipe Material
8-inch DR18	1	PVC
	2	Ductile Iron
	3	HDPE
8-inch DR25	1	PVC
	2	HDPE
	3	Ductile Iron
24-inch	1	PVC
	2	PCCP

	3	Ductile Iron
	4	HDPE

Recycled Content of Pipe Material and Recycling End of Life Pipe

Current studies of carbon intensity of pipe materials assume no recycled content in pipe material purchased and an assumption of standard practice for the percentage of pipe material recycled (from 20 to 80 percent, depending upon the type of pipe material). Two measures that could lower the net GHG during the life cycle of water supply pipes are: (1) purchasing pipe material with recycled material content, and (2) increasing recycling used pipe at the end of service life at the time of replacement. If these measures are adopted, monitoring and recording of annual data associated with each would be needed and could be included in annual GHG inventory accounting.

Chemicals

Of the five chemicals TW purchases on an annual basis, the largest quantities for CY 2018 in rank order are chlorine, sulfuric acid, hydrogen peroxide, ammonia and sodium bisulfate. After 2018, chlorine is no longer purchased and sodium hypochlorite is substituted.

There are LCA data gaps for all bulk chemicals commonly used in water treatment as these are not specifically included in existing LCA databases (WEF 2013) and have only recently been partially addressed. An LCA (Cradle-to-Gate) for eleven typical water treatment chemicals was completed by WEF; two of those chemicals used by TW, sulfuric acid and sodium hypochlorite, were included, as shown in the table below. Based on an analysis using the WESTweb tool, a factor for chlorine was identified and is included below (WESTweb 2018). Thus, climate LCA factors are available to compare for a total of three of the five water treatment chemicals purchased by TW in 2018, plus for sodium hypochlorite.

With the available data, below in rank order, is a numerical comparison of the relative LCA carbon intensity of alternative types of water treatment chemicals.

Table 8. Comparison of Global Warming Factors for Water Treatment Chemicals

Water Treatment Chemical	Global Warming Factor (g CO_2eq / kg)
Ammonium sulfate	2370
Chlorine (from WESTweb)*	1,357
Phosphoric acid, 85% in H_2O	1,210
Hydrochloric acid	1,170
Sodium hydroxide, 50% in H_2O	1,010
Quicklime, milled, packed	982

Sodium hypochlorite, 15% in H_2O	763
Hydrochloric acid, 30% in H_2O	735
Iron (III) chloride, 40% in H_2O	617
Aluminum sulfate, powder (Alum)	458
Sulfuric acid, liquid	86

*included for comparison

Source: WEF 2013. WESTweb 2018.

Chlorine's Global Warming Factor is almost twice as carbon intense as sodium hypochlorite. Sulfuric acid is low in carbon intensity; however, a comparison to other TW chemical purchases of hydrogen peroxide, ammonia and sodium bisulfate is not possible without additional LCA factors. These chemicals perform differing functions during water treatment and the substitution of alternatives would be subject to the process in use at each treatment stage.

8 Exclusions

Data availability limits TW from being able to measure and estimate all GHG emissions associated with the operation of the utility. The emissions sources described below are excluded.

8.1 Scope 1 Exclusions

- *Fugitive Emissions from TW owned vehicle fleet* – Leaking refrigerants from the TW fleet could not be determined for the CY 2018 due to a lack of data availability.

8.2 Relevant Scope 3 Exclusions

- *Emissions from Purchased (Contracted) Services* – Emissions from purchased services because of TW capital projects or operations could not be determined due to limitations in available information. ICELI recommends reporting this emissions category if data are available (ICELI 2010). In the future, TW could begin gathering this information by tracking overall construction expense completed by third party contractors or, more specifically, having contractors estimate emissions through tracking fuel use and materials purchased for construction or maintenance of TW projects and equipment.
- *Upstream production of emissions of purchased fuels* – Upstream emissions of purchased fuels were outside the scope of this inventory. This is an optional Scope 3 emissions source for reporting per the ICELI (2010) protocol.
- *Employee Commute* – Emissions from this category were excluded since employee commute data associated with TW employees could not be disaggregated from data

for all City staff (PAG 2020). This is a required Scope 3 emissions source for reporting per the ICELI (2010) protocol. It is recommended to review the current PAG methodology for *quantifying* the City's employee commute emissions and that TW arrange for future data collection to allow for disaggregation for TW to enable incorporating this information by category into future TW and City-wide inventories.

- *Processing, Use, and End-of-Life Treatment of Sold Products* – Emissions associated with the energy used by potable water consumers were not estimated for this inventory. This is an optional Scope 3 emissions source for reporting per the ICELI (2010) protocol. To estimate these emissions TW could create a tracking inventory of all purchased materials for utility operations on an annual basis.
- *Investments* – Emissions related to TW investments were not quantified for this inventory. This is an optional Scope 3 emissions source for reporting per the ICELI (2010) protocol. If TW has investments in securities quantifying and categorizing these investments by industry or sector and the amount invested could help estimate emissions associated with TW holdings.
- *Employee Business Travel* – Employee business travel is an optional Scope 3 emissions source for reporting per the ICELI (2010) protocol. TW does track travel through travel orders and purchasing. These data were not able to be included for CY 2018, and in the future, could be collected, compiled, and included per the guidance in the ICLEI protocol and input requirements of their ClearPath tool. Emissions from travel in personal vehicles for work and air travel can be investigated for incorporation in future TW inventories.

8.3 Non - Relevant Scope 3 Exclusions

- *Leased assets* – TW does not have a significant amount of leased assets. This is an optional Scope 3 emissions source for reporting per the ICELI (2010) protocol.
- *Franchises* – Not relevant for a public water utility This is an optional Scope 3 emissions source for reporting per the ICELI (2010) protocol.

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