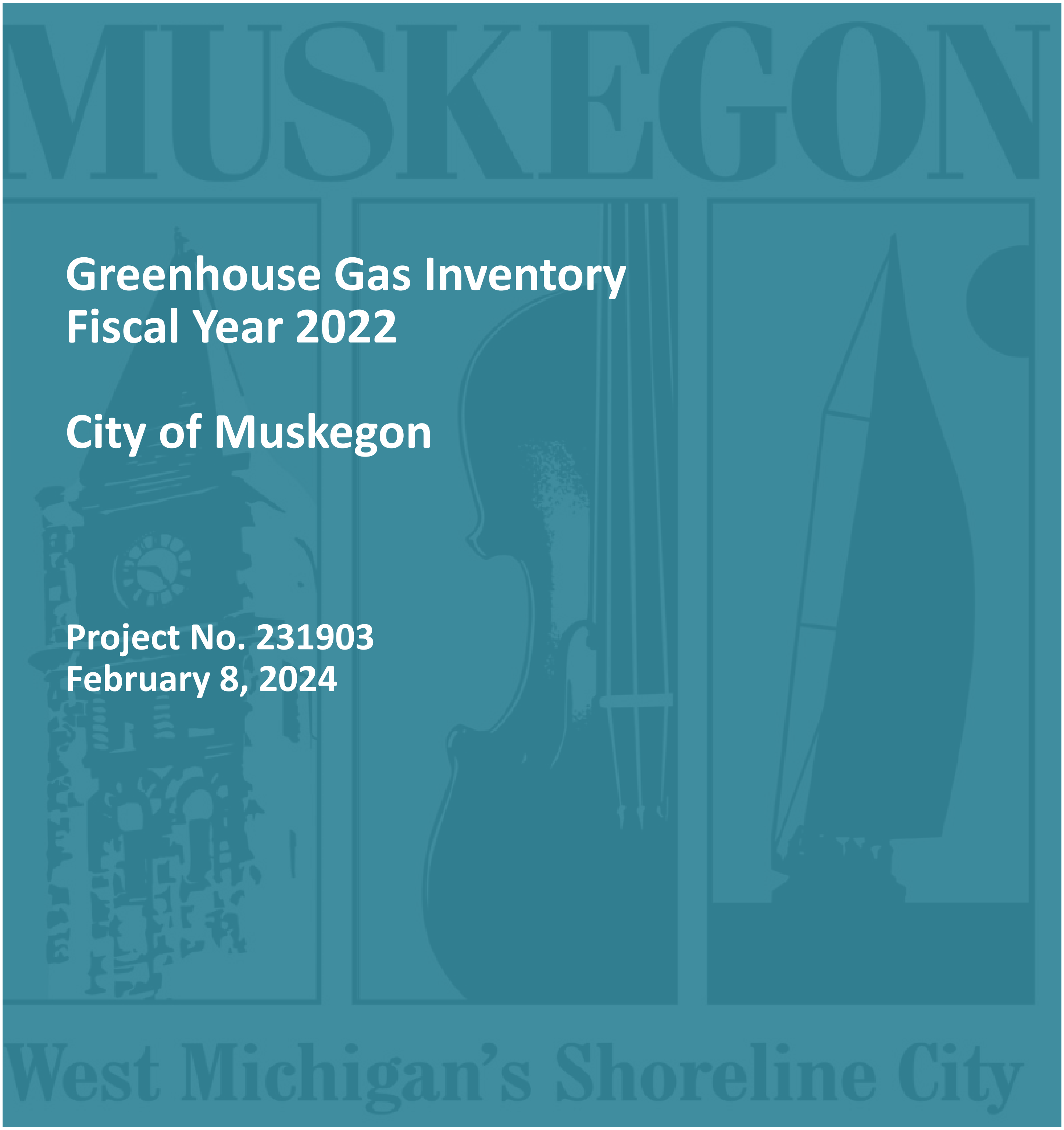

Greenhouse Gas Inventory Fiscal Year 2022

City of Muskegon

Project No. 231903
February 8, 2024

fishbeck
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Greenhouse Gas Inventory
Fiscal Year 2022

Prepared For:
City of Muskegon
Muskegon, Michigan

February 8, 2024
Project No. 231903

MUSKEGON
West Michigan's Shoreline City
www.shorelinecity.com

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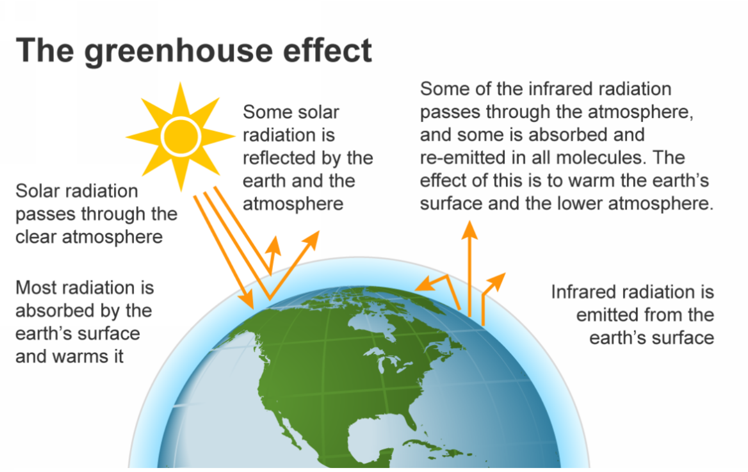
List of Abbreviations/Acronyms

CDP	Climate Disclosure Project
CH_4	methane
CH_4e	methane equivalent
City	City of Muskegon, Michigan
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
eGRID	Emissions & Generation Resource Integrated Database
FTE	full-time equivalent personnel
FY	Fiscal Year
GGP	Green Generation Program (Consumer’s Energy)
GWP	global warming potential
GHG	greenhouse gas
GWP	global warming potential
HFCs	hydrofluorocarbons
HVAC	heating, ventilation, and cooling
IPCC	The Intergovernmental Panel on Climate Change
kg	kilogram(s)
MGD	million gallon(s) per day
mt	metric tons
N_2O	nitrous oxide
N_2Oe	nitrous oxide equivalent
PE	Professional Engineer
PFCs	perfluorocarbons
Scope 1	direct emissions
Scope 2	indirect emissions
Scope 3	other indirect emissions by contractors
SF_6	sulfur hexafluoride
USEPA	U.S. Environmental Protection Agency
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute

Executive Summary

Fishbeck, on behalf of the City of Muskegon (City), has prepared this greenhouse gas (GHG) emission inventory for fiscal year (FY) 2022 (July 1, 2021 to June 30, 2022).[1] The City's goal is to eliminate or off-set their GHG emissions by 2040 without compromising city services.

GHGs are gases in the Earth's atmosphere that trap heat. They allow sunlight to pass through the atmosphere, but prevent the heat from that sunlight from the leaving the atmosphere, causing the earth to warm over time (i.e., climate change). Reducing GHGs is key to mitigating the risk of climate change.



Source: Adapted from U.S. Environmental Protection Agency

The first step for the City to take toward meeting this goal is to quantify the City's GHGs, and understand how City operations contribute to GHG emissions (also known as the City's carbon footprint). This inventory can then be used by the City to manage its GHG risks, identify reduction targets, and participate in voluntary or mandatory GHG reporting programs. The GHG emissions that were able to be quantified for the governmental operations in FY2022 were approximately **10,337 tons of carbon dioxide equivalent (CO_2e),[2] or 40 ton CO_2e per full-time equivalent personnel (FTE)**. Approximately 110,000 18-inch-diameter oak trees, or about 65,000 26-inch-diameter oak trees would be required to uptake/off-set the City's FY 2022 GHG emissions.[3]

Scope 1 and 2 emissions from City operations are direct and indirect GHG emissions, respectively.

Scope 1 Emissions (Direct GHG Emissions) are a result of the following City activities:

- Combustion of fuel or natural gas in facility boilers, furnaces, and generators
- Consumption of fuel oil or gasoline in City-owned/leased vehicles
- Combustion of propane in mobile equipment

Scope 2 Emissions (Indirect GHG Emissions) are a result of the following City activities:

- Purchased electricity for facility use.

Scope 3 Emissions are other indirect emissions, that result from activities by the City, but are not owned or controlled by the City, such as contractors or employee commuting to work. Scope 3 is an optional reporting category, which was outside of the organizational boundary for this GHG Inventory.

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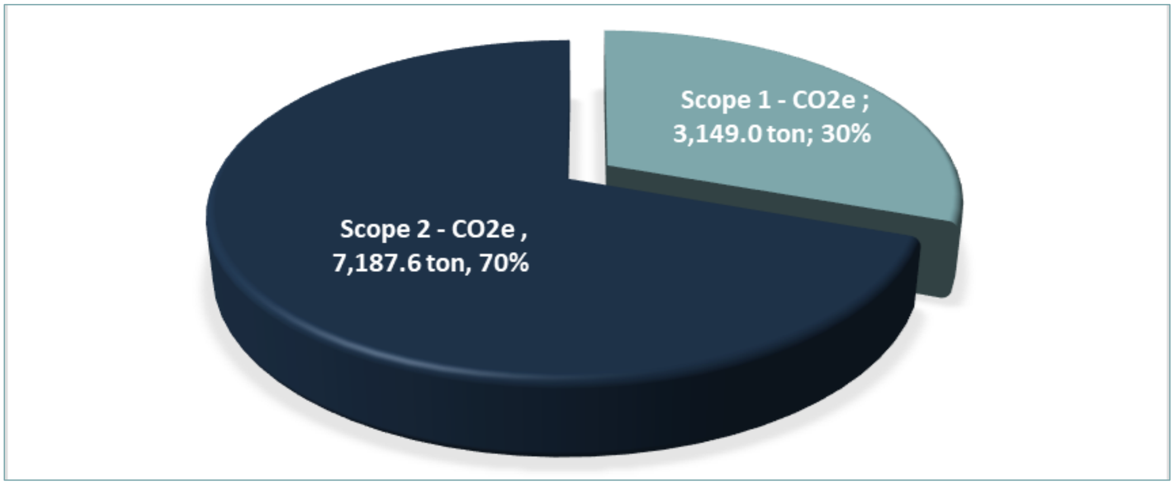
[1] FY2022 was selected because the quality of available data would produce the most accurate inventory – at the time of calculation, and it is the year for which the most recent audited financial information was available.

[2] CO_2e as presented in this report is measured in short tons; a short ton is 2,000 pounds. Picture a cube almost as tall, wide, and long as a telephone pole; that would hold approximately 1 short ton of CO_2e. For simplicity, we use tons of CO_2e herein.

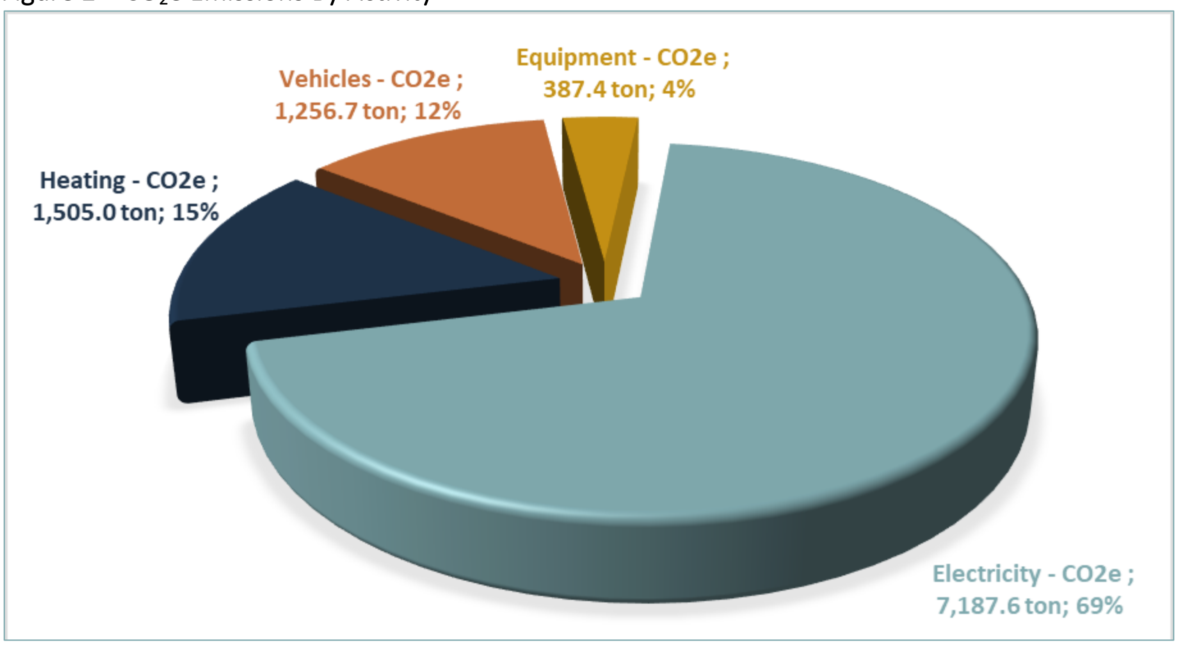
[3] My tree benefits - itreetools.org

Figure 1 – Muskegon CO_2e Emissions



The majority of the City's GHG emissions (approximately 70 %) result from purchased electricity (or Scope 2 Emissions)' more than 40% of the purchased electricity is for the water filtration plant.

Figure 2 – CO_2e Emissions By Activity



The City followed the GHG Emission Inventory Protocol established by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) as presented in the *Greenhouse Gas Protocol: Corporate Accounting and Reporting Standard* (WRI and WBCSD, September 2001) and further refined in the *Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard, Revised Edition* (WRI and WBCSD, 2015), hereafter referred to as the *GHG Protocol.*[4] These protocols were designed to address the Kyoto Protocol – a treaty developed to set binding obligations on industrialized nations to reduce their impacts on climate change. Additional tools from the USEPA were used, including the *Local Greenhouse Gas Inventory Tool* and *Center for Corporate Climate Leadership*.

[4] Note - we chose to report in English units, (i.e., pounds and short tons) in lieu of metric tonnes used in the protocol. A metric ton is approximately 2,204 pounds.

The GHG Protocol is the most widely used international accounting tool to quantify and manage GHG emissions. It is the framework used by most multinational companies, as well as by The Climate Registry (currently used in select areas of the U.S., Mexico, and Canada), the European Union Emission Trading Scheme, and the International Standards Organization.

1.0 Muskegon GHG Emission Philosophy

The City is committed to reducing its carbon footprint while continuing to provide its residents with efficient and superior infrastructure and services. In April 2023, the City Commission passed a resolution declaring the City's commitment to climate action initiatives and to combat the impact of climate change on the community and planet. The City is dedicated to reducing the risks of climate change by implementing actions that save money, improve productivity, and lower GHG emissions. The City intends to reduce its organizational GHG emissions through deliberative budget, policy, and administrative actions.

In an effort to reduce GHG emissions, the City must first understand its current GHG footprint and the drivers of those emissions. Therefore, the City Commission directed an organization-wide GHG Inventory which will be used by the City to set target reductions with the goal of eliminating the City's GHG emissions by 2040.

2.0 Introduction

The risk of climate change to governmental operations may include:

- Increased frequency and intensity of extreme weather, which can disrupt critical infrastructure, such as power grids, transportation systems, and water supply networks, leading to service disruptions and economic losses.
- Changes in Lake Michigan water levels may become more extreme. Warming temperatures can cause algal blooms and are more hospitable for invasive species. While heavy rainfall events can overwhelm drainage systems and cause water contamination. These issues can impact water supply, sanitation, and public health in cities. Alternately, droughts can lead to water scarcity.
- Rising temperatures can lead to increased heat stress, especially in urban areas. Heatwaves pose health risks, particularly for vulnerable populations, such as the elderly and those with pre-existing health conditions. This can strain cities first response services.
- Climate change can impact agricultural productivity and food supply chains, leading to food shortages and price volatility. Cities that are heavily reliant on imported food may face challenges in ensuring food security.
- Climate change-related disruptions can have significant economic consequences for cities. Damage to infrastructure, increased insurance costs, and decreased productivity due to extreme weather events can result in financial losses. Additionally, cities that rely on industries vulnerable to climate change, such as tourism or agriculture, may experience economic downturns.

Source: The Signs of Climate Change | A Student's Guide to Global Climate Change | USEPA

A 2021 U.S. Environmental Protection Agency (USEPA) analysis indicated that racial and ethnic minority communities are particularly vulnerable to the greatest impacts of climate change which can exacerbate existing social inequalities.[5] Vulnerable populations, such as low-income communities and marginalized groups, may be disproportionately affected due to limited resources and access to services. This can lead to social unrest and increased social disparities within cities.

To mitigate the risks of climate change, cities need to develop climate adaptation and resilience strategies, invest in infrastructure upgrades, and implement policies to reduce GHG emissions. "Having a climate-resilient economy—one that can withstand or recover quickly from climate impacts in the short and long terms—is essential to a community's well-being. Starting to plan now with climate and economic resilience in mind will help the community and its businesses protect themselves against short-term shocks such as storms, reduce the need (and cost) to recover from a shock, incorporate economic resilience into other planning efforts, and get a jump-start on pursuing new opportunities that might arise as the climate changes."[6]

Collaboration between local governments, local businesses and the community they serve is crucial to effectively address the risks of climate change to City operations. One of the first steps is to develop a framework for accounting and reporting GHG emissions resulting from City operations and activities. The purpose of the inventory is to provide baseline information, which will allow the City to make informed and effective policy decisions.

This document may be updated periodically as technologies evolve and budgets warrant. It is a basis upon which benchmarking can be further defined. The document is intended to allow the City leaders to formulate opportunities and select strategies the City wishes to pursue in striving to reduce its GHG emissions. For the first time, the City has gathered and analyzed data to provide a comprehensive understanding of GHG for all City facilities and fleet. Development of a baseline GHG inventory will allow the City to extend their history of leadership in environmental and economic sustainability and bring benefits to the local community for many years.

City team members responsible for providing information and data for this effort included:

- Peter Wills, Director of Government Relations & Strategic Operations
- Dan VanderHeide, PE, Public Works Director
- Jacqui Erny, Administrative Supervisor
- Jill J. Hernandez, Department of Public Works

3.0 Methodology

3.1 Organizational Boundaries

For the purposes of this GHG inventory, the City focused on its City operations, fleet, and equipment, as the City has both financial and operational control of these assets. City operations include City Hall, the Department of Public Works (DPW), Water Filtration Plant, Trinity Health Arena, three fire stations, police services, four cemeteries, 40 parks, and half of the Harvey Pump Station, as well as the associated 5 million gallon reservoir, 3 elevated water tanks, and 18 sanitary sewer lift stations. The following operations and activities are included in the FY2022 analysis:

- City-owned buildings
- Emergency generators
- Fleet vehicles

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[5] *EPA Report Shows Disproportionate Impacts of Climate Change on Socially Vulnerable Populations in the United States*

[6] Planning Framework for a Climate-Resilient Economy, USEPA, April 2016.

- Movable bridges
- Lighting infrastructure (includes street lights and parking facilities)
- Pump stations
- Water management infrastructure
- Equipment

GHG Emissions were summarized into several departments and Activities. A list of City departments and activities, along with GHG emissions is provided in Table 1.

The following activities were not included in the analysis due to the challenges in collecting the necessary data, or a lack of available data to support robust emissions calculations:

- Air travel
- Travel for City business in non-City vehicles
- Losses from heating, ventilating, and air conditioning (HVAC) equipment in City-owned or -operated buildings

If additional data is collected, GHG emissions from the activities listed above will be included in future inventories.

Table 1 - City Departments/Activities and GHG Emissions

Account/Department	Budgeted FTEs	CO_2e (ton)	CO_2e (tons/FTE)
Arena	6.00	2,186.4	364.4
Cemeteries	2.00	71.9	35.9
City Hall	31.55	718.7	22.8
Community & Neighborhood Services	5.30	2.6	0.5
Department of Public Works	8.75	7.6	0.9
Engineering	4.25	20.8	4.9
Equipment	6.25	158.0	25.3
Fire Department	29.50	704.0	23.9
Forestry	0.25	20.6	82.5
General	0.00	41.9	--
Highway	13.20	268.4	20.3
Marina	0.30	214.4	714.5
McGraft Park	0.15	21.0	140.2
Miscellaneous	0.00	7.8	--
Parks Maintenance	10.60	365.4	34.5
Planning	4.00	105.8	26.5
Police Department	91.00	554.9	6.1
Sanitation Department	0.20	3.3	16.6
Street Lighting	0.00	644.9	--
Traffic Services	7.20	17.8	2.5
Water Filtration Plant	12.15	3,661.1	301.3
Water & Sewer	25.85	539.4	20.9
Total	***258.50***	***10,336.7***	***40.0***

3.1.1 Water Management Infrastructure

The City's Water Filtration Plant is a 40 million gallon per day (MGD) capacity drinking water treatment facility located on the Lake Michigan shoreline near Pere Marquette Park.

The drinking water filtered through the City's plant serves a population of approximately 90,000 in the City and several neighboring communities, including: Dalton, Fruitland, Fruitport, Laketon, and Muskegon Townships, as well as the cities of North Muskegon, Norton Shores, and Roosevelt Park. Within these communities, the 12 MGD daily average (20 MGD peak) production is used by residential, commercial, and industrial users, in addition to supplying water to fire hydrants.

One of the largest expenses encountered in water treatment is electricity, the majority of which is used by the large pumps used to pump water to the communities the plant serves. The electricity purchased for the water treatment facility contributes to the City's indirect (or Scope 2) emissions. The Water Filtration Plant uses nearly 5 million kilowatt hours per year (kWh/yr). Because the Water Filtration Plant needs to run continuously, two large diesel generators are able to power the plant during power outages to ensure an uninterrupted supply of water. The diesel generators contribute to the City's direct (or Scope 1) emissions.

The water filtration plant is the single largest source of GHG emissions for the City; however, the emissions generated are also the result of servicing nearby communities. It is the City's intention to perform an analysis separating the GHG emissions generated to service the City's population from those generated to service neighboring communities.

3.2 Protocol Selection

The City followed the GHG Emission Inventory Protocol established by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) as presented in the *Greenhouse Gas Protocol: Corporate Accounting and Reporting Standard* (WRI and WBCSD, September 2001) and further refined in the *Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard, Revised Edition* (WRI and WBCSD, 2015), hereafter referred to as the *GHG Protocol*. These protocols were designed to address the Kyoto Protocol – a treaty developed to set binding obligations on industrialized nations to reduce their impacts on climate change. Additional tools from the USEPA were used, including the *Local Greenhouse Gas Inventory Tool* and *Center for Corporate Climate Leadership*.

The GHG Protocol is the most widely used international accounting tool to quantify and manage GHG emissions. It is the framework used by most multinational companies, as well as by The Climate Registry (currently used in select areas of the U.S., Mexico, and Canada), the European Union Emission Trading Scheme, and the International Standards Organization.

The 6 GHGs identified in the Kyoto Protocol, include:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur hexafluoride (SF_6)

Of these gases, City activities result predominately in emissions of CO_2, CH_4, and N_2O, which are released by the combustion of fossil fuels. The remaining gases in the Kyoto Protocol are man-made and are generally released through specific refrigeration and building cooling equipment as well as energy transmission activities.
Losses from refrigeration and building cooling equipment in City buildings were not evaluated as part of this GHG inventory.

A verification process is part of the GHG Protocol, developed to ensure that the data, assumptions, and procedures used to develop the inventory are reliable and defensible. The City has developed this inventory with the intent that it could be verified by a third-party auditor.

3.2.1 Emission Sources

Scope 1 and 2 emissions from City operations are direct and indirect GHG emissions, respectively.

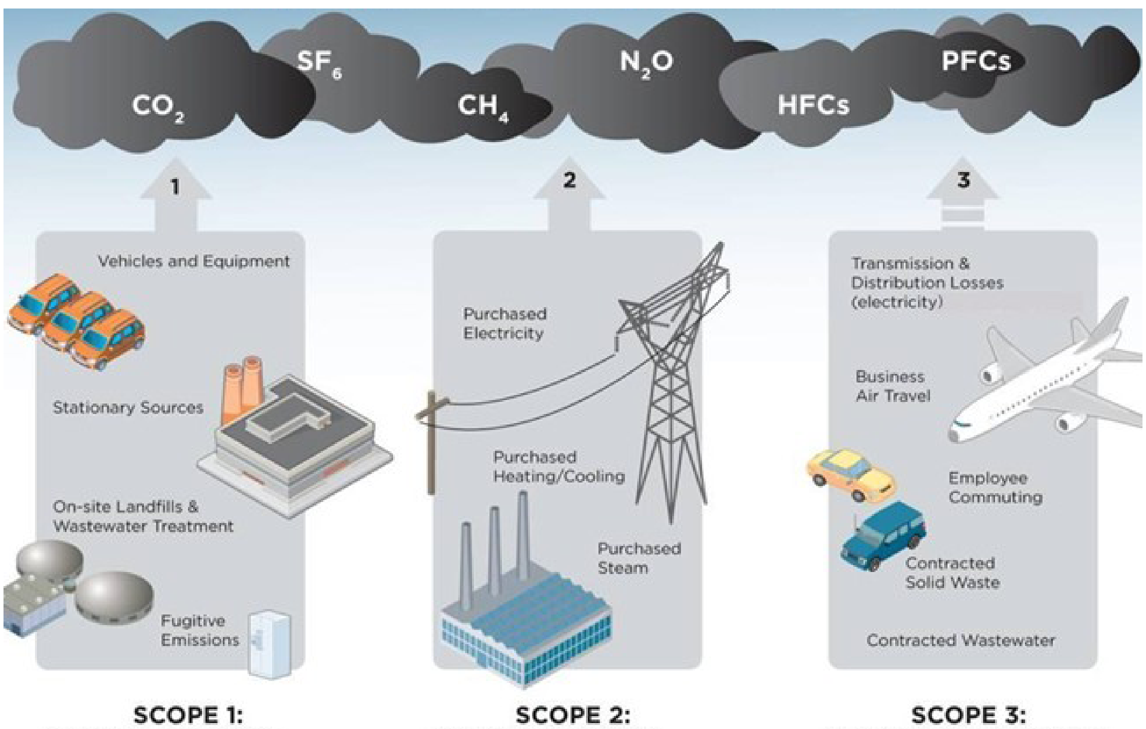
Scope 1 Emissions (Direct GHG Emissions) are a result of the following City activities:

- Combustion of fuel or natural gas in facility boilers, furnaces, and generators
- Consumption of fuel oil or gasoline in City-owned/leased vehicles
- Combustion of propane in mobile equipment

Scope 2 Emissions (Indirect GHG Emissions) are a result of the following City activities:

- Purchased electricity for facility use.

Scope 3 Emissions are other indirect emissions by contractors. Scope 3 is an optional reporting category that allows for the accounting of all other indirect emissions which are a consequence of the activities of the City, but occur from sources not owned or controlled by the City. Some examples of Scope 3 activities are extraction and production of purchased materials, transportation of purchased fuels, and use of sold products and services. Scope 3 emissions were outside of the organizational boundary for this GHG inventory.



Source: https://www.epa.gov/greeningepa/greenhouse-gases-epa

3.2.2 Data Sources

The data used to calculate Scope 1 and Scope 2 GHG emissions came from sources and matrices already recorded and maintained by City Facilities personnel or by contacting utility companies. These data include:

- Electricity consumption
- Natural gas consumption
- Fuel oil consumption
- Vehicle fuel consumption

3.2.3 Reporting Year

A primary aspect of the GHG emissions inventory process is the requirement to select an appropriate baseline year with which to compare emissions among time periods. Although the City signed the *U.S. Council of Mayors Climate Protection Agreement*, which recommends using 1990 as the baseline year, this would prove difficult for the City because the quality of available data would not produce an accurate inventory.

The City established FY2022 as the baseline year. At the time the baseline year was selected/calculations performed, FY2022 was the year for which the most recent **audited** financial information was available.

3.2.4 Emission Factors

Emission factors for the most common emission sources at City facilities are from the *USEPA Center for Corporate Climate Leadership GHG Emission Factors Hub* (modified September 2023). Emission factors included in the hub are :

- Stationary combustion sources
- Mobile combustion sources for on-road vehicles (1973 to 2020)
- Mobile combustion sources for non-road vehicles
- Emissions & Generation Resource Integrated Database (eGRID 2021)

All GHGs are calculated separately and converted to CO_2e on the basis of their global warming potential (GWP) provided in The Intergovernmental Panel on Climate Change (IPCC), Fourth Assessment Report, 2007. The GWPs were developed to compare the global warming impacts of different gases relative to CO_2. The larger the GWP the more that gas warms the earth when compared to CO_2. For instance, the GWP for N_2O is 25 times that of CO_2, and the GWP of CH_4 is 298 times that of CO_2. All GHGs in this analysis are presented as their CO_2e value. A summary of the City's GHG emissions is provided in Appendix 1.

Emission factors used in the calculations are summarized in the facility workbooks developed for the City and are presented in Appendix 2.

3.2.5 Emission Calculations

In general, emissions were calculated by multiplying the fuel usage or electric consumption by the emission factors described in 3.2.4. For example, the CO_2 emissions from electric usage at the Terrace St Fire Station was calculated as follows:

$$CO2\left(\frac{lb}{yr}\right) = 576.6\ \frac{MWh}{yr}\ of\ Electric\ Used\ x\ 1{,}214.1\,\frac{lb\ CO2}{MWh}$$

$$CO2\ emissions\left(\frac{lb}{yr}\right) = 699{,}807.24\,\frac{lb}{yr}$$

All GHG emissions were then converted to CO_2e using global warming potentials as follows:

$$CO2e\left(\frac{ton}{yr}\right) = \frac{\left(CO2\left(\frac{lb}{yr}\right)x\ 1 + CH4\left(\frac{lb}{yr}\right)x\ 25 + N2O\left(\frac{lb}{yr}\right)x\ 298\right)}{2000\,\frac{lb}{ton}}$$

Emissions were calculated in an Excel-based workbook, which was populated with the City's raw consumption data and applicable emission and conversion factors. The complete workbook was provided to the City under separate cover.

3.2.6 Renewable Energy Credits and Biofuels

Renewable energy and biofuels were not evaluated as part of the GHG inventory.

The City purchases energy through Consumers Energy, which has a program called the *Green Generation Program* (GGP).[7] The GGP is governed by tariff which is approved by the Michigan Public Service Commission (MPSC). According to the 2019 GGP Terms and Conditions, Consumers Energy purchases renewable energy from a number of qualified renewable generating facilities in the state of Michigan. Supply for the GGP is produced in Michigan and is made up of approximately 70% wind and 30% biomass. The City does not currently participate in the GGP. In the future, should the City elect to participate in the GGP or other renewable energy credit, then GHG emissions from electricity usage may be off-set.

Source: https://www.epa.gov/air-research/energy-and-environment-research

Biofuels, such as biodiesel and gasoline ethanol blends, have historically been considered *biogenic emissions*, and therefore carbon neutral. However, according to the Climate Disclosure Project (CDP) Biofuels Technical Note,[8] *It is challenging to draw overarching conclusions about the environmental impacts of biofuels*. The CDP suggests that sources should mitigate negative impacts by purchasing sustainably produced (and certified) biofuels. For the City's inventory, biofuels were not included in fuel purchase records; however, should the City determine that purchasing biofuel in lieu of non-biofuels to mitigate the City's future carbon impact, the source of the biofuels should be carefully evaluated.

4.0 Assumptions and Uncertainty Assessment

Generally, emissions are based on the purchase records and the assumption that all materials were processed, consumed, wasted, or emitted. However, for certain activities, site-specific knowledge of the activity and/or emission factors are used to determine actual emissions. For this inventory, the assumption is that the information provided by the City is accurate and verifiable through any audit process. The quality of this GHG inventory is reliant on this assumption.

The most reliable data available was used and this inventory fairly represents the City's GHG emissions; however, there are uncertainties associated with the emission estimates. Select estimates, such as those for CO_2 emissions from energy-related activities, are considered to have low levels of uncertainty. For other categories of emissions, such as the emissions from vehicle use, increases the uncertainty level associated with the estimates presented (e.g., lack of data or details regarding the vehicle make/model, driving habits surface roads/highway, etc.). As part of this evaluation, the City provided vehicle fuel usage and mileage based on data reported to the City's fuel supplier Van Manen. CO_2 emission factors from vehicles are determined based on fuel usage, while CH_4 and N_2O emission factors are based on mileage. Fuel usage records are considered accurate, as they are recorded using the City's fuel pump meters. For vehicle mileage, the records rely on data entry by employees. In some instances, vehicle mileage data entry appeared to have typographical errors. The City has 159 vehicles and it was not possible to manually assess each vehicles odometer readings; therefore, the City elected to calculate emissions of CH_4 and N_2O based on gallons of fuel multiplied by the emission factors in gram per mile converted to gram per gallon, based on USEPA Community GHG Inventory Tool, which provides an average mile per gallon for different vehicle types. Additionally, emission factors for vehicles were currently only available through model year 2020.

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7 Microsoft Word - 1605 3-2018 (consumersenergy.com)

8 CDP-technical-note-on-biofuels.pdf

For vehicles with model years 2021 to 2023, the emission factors for model year 2020 were used. In addition, for vehicles where the model year was not readily available, the City elected to use model year 2015 emission factors. For City vehicles, it should also be noted that calculating emissions based on mileage for certain vehicles may have inherent uncertainties. For example, many City owned vehicles, such as Police and Maintenance vehicles may idle for longer periods of time than the vehicles used to develop the emission factor averages in the USEPA emissions hub.

As this is the first year the City has developed a GHG inventory, the City can work toward improving the quality and accuracy of the data collected and used for future inventories. This includes more accurate mileage record keeping and may include developing a data base for each new vehicle purchased or leased, which includes the manufacturer's emission related data for the specific vehicle.

5.0 Findings

5.1 Muskegon GHG Inventory

5.1.1 GHG Emissions

The City's GHG emissions from the activities for which there was adequate data are **10,336.67 tons** of CO_2e. A summary of the GHG emissions from City Departments is presented in Table 2

Table 2 – Greenhouse Gas Emissions by Department

Account/Department	CO_2 (ton)	CH_4 (lb)	N_2O (lb)	CO_2e (ton)	%Scope 1	% Scope 2
Arena	2,175.30	329.30	46.58	2,186.36	25%	75%
Cemeteries	71.56	8.81	1.31	71.87	46%	54%
City Hall	715.28	105.32	14.34	718.73	28%	72%
Community & Neighborhood Services	2.60	0.01	0.00	2.60	100%	0%
Department of Public Works	7.60	0.07	0.07	7.61	100%	0%
Engineering	20.75	0.42	0.14	20.78	100%	0%
Equipment	153.66	35.17	26.08	157.98	100%	0%
Fire Department	700.47	86.97	16.47	704.01	44%	56%
Forestry	20.25	1.63	2.38	20.63	100%	0%
General	40.97	6.68	5.97	41.94	100%	0%
Highway	265.99	15.44	14.62	268.36	100%	0%
Marina	213.01	41.80	5.55	214.36	5%	95%
McGraft Park	20.90	3.96	0.55	21.03	0%	100%
Miscellaneous	7.83	0.10	0.01	7.83	100%	0%
Parks Maintenance	362.42	66.99	14.29	365.38	47%	53%
Planning	105.22	18.62	2.63	105.84	7%	93%
Police Department	554.79	1.73	0.44	554.88	100%	0%
Sanitation Department	3.30	0.04	0.11	3.31	100%	0%
Street Lighting	640.87	121.41	16.89	644.90	0%	100%
Traffic Services	17.83	0.07	0.10	17.85	100%	0%
Water Filtration Plant	3,640.81	611.33	84.54	3,661.05	14%	86%
Water & Sewer	535.93	68.53	17.25	539.36	45%	55%
Total	*10,277.33*	*1,524.37*	*270.35*	*10,336.67*	**30%**	**70%**

City Emissions can be categorized as Scope 1 – Direct Emissions or Scope 2 – Indirect Emissions. The emissions illustrated in Figures 3 to 5 present the Scope 1 (Heating, Vehicles, Equipment) emissions by department.

Figure 3 – Scope 1 (Heating) Emissions by Department

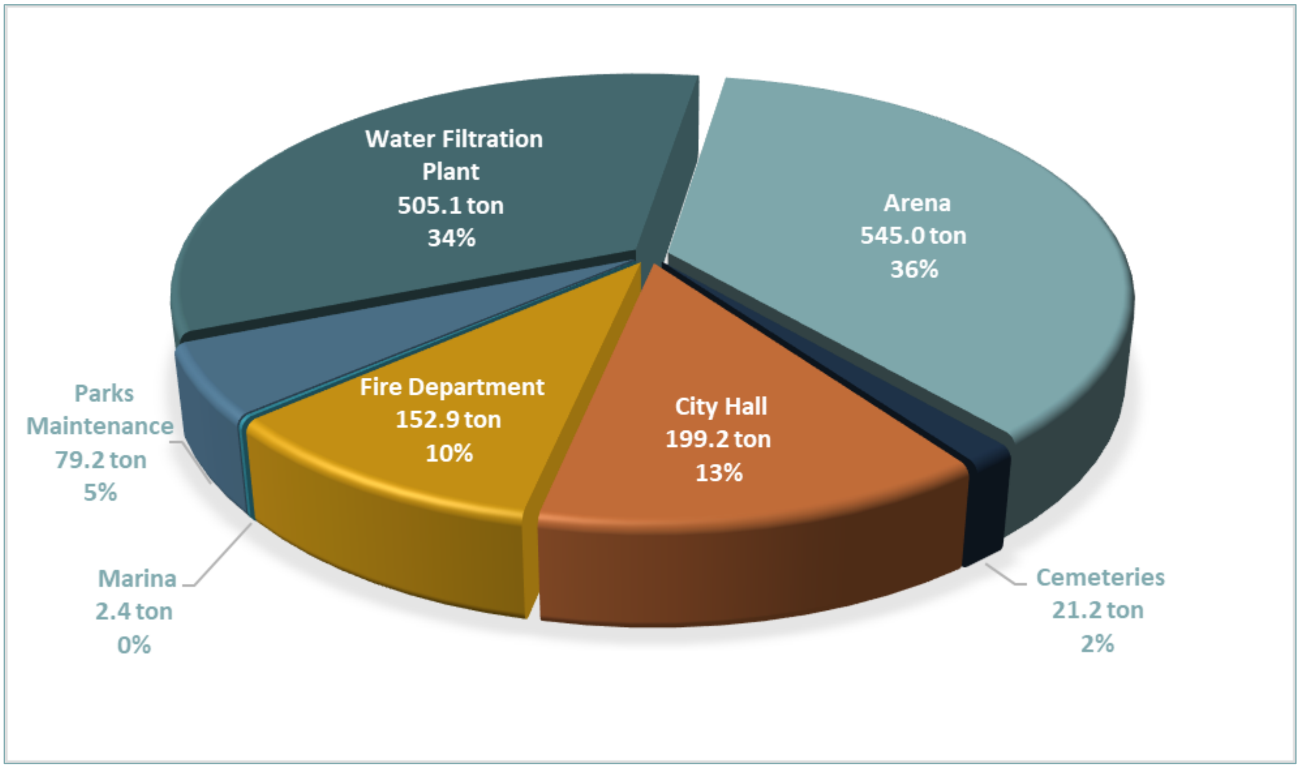


Figure 4 – Scope 1 (Vehicles) Emissions by Department

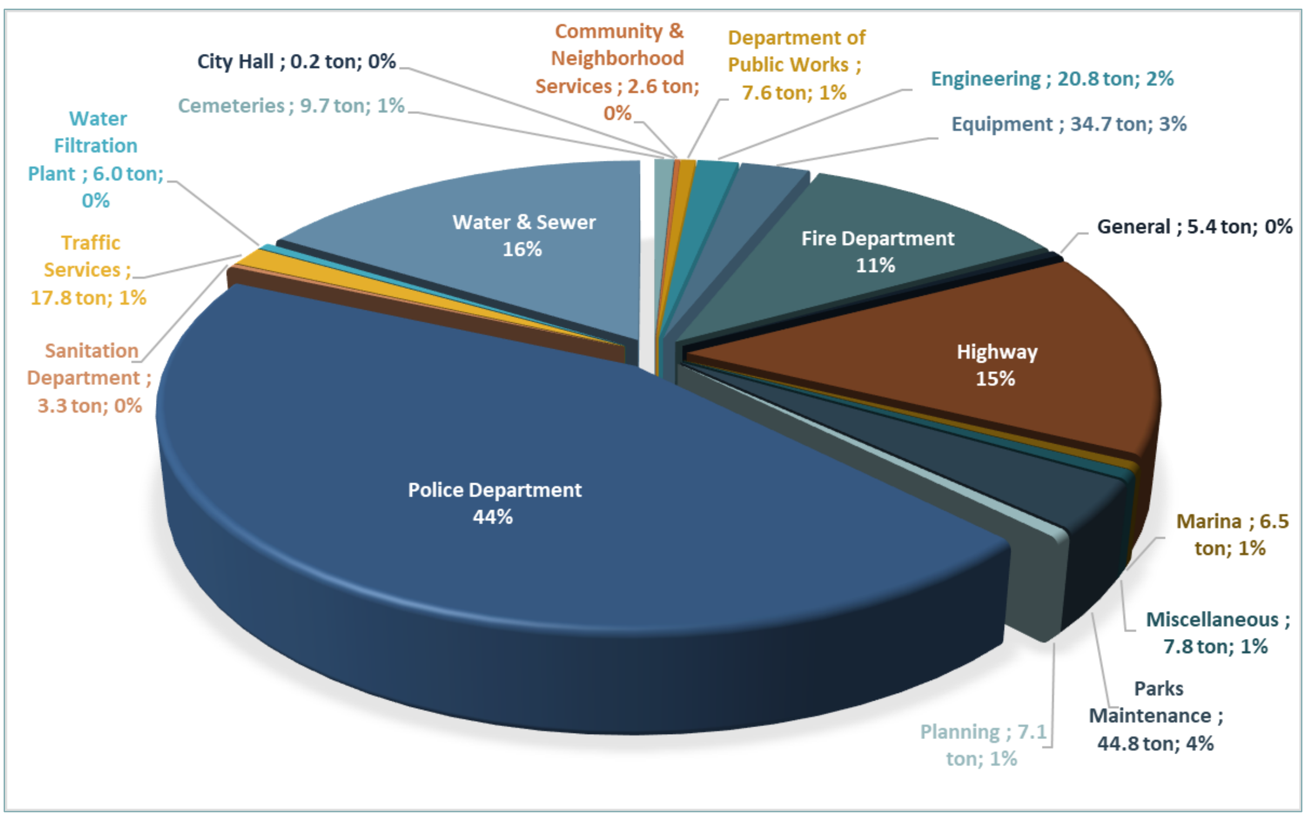
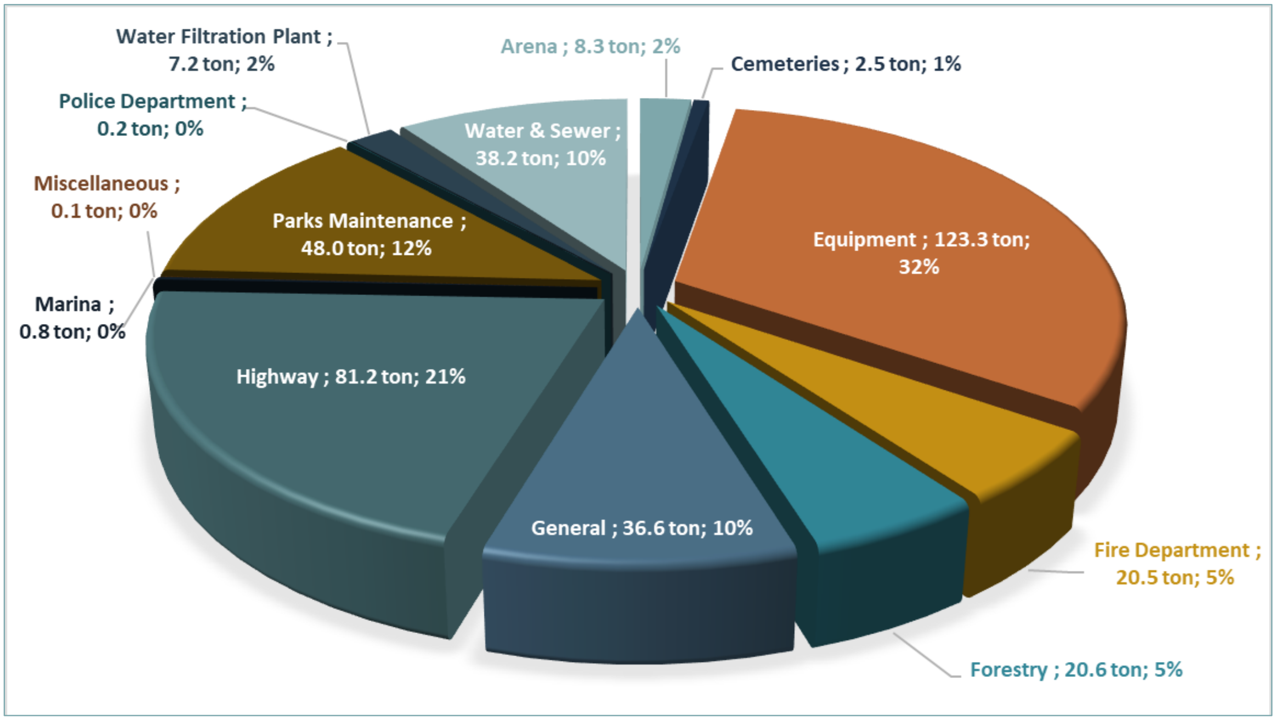
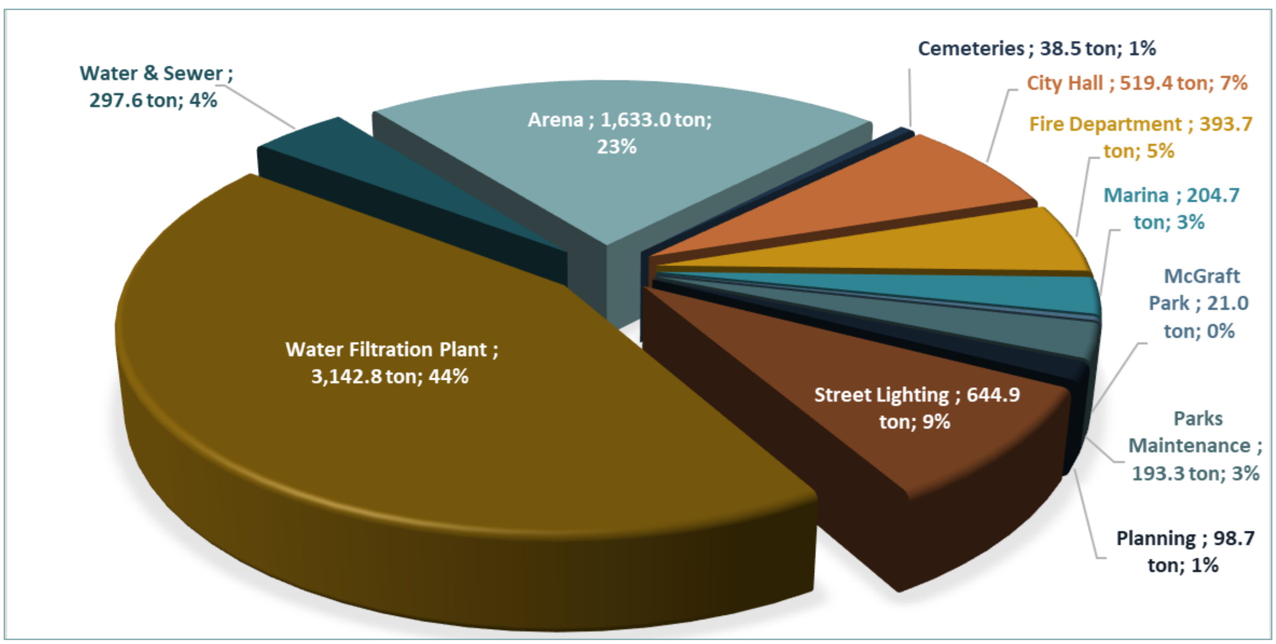


Figure 5 – Scope 1 (Equipment) Emissions by Department



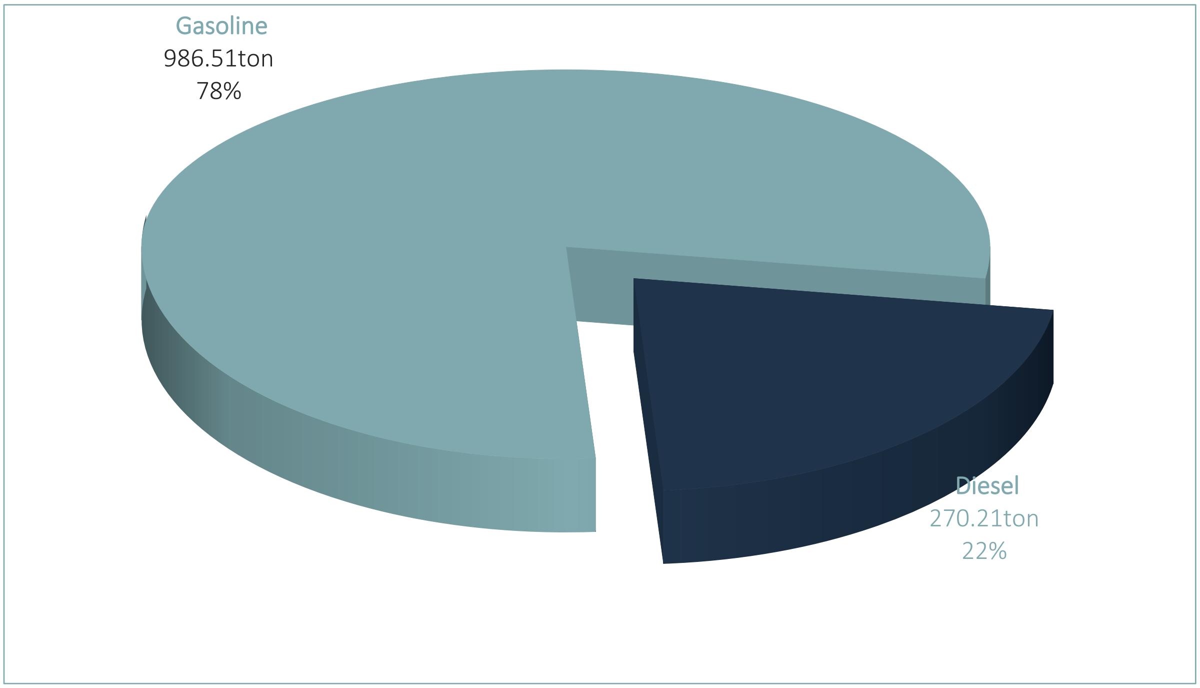
The GHG from purchased electricity accounts for 70% of the City's emissions; more than 40% of the emissions are from the water filtration plant. The emissions illustrated in Figure 6 present the Scope 2 (electricity) emissions by department.

Figure 6 – Scope 2 (Electricity) Emissions by Department



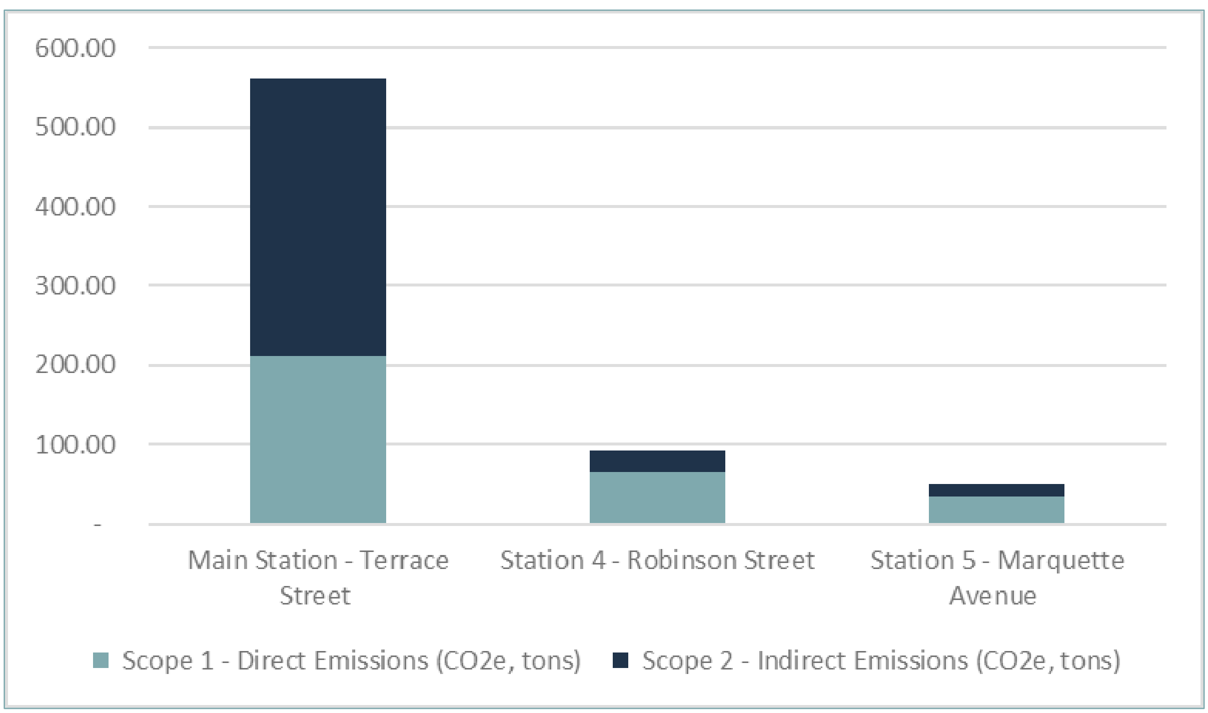
Based on the data available, GHG emissions from vehicles account for 12% of the City's emissions. As illustrated in Figure 4, emissions are from the combustion of gasoline and diesel fuel.

Figure 7 – Sources of CO_2e Vehicle Emissions by Fuel Type



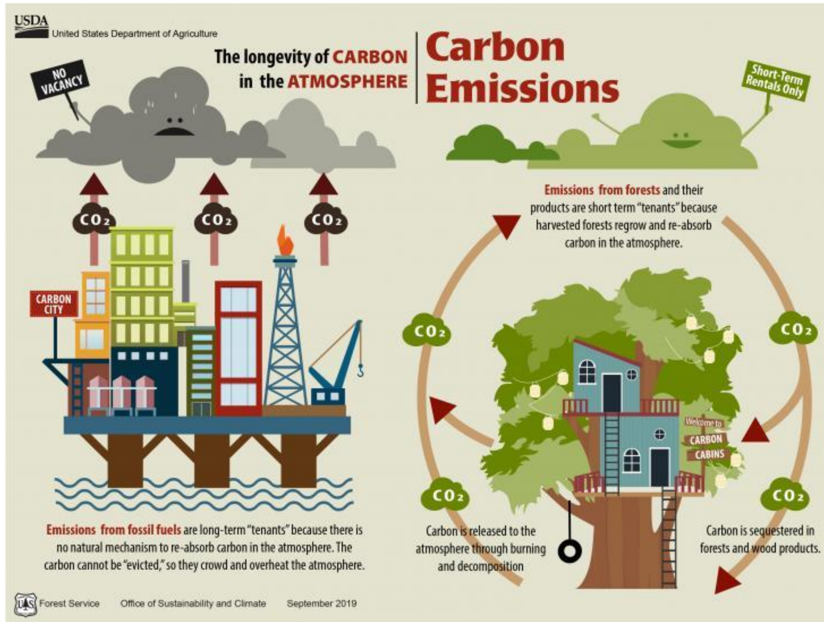
The City has three Fire Stations, emissions from each of the fire stations are provided in Figure 8.

Figure 8 – CO_2e Emissions by Fire Department



6.0 Carbon Sinks

Now that a baseline of the City's GHG emissions has been established, future inventories can use the City's carbon sinks to counteract GHG emissions. **Carbon sinks** are *features that naturally remove carbon from the atmosphere for temporary storage, such as trees and compost yards*. Across the City, thousands of trees form a canopy which serves as a carbon sink. This canopy is primarily made up of oak trees, which are one of the most effective deciduous trees for absorbing carbon. This canopy is supplemented by the City's compost yard. This yard is primarily non-residential; however, it is open to residents for a fee. The compost at the yard is composed of wood and leaf waste and lawn clippings. As the organic materials in the compost yard break down, they pull carbon from the atmosphere and trap it in the soil.



According to itreetools.org, which is a peer-reviewed software suite from the USDA Forest Service that provides urban and rural forestry analysis, a 30-inch-diameter northern red oak tree located in Muskegon and in good condition can absorb an equivalent of 4.5 tons of CO_2 over 20 years. Using the itreetools.org website, Fishbeck estimated the number of red oak trees it would take to absorb the City's GHG emissions for FY2022.

Table 3 – Red Oak CO_2 Sequestration

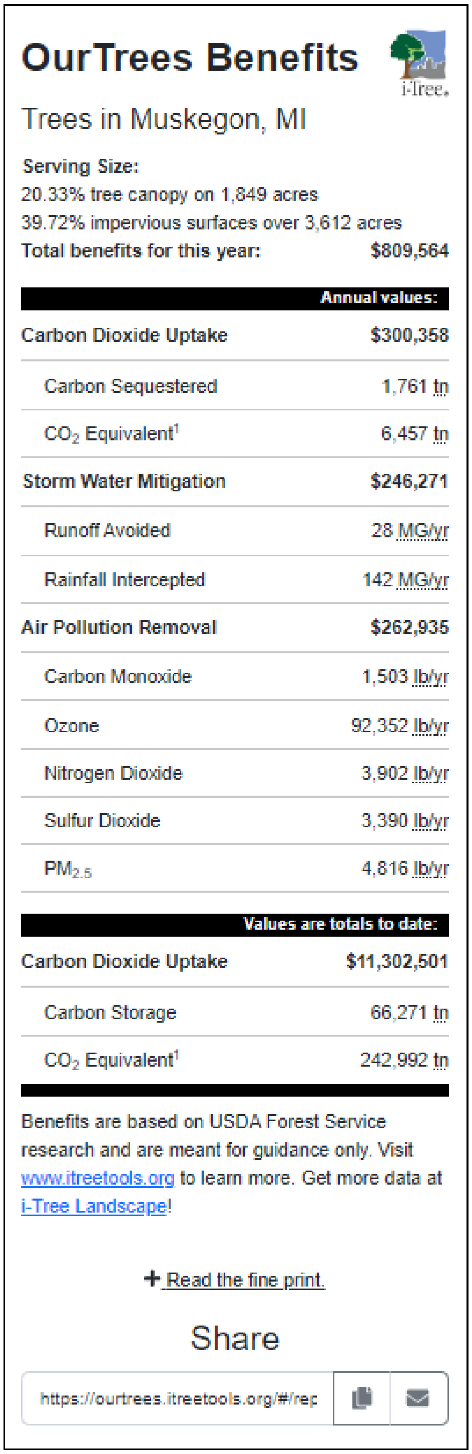
Diameter at DBH (inches)	Red Oak Estimated Age (years)	CO_2 Sequestration (lb/tree/yr)	No. of Trees Needed to Off-Set
10.00	40.00	83.86	246,522.01
12.00	48.00	107.79	191,792.70
14.00	56.00	134.02	154,255.60
16.00	64.00	161.89	127,699.89
18.00	72.00	191.28	108,078.92
20.00	80.00	222.10	93,081.20
22.00	88.00	254.24	81,315.21
24.00	96.00	287.71	71,854.77
26.00	104.00	322.36	64,131.21
27.00	108.00	340.13	60,780.69
28.00	112.00	358.17	57,719.34
30.00	120.00	395.09	52,325.64

MyTree (itreetools.org)
Diameter at breast height, or DBH, is the standard for measuring trees. DBH refers to the tree diameter measured at 4.5 feet above the ground

Growth Factor for Red Oak per DBH 4.00

2022 GHG Emissions 20,673,335.59 lb CO_2e

The i-Tree website also provides a canopy evaluation for certain areas, which included Muskegon. The following graphics represent the output for the Muskegon area.[9]



OurTrees Benefits

i-Tree.

Trees in Muskegon, MI

Serving Size:
20.33% tree canopy on 1,849 acres
39.72% impervious surfaces over 3,612 acres

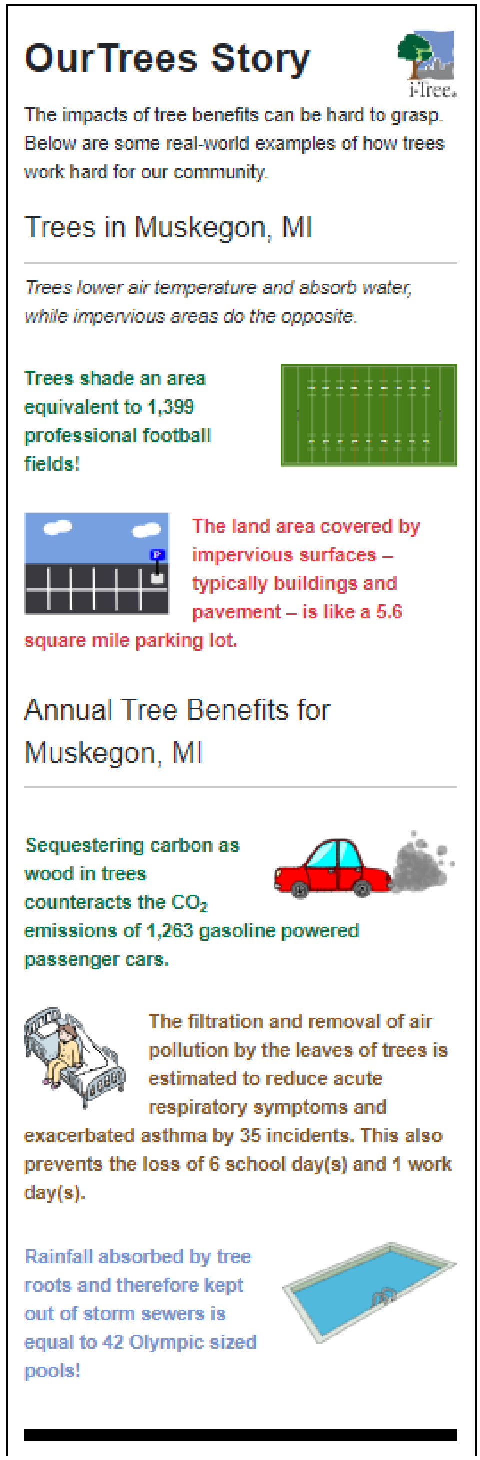
Total benefits for this year:	**$809,564**
	Annual values:
Carbon Dioxide Uptake	**$300,358**
Carbon Sequestered	1,761 tn
CO_2 Equivalent[1]	6,457 tn
Storm Water Mitigation	**$246,271**
Runoff Avoided	28 MG/yr
Rainfall Intercepted	142 MG/yr
Air Pollution Removal	**$262,935**
Carbon Monoxide	1,503 lb/yr
Ozone	92,352 lb/yr
Nitrogen Dioxide	3,902 lb/yr
Sulfur Dioxide	3,390 lb/yr
$PM_{2.5}$	4,816 lb/yr
	Values are totals to date:
Carbon Dioxide Uptake	**$11,302,501**
Carbon Storage	66,271 tn
CO_2 Equivalent[1]	242,992 tn

Benefits are based on USDA Forest Service research and are meant for guidance only. Visit www.itreetools.org to learn more. Get more data at i-Tree Landscape!

+ Read the fine print.

Share

https://ourtrees.itreetools.org/#/rep



OurTrees Story

i-Tree.

The impacts of tree benefits can be hard to grasp. Below are some real-world examples of how trees work hard for our community.

Trees in Muskegon, MI

Trees lower air temperature and absorb water, while impervious areas do the opposite.

Trees shade an area equivalent to 1,399 professional football fields!

The land area covered by impervious surfaces – typically buildings and pavement – is like a 5.6 square mile parking lot.

Annual Tree Benefits for Muskegon, MI

Sequestering carbon as wood in trees counteracts the CO_2 emissions of 1,263 gasoline powered passenger cars.

The filtration and removal of air pollution by the leaves of trees is estimated to reduce acute respiratory symptoms and exacerbated asthma by 35 incidents. This also prevents the loss of 6 school day(s) and 1 work day(s).

Rainfall absorbed by tree roots and therefore kept out of storm sewers is equal to 42 Olympic sized pools!

[9] Benefits are based on USDA Forest Service research and are meant for guidance only. Visit www.itreetools.org to learn more. Get more data at i-Tree Landscape!

7.0 Conclusions and Initial Implementation Action Plan

7.1 Recommendations for Future GHG Emission Inventories

To improve the GHG inventory for City operations, Fishbeck proposes the following recommendations:

- Implement a process for better verification of mileage entered for City-owned vehicles.
- Collect vehicle make and model data for employees using personal or other non-City controlled vehicles for business travel.
- Request refrigerant replacement data from HVAC maintenance contractors.
- Begin to develop a Community-wide GHG inventory which includes public participation.

7.2 Recommendations for GHG Emission Reductions

As the goal of this process is to set a City baseline to be used for future GHG reduction tracking, following are potential areas for the City to consider for GHG emission reductions :

- City-owned and operated buildings are responsible for more than 30% of the total emissions. Recommendations for building energy reductions include:
  - Establish an exhaust fan control strategy and obtain control by setpoint adjustments, control modifications, and rewiring where necessary. Generally, exhaust and make up air systems use excess energy due to lack of controlled operation.
  - Reduce excessive lighting in buildings with foot candle levels above the recommended level of 35, as long as it is appropriate for the activities in a particular facility.
  - Replace aging light fixtures with LED or modern fluorescent systems.
  - Establish minimum design and energy efficiency construction requirements for all new and renovated City buildings.
  - Keep exterior fixtures free of bug debris to provide more light and to dissipate fixture heat.
  - Evaluate demand and capacity of domestic hot water systems in buildings to facilitate optimization.
  - Install aerators in lavatory faucets to reduce flow.
- For City fleet vehicles, as replacement opportunities arise, and the infrastructure exists or can be installed to support it, alternative fuel vehicles should be considered,[10] including:
  - **Biodiesel** – Sustainable Biodiesel is a clean burning, renewable alternative fuel produced from vegetable oils or animal fats and which can be blended with petroleum diesel to create a biodiesel blend.
  - **Ethanol** – Sustainable Ethanol can be blended with gasoline in varying quantities. E85, a mixture of 85% ethanol and 15% unleaded gasoline, is an alternative fuel for use in flexible fuel vehicles.
  - **Electricity** – Vehicles that run on electricity have no tailpipe emissions.
  - **Compressed Natural Gas** – Natural gas that is extracted from wells and compressed. Natural gas vehicles have been found to produce fewer GHG emissions than gasoline vehicles.
  - **Hydrogen**[11] – Hydrogen Fuel Cells is a renewable alternative fuel that can be used to create electricity with the only resulting emission being water vapor.
- Use of low-rolling resistance tires in larger City fleet trucks.
- Use of conference calling and video meetings in lieu of travel for routine meetings.

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[10] CDP Recommends – Organizations *should put in place a biofuels strategy, which includes long-term targets on the use of biofuels and definitions of what they consider sustainable biofuel. Companies should assess the local and regional context to determine what biofuels are most appropriate for their needs. Factors influencing their decisions could include market availability, preferences for local production, and other sustainability considerations. Finally, any sustainability-related requirements should be included in biofuel supplier contracts where possible*.

[11] Producing hydrogen is energy intensive and may come from cracking natural gas (Grey or Blue Hydrogen). For sustainability purposes, Green Hydrogen, which is produced by passing electricity generated from renewable sources through water, results in low carbon emissions.

Appendix 1

GHG Emission Summary

Muskegon Greenhouse Gas Emission Inventory

City of Muskegon

		Electric Emissions (Consumers)					Natural Gas Emissions (DTE)				
Account/Department	Budgeted FTEs	CO2 (lb)	CH4 (lb)	N2O (lb)	CO2e (lb)	CO2e (ton)	CO2 (lb)	CH4 (lb)	N2O (lb)	CO2e (lb)	CO2e (ton)
Arena	6.00	3,245,522.3	307.42	42.77	3,265,953.46	1,633.0	1,088,986.3	20.6	2.0	1,090,097.5	545.0
Cemeteries	2.00	76,545.4	7.25	1.01	77,027.23	38.5	42,270.9	0.8	0.1	42,314.1	21.2
City Hall	31.55	1,032,212.0	97.77	13.60	1,038,710.02	519.4	398,021.2	7.5	0.7	398,427.3	199.2
Community & Neighborhood Services	5.30	-	-	-	-	-	-	-	-	-	-
Department of Public Works	8.75	-	-	-	-	-	-	-	-	-	-
Engineering	4.25	-	-	-	-	-	-	-	-	-	-
Equipment	6.25	-	-	-	-	-	-	-	-	-	-
Fire Department	29.50	782,486.2	74.12	10.31	787,412.14	393.7	305,498.0	5.8	0.6	305,809.8	152.9
Forestry	0.25	-	-	-	-	-	-	-	-	-	-
General	0.00	-	-	-	-	-	-	-	-	-	-
Highway	13.20	-	-	-	-	-	-	-	-	-	-
Marina	0.30	406,807.3	38.53	5.36	409,368.21	204.7	4,740.8	0.1	0.0	4,745.6	2.4
McGraft Park	0.15	41,805.1	3.96	0.55	42,068.28	21.0	-	-	-	-	-
Miscellaneous	0.00	-	-	-	-	-	-	-	-	-	-
Parks Maintenance	10.60	384,278.4	36.40	5.06	386,697.54	193.3	158,269.9	3.0	0.3	158,431.4	79.2
Planning	4.00	196,252.0	18.59	2.59	197,487.43	98.7	-	-	-	-	-
Police Department	91.00	-	-	-	-	-	-	-	-	-	-
Sanitation Department	0.20	-	-	-	-	-	-	-	-	-	-
Street Lighting	0.00	1,281,739.9	121.41	16.89	1,289,808.75	644.9	-	-	-	-	-
Traffic Services	7.20	-	-	-	-	-	-	-	-	-	-
Water Filtration Plant	12.15	6,246,295.6	591.65	82.32	6,285,617.28	3,142.8	1,009,089.3	19.1	1.9	1,010,118.9	505.1
Water & Sewer	25.85	591,382.0	56.02	7.79	595,104.91	297.6	-	-	-	-	-
		Electricity	Electricity	Electricity	Electricity	Electricity	Natural Gas	Natural Gas	Natural Ga	Natural Gas	Natural Gas
Total Emissions	258.50	14,285,326.3	1,353.11	188.26	14,375,255.23	7,187.6	3,006,876.4	56.9	5.5	3,009,944.6	1,505.0

GHG Emission Summary
Muskegon Greenhouse Gas Emission Inventory
City of Muskegon

		Vehicle Emissions (Van Manen)					Equipment Emissions (Van Manen)				
Account/Department	Budgeted FTEs	CO2 (lb)	CH4 (lb)	N2O (lb)	CO2e (lb)	CO2e (ton)	CO2 (lb)	CH4 (lb)	N2O (lb)	CO2e (lb)	CO2e (ton)
Arena	6.00	-	-	-	-	-	-	-	-	-	-
Cemeteries	2.00	19,493.1	0.08	0.00	19,495.92	9.7	4,818.0	0.7	0.2	4,902.1	2.5
City Hall	31.55	323.8	0.01	0.00	325.07	0.2	-	-	-	-	-
Community & Neighborhood Services	5.30	5,191.0	0.01	0.00	5,191.73	2.6	-	-	-	-	-
Department of Public Works	8.75	15,200.5	0.07	0.07	15,223.10	7.6	-	-	-	-	-
Engineering	4.25	41,506.7	0.42	0.14	41,560.05	20.8	-	-	-	-	-
Equipment	6.25	69,349.6	0.33	0.33	69,455.92	34.7	237,966.7	34.8	25.7	246,510.3	123.3
Fire Department	29.50	273,479.5	0.26	1.04	273,794.86	136.9	39,469.5	6.8	4.6	40,999.2	20.5
Forestry	0.25	-	-	-	-	-	40,506.7	1.6	2.4	41,256.7	20.6
General	0.00	10,692.2	0.33	0.16	10,746.91	5.4	71,238.0	6.4	5.8	73,130.6	36.6
Highway	13.20	374,173.8	0.81	0.65	374,386.82	187.2	157,807.7	14.6	14.0	162,337.4	81.2
Marina	0.30	12,930.4	0.44	0.16	12,987.95	6.5	1,534.3	2.7	0.0	1,610.2	0.8
McGraft Park	0.15	-	-	-	-	-	-	-	-	-	-
Miscellaneous	0.00	15,558.8	0.02	0.01	15,561.15	7.8	103.0	0.1	0.0	106.2	0.1
Parks Maintenance	10.60	89,432.7	0.60	0.32	89,543.59	44.8	92,854.0	27.0	8.6	96,096.5	48.0
Planning	4.00	14,185.7	0.03	0.05	14,200.90	7.1	-	-	-	-	-
Police Department	91.00	1,109,219.5	1.01	0.44	1,109,374.76	554.7	358.9	0.7	0.0	378.2	0.2
Sanitation Department	0.20	6,590.3	0.04	0.11	6,624.26	3.3	-	-	-	-	-
Street Lighting	0.00	-	-	-	-	-	-	-	-	-	-
Traffic Services	7.20	35,663.7	0.07	0.10	35,694.22	17.8	-	-	-	-	-
Water Filtration Plant	12.15	11,975.9	0.01	0.00	11,977.59	6.0	5,059.2	0.2	0.3	5,152.8	2.6
Water & Sewer	25.85	406,809.6	1.13	1.52	407,290.22	203.6	73,671.9	11.4	7.9	76,322.9	38.2
		Fleet	Fleet	Fleet	Fleet	Fleet	Equipment	Equipment	Equipment	Equipment	Equipment
Total Emissions	258.50	2,511,776.9	5.67	5.09	2,513,435.03	1,256.7	725,387.8	107.0	69.6	748,803.0	374.4

GHG Emission Summary
Muskegon Greenhouse Gas Emission Inventory
City of Muskegon

		Other Equipment Emissions (Misc.)					Total Emissions					
Account/Department	Budgeted FTEs	CO2 (lb)	CH4 (lb)	N2O (lb)	CO2e (lb)	CO2e (ton)	CO2 (lb)	CH4 (lb)	N2O (lb)	CO2e (lb)	CO2e (ton)	CO2e (tons)/FTE)
Arena	6.00	16,088.6	1.27	1.81	16,660.67	8.3	4,350,597.2	329.3	46.6	4,372,711.7	2,186.4	364.4
Cemeteries	2.00	-	-	-	-	-	143,127.3	8.8	1.3	143,739.3	71.9	35.9
City Hall	31.55	-	-	-	-	-	1,430,557.1	105.3	14.3	1,437,462.4	718.7	22.8
Community & Neighborhood Services	5.30	-	-	-	-	-	5,191.0	0.0	0.0	5,191.7	2.6	0.5
Department of Public Works	8.75	-	-	-	-	-	15,200.5	0.1	0.1	15,223.1	7.6	0.9
Engineering	4.25	-	-	-	-	-	41,506.7	0.4	0.1	41,560.0	20.8	4.9
Equipment	6.25	-	-	-	-	-	307,316.2	35.2	26.1	315,966.2	158.0	25.3
Fire Department	29.50	-	-	-	-	-	1,400,933.3	87.0	16.5	1,408,015.9	704.0	23.9
Forestry	0.25	-	-	-	-	-	40,506.7	1.6	2.4	41,256.7	20.6	82.5
General	0.00	-	-	-	-	-	81,930.2	6.7	6.0	83,877.5	41.9	--
Highway	13.20	-	-	-	-	-	531,981.5	15.4	14.6	536,724.3	268.4	20.3
Marina	0.30	-	-	-	-	-	426,012.7	41.8	5.6	428,712.0	214.4	714.5
McGraft Park	0.15	-	-	-	-	-	41,805.1	4.0	0.6	42,068.3	21.0	140.2
Miscellaneous	0.00	-	-	-	-	-	15,661.8	0.1	0.0	15,667.3	7.8	--
Parks Maintenance	10.60	-	-	-	-	-	724,835.0	67.0	14.3	730,769.0	365.4	34.5
Planning	4.00	-	-	-	-	-	210,437.6	18.6	2.6	211,688.3	105.8	26.5
Police Department	91.00	-	-	-	-	-	1,109,578.4	1.7	0.4	1,109,753.0	554.9	6.1
Sanitation Department	0.20	-	-	-	-	-	6,590.3	0.0	0.1	6,624.3	3.3	16.6
Street Lighting	0.00	-	-	-	-	-	1,281,739.9	121.4	16.9	1,289,808.7	644.9	--
Traffic Services	7.20	-	-	-	-	-	35,663.7	0.1	0.1	35,694.2	17.8	2.5
Water Filtration Plant	12.15	9,206.3	0.37	0.07	9,237.00	4.6	7,281,626.2	611.3	84.5	7,322,103.6	3,661.1	301.3
Water & Sewer	25.85	-	-	-	-	-	1,071,863.5	68.5	17.3	1,078,718.0	539.4	20.9
		Other	Other	Other	Other	Other						
Total Emissions	258.50	25,294.9	1.64	1.88	25,897.68	12.9	20,554,662.2	1,524.4	270.3	20,673,335.6	10,336.7	40.0

Appendix 2

Emission Factors for Greenhouse Gas Inventories

Last Modified: 12 September 2023

Blue text indicates an update from the 2022 version of this document.

Typically, greenhouse gas emissions are reported in units of carbon dioxide equivalent (CO_2e). Gases are converted to CO_2e by multiplying by their global warming potential (GWP). The emission factors listed in this document have not been converted to CO_2e. To do so, multiply the emissions by the corresponding GWP listed in the table below.

Gas	100-Year GWP
CH_4	25
N_2O	298

Source: Intergovernmental Panel on Climate Change (IPCC), Fourth Assessment Report (AR4), 2007. See the source note to Table 11 for further explanation.

Table 1 Stationary Combustion

Fuel Type	Heat Content (HHV)	CO_2 Factor	CH_4 Factor	N_2O Factor	CO_2 Factor	CH_4 Factor	N_2O Factor
	mmBtu per short ton	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu	kg CO_2 per short ton	g CH_4 per short ton	g N_2O per short ton
Coal and Coke							
Anthracite Coal	25.09	103.69	11	1.6	2,602	276	40
Bituminous Coal	24.93	93.28	11	1.6	2,325	274	40
Sub-bituminous Coal	17.25	97.17	11	1.6	1,676	190	28
Lignite Coal	14.21	97.72	11	1.6	1,389	156	23
Mixed (Commercial Sector)	21.39	94.27	11	1.6	2,016	235	34
Mixed (Electric Power Sector)	19.73	95.52	11	1.6	1,885	217	32
Mixed (Industrial Coking)	26.28	93.90	11	1.6	2,468	289	42
Mixed (Industrial Sector)	22.35	94.67	11	1.6	2,116	246	36
Coal Coke	24.80	113.67	11	1.6	2,819	273	40
Other Fuels - Solid							
Municipal Solid Waste	9.95	90.70	32	4.2	902	318	42
Petroleum Coke (Solid)	30.00	102.41	32	4.2	3,072	960	126
Plastics	38.00	75.00	32	4.2	2,850	1,216	160
Tires	28.00	85.97	32	4.2	2,407	896	118
Biomass Fuels - Solid							
Agricultural Byproducts	8.25	118.17	32	4.2	975	264	35
Peat	8.00	111.84	32	4.2	895	256	34
Solid Byproducts	10.39	105.51	32	4.2	1,096	332	44
Wood and Wood Residuals	17.48	93.80	7.2	3.6	1,640	126	63
	mmBtu per scf	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu	kg CO_2 per scf	g CH_4 per scf	g N_2O per scf
Natural Gas							
Natural Gas	0.001026	53.06	1.0	0.10	0.05444	0.00103	0.00010
Other Fuels - Gaseous							
Blast Furnace Gas	0.000092	274.32	0.022	0.10	0.02524	0.000002	0.000009
Coke Oven Gas	0.000599	46.85	0.48	0.10	0.02806	0.000288	0.000060
Fuel Gas	0.001388	59.00	3.0	0.60	0.08189	0.004164	0.000833
Propane Gas	0.002516	61.46	3.0	0.60	0.15463	0.007548	0.001510
Biomass Fuels - Gaseous							
Landfill Gas	0.000485	52.07	3.2	0.63	0.025254	0.001552	0.000306
Other Biomass Gases	0.000655	52.07	3.2	0.63	0.034106	0.002096	0.000413
	mmBtu per gallon	kg CO_2 per mmBtu	g CH_4 per mmBtu	g N_2O per mmBtu	kg CO_2 per gallon	g CH_4 per gallon	g N_2O per gallon
Petroleum Products							
Asphalt and Road Oil	0.158	75.36	3.0	0.60	11.91	0.47	0.09
Aviation Gasoline	0.120	69.25	3.0	0.60	8.31	0.36	0.07
Butane	0.103	64.77	3.0	0.60	6.67	0.31	0.06
Butylene	0.105	68.72	3.0	0.60	7.22	0.32	0.06
Crude Oil	0.138	74.54	3.0	0.60	10.29	0.41	0.08
Distillate Fuel Oil No. 1	0.139	73.25	3.0	0.60	10.18	0.42	0.08
Distillate Fuel Oil No. 2	0.138	73.96	3.0	0.60	10.21	0.41	0.08
Distillate Fuel Oil No. 4	0.146	75.04	3.0	0.60	10.96	0.44	0.09
Ethane	0.068	59.60	3.0	0.60	4.05	0.20	0.04
Ethylene	0.058	65.96	3.0	0.60	3.83	0.17	0.03
Heavy Gas Oils	0.148	74.92	3.0	0.60	11.09	0.44	0.09
Isobutane	0.099	64.94	3.0	0.60	6.43	0.30	0.06
Isobutylene	0.103	68.86	3.0	0.60	7.09	0.31	0.06
Kerosene	0.135	75.20	3.0	0.60	10.15	0.41	0.08
Kerosene-Type Jet Fuel	0.135	72.22	3.0	0.60	9.75	0.41	0.08
Liquefied Petroleum Gases (LPG)	0.092	61.71	3.0	0.60	5.68	0.28	0.06
Lubricants	0.144	74.27	3.0	0.60	10.69	0.43	0.09
Motor Gasoline	0.125	70.22	3.0	0.60	8.78	0.38	0.08
Naphtha (<401 deg F)	0.125	68.02	3.0	0.60	8.50	0.38	0.08
Natural Gasoline	0.110	66.88	3.0	0.60	7.36	0.33	0.07
Other Oil (>401 deg F)	0.139	76.22	3.0	0.60	10.59	0.42	0.08
Pentanes Plus	0.110	70.02	3.0	0.60	7.70	0.33	0.07
Petrochemical Feedstocks	0.125	71.02	3.0	0.60	8.88	0.38	0.08
Propane	0.091	62.87	3.0	0.60	5.72	0.27	0.05
Propylene	0.091	67.77	3.0	0.60	6.17	0.27	0.05
Residual Fuel Oil No. 5	0.140	72.93	3.0	0.60	10.21	0.42	0.08
Residual Fuel Oil No. 6	0.150	75.10	3.0	0.60	11.27	0.45	0.09
Special Naphtha	0.125	72.34	3.0	0.60	9.04	0.38	0.08
Unfinished Oils	0.139	74.54	3.0	0.60	10.36	0.42	0.08
Used Oil	0.138	74.00	3.0	0.60	10.21	0.41	0.08
Biomass Fuels - Liquid							
Biodiesel (100%)	0.128	73.84	1.1	0.11	9.45	0.14	0.01
Ethanol (100%)	0.084	68.44	1.1	0.11	5.75	0.09	0.01
Rendered Animal Fat	0.125	71.06	1.1	0.11	8.88	0.14	0.01
Vegetable Oil	0.120	81.55	1.1	0.11	9.79	0.13	0.01
Biomass Fuels - Kraft Pulping Liquor, by Wood Furnish							
North American Softwood		94.4	1.9	0.42			
North American Hardwood		93.7	1.9	0.42			
Bagasse		95.5	1.9	0.42			
Bamboo		93.7	1.9	0.42			
Straw		95.1	1.9	0.42			

Source:

Federal Register EPA; 40 CFR Part 98; e-CFR, (see link below). Table C-1 and Table C-2 (78 FR 71950, Nov. 29, 2013, as amended at 81 FR 89252, Dec. 9, 2016), Table AA-1 (78 FR 71965, Nov. 29, 2013).

https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-98

Notes:

Emission factors are per unit of heat content using higher heating values (HHV). If heat content is available from the fuel supplier, it is preferable to use that value. If not, default heat contents are provided.

The factors represented in the table above represent combustion emissions only (tank-to-wheel) and do not represent upstream emissions or well-to-wheel emissions.

Table 2 Mobile Combustion CO_2

Fuel Type	kg CO_2 per unit	Unit
Aviation Gasoline	8.31	gallon
Biodiesel (100%)	9.45	gallon
Compressed Natural Gas (CNG)	0.05444	scf
Diesel Fuel	10.21	gallon
Ethanol (100%)	5.75	gallon
Kerosene-Type Jet Fuel	9.75	gallon
Liquefied Natural Gas (LNG)	4.50	gallon
Liquefied Petroleum Gases (LPG)	5.68	gallon
Motor Gasoline	8.78	gallon
Residual Fuel Oil	11.27	gallon

Source:
Federal Register EPA; 40 CFR Part 98; e-CFR, (see link below). Table C-1 (78 FR 71950, Nov. 29, 2013, as amended at 81 FR 89252, Dec. 9, 2016)
https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-98
Notes:
LNG: The factor was developed based on the CO_2 factor for Natural Gas factor and LNG fuel density from GREET1_2022.xlsx Model, Argonne National Laboratory (Fuel_Specs worksheet).
The factors represented in the table above represent combustion emissions only (tank-to-wheel) and do not represent upstream emissions or well-to-wheel emissions.

Table 3 Mobile Combustion CH_4 and N_2O for On-Road Gasoline Vehicles

Vehicle Type	Year	CH_4 Factor (g / mile)	N_2O Factor (g / mile)
Gasoline Passenger Cars	1973-1974	0.1696	0.0197
	1975	0.1423	0.0443
	1976-1977	0.1406	0.0458
	1978-1979	0.1389	0.0473
	1980	0.1326	0.0499
	1981	0.0802	0.0626
	1982	0.0795	0.0627
	1983	0.0782	0.0630
	1984-1993	0.0704	0.0647
	1994	0.0617	0.0603
	1995	0.0531	0.0560
	1996	0.0434	0.0503
	1997	0.0337	0.0446
	1998	0.0240	0.0389
	1999	0.0215	0.0355
	2000	0.0175	0.0304
	2001	0.0105	0.0212
	2002	0.0102	0.0207
	2003	0.0095	0.0181
	2004	0.0078	0.0085
	2005	0.0075	0.0067
	2006	0.0076	0.0075
	2007	0.0072	0.0052
	2008	0.0072	0.0049
	2009	0.0071	0.0046
	2010	0.0071	0.0046
	2011	0.0071	0.0046
	2012	0.0071	0.0046
	2013	0.0071	0.0046
	2014	0.0071	0.0046
	2015	0.0068	0.0042
	2016	0.0065	0.0038
	2017	0.0054	0.0018
	2018	0.0052	0.0016
	2019	0.0051	0.0015
	2020	0.0050	0.0014
Gasoline Light-Duty Trucks (Vans, Pickup Trucks, SUVs)	1973-1974	0.1908	0.0218
	1975	0.1634	0.0513
	1976	0.1594	0.0555
	1977-1978	0.1614	0.0534
	1979-1980	0.1594	0.0555
	1981	0.1479	0.0660
	1982	0.1442	0.0681
	1983	0.1368	0.0722
	1984	0.1294	0.0764
	1985	0.1220	0.0806
	1986	0.1146	0.0848
	1987-1993	0.0813	0.1035
	1994	0.0646	0.0982
	1995	0.0517	0.0908
	1996	0.0452	0.0871
	1997	0.0452	0.0871
	1998	0.0412	0.0787
	1999	0.0333	0.0618
	2000	0.0340	0.0631
	2001	0.0221	0.0379
	2002	0.0242	0.0424
	2003	0.0221	0.0373
	2004	0.0115	0.0088
	2005	0.0105	0.0064
	2006	0.0108	0.0080
	2007	0.0103	0.0061
	2008	0.0095	0.0036
	2009	0.0095	0.0036
	2010	0.0095	0.0035
	2011	0.0096	0.0034
	2012	0.0096	0.0033
	2013	0.0095	0.0035
	2014	0.0095	0.0033
	2015	0.0094	0.0031
	2016	0.0091	0.0029
	2017	0.0084	0.0018
	2018	0.0081	0.0015
	2019	0.0080	0.0013
	2020	0.0079	0.0012
Gasoline Heavy-Duty Vehicles	≤1980	0.4604	0.0497
	1981-1984	0.4492	0.0538
	1985-1986	0.4090	0.0515
	1987	0.3675	0.0849
	1988-1989	0.3492	0.0933
	1990-1995	0.3246	0.1142
	1996	0.1278	0.1680
	1997	0.0924	0.1726
	1998	0.0655	0.1750
	1999	0.0648	0.1724
	2000	0.0630	0.1660
	2001	0.0577	0.1468
	2002	0.0634	0.1673
	2003	0.0602	0.1553
	2004	0.0298	0.0164
	2005	0.0297	0.0083
	2006	0.0299	0.0241
	2007	0.0322	0.0015
	2008	0.0340	0.0015
	2009	0.0339	0.0015
	2010	0.0320	0.0015
	2011	0.0304	0.0015
	2012	0.0313	0.0015
	2013	0.0313	0.0015
	2014	0.0315	0.0015
	2015	0.0332	0.0021
	2016	0.0321	0.0061
	2017	0.0329	0.0084
	2018	0.0326	0.0082
	2019	0.0330	0.0091
	2020	0.0328	0.0098
Gasoline Motorcycles	1960-1995	0.0070	0.0083
	1996-2005	0	0
	2006-2020	0.0070	0.0083

Source: EPA (2022) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020 (Annexes). All values are calculated from Tables A-84 through A-88.

Notes:
Emission factor updates due to a methodology change.
The factors represented in the table above represent combustion emissions only (tank-to-wheel) and do not represent upstream emissions or well-to-wheel emissions.

Table 4 Mobile Combustion CH_4 and N_2O for On-Road Diesel and Alternative Fuel Vehicles

Vehicle Type	Fuel Type	Vehicle Year	CH_4 Factor (g / mile)	N_2O Factor (g / mile)
Passenger Cars	Diesel	1960-1982	0.0006	0.0012
		1983-2006	0.0005	0.0010
		2007-2020	0.0302	0.0192
Light-Duty Trucks	Diesel	1960-1982	0.0011	0.0017
		1983-2006	0.0009	0.0014
		2007-2020	0.0290	0.0214
Medium- and Heavy-Duty Vehicles	Diesel	1960-2006	0.0051	0.0048
		2007-2020	0.0095	0.0431
Light-Duty Cars	Methanol		0.0150	0.0040
	Ethanol		0.0150	0.0040
	CNG		0.1460	0.0040
	LPG		0.0150	0.0040
	Biodiesel		0.0300	0.0190
Light-Duty Trucks	Ethanol		0.0160	0.0050
	CNG		0.1580	0.0050
	LPG		0.0160	0.0050
	LNG		0.1580	0.0050
	Biodiesel		0.0290	0.0210
Medium-Duty Trucks	CNG		1.8290	0.0010
	LPG		0.0090	0.0180
	LNG		1.8290	0.0010
	Biodiesel		0.0090	0.0430
Heavy-Duty Trucks	Methanol		0.0750	0.0280
	Ethanol		0.0750	0.0280
	CNG		0.9210	0
	LPG		0.0030	0.0070
	LNG		0.9210	0
	Biodiesel		0.0090	0.0430
Buses	Methanol		0.1020	0.0470
	Ethanol		0.1020	0.0470
	CNG		2.7870	0.0010
	LPG		0.0100	0.0110
	LNG		2.7870	0.0010
	Biodiesel		0.0090	0.0430

Source: EPA (2022) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020 (Annexes). All values are calculated from Tables A-88 through A-90.
https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

Notes:
Emission factor updates due to a methodology change.
The factors represented in the table above represent combustion emissions only (tank-to-wheel) and do not represent upstream emissions or well-to-wheel emissions.

Table 5 Mobile Combustion CH_4 and N_2O for Non-Road Vehicles

Vehicle Type	Fuel Type	CH_4 Factor (g / gallon)	N_2O Factor (g / gallon)
Ships and Boats	Residual Fuel Oil	1.11	0.32
	Gasoline (2 stroke)	4.61	0.08
	Gasoline (4 stroke)	2.25	0.01
	Diesel	6.41	0.17
Locomotives	Diesel	0.80	0.26
Aircraft	Jet Fuel	0	0.30
	Aviation Gasoline	7.06	0.11
Agricultural Equipment[A]	Gasoline (2 stroke)	6.92	0.47
	Gasoline (4 stroke)	1.93	1.20
	Gasoline Off-Road Trucks	1.93	1.20
	Diesel Equipment	1.27	1.07
	Diesel Off-Road Trucks	0.91	0.56
	LPG	0.33	0.94
Construction/Mining Equipment[B]	Gasoline (2 stroke)	7.98	0.12
	Gasoline (4 stroke)	2.85	1.47
	Gasoline Off-Road Trucks	2.85	1.48
	Diesel Equipment	1.01	0.94
	Diesel Off-Road Trucks	0.91	0.56
	LPG	0.59	0.50
Lawn and Garden Equipment	Gasoline (2 stroke)	7.28	0.31
	Gasoline (4 stroke)	2.99	1.49
	Diesel	0.67	0.49
	LPG	0.41	0.63
Airport Equipment	Gasoline	1.03	1.07
	Diesel	1.88	1.16
	LPG	0.35	0.89
Industrial/Commercial Equipment	Gasoline (2 stroke)	7.12	0.50
	Gasoline (4 stroke)	2.74	1.54
	Diesel	0.41	0.60
	LPG	0.45	0.64
Logging Equipment	Gasoline (2 stroke)	9.68	0
	Gasoline (4 stroke)	3.24	2.05
	Diesel	0.48	1.27
Railroad Equipment	Gasoline	3.24	1.81
	Diesel	0.38	0.95
	LPG	1.99	0.01
Recreational Equipment	Gasoline (2 stroke)	17.61	0.11
	Gasoline (4 stroke)	2.87	1.50
	Diesel	0.73	0.66
	LPG	0.43	0.60

Source: EPA (2022) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020 (Annexes). All values are calculated from Tables A-91 through A-92.
https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

Notes:
Emission factor updates due to a methodology change.
The factors represented in the table above represent combustion emissions only (tank-to-wheel) and do not represent upstream emissions or well-to-wheel emissions.
[A] Includes equipment, such as tractors and combines, as well as fuel consumption from trucks that are used off-road in agriculture.
[B] Includes equipment, such as cranes, dumpers, and excavators, as well as fuel consumption from trucks that are used off-road in construction.

Table 6 Electricity

eGRID Subregion Acronym	eGRID Subregion Name	Total Output Emission Factors			Non-Baseload Emission Factors		
		CO_2 Factor (lb / MWh)	CH_4 Factor (lb / MWh)	N_2O Factor (lb / MWh)	CO_2 Factor (lb / MWh)	CH_4 Factor (lb / MWh)	N_2O Factor (lb / MWh)
AKGD	AKGD (ASCC Alaska Grid)	1,067.7	0.091	0.012	1,229.6	0.120	0.016
AKMS	AKMS (ASCC Miscellaneous)	485.2	0.025	0.004	1,531.3	0.066	0.012
AZNM	AZNM (WECC Southwest)	819.7	0.052	0.007	1,227.6	0.067	0.009
CAMX	CAMX (WECC California)	531.7	0.031	0.004	1,047.5	0.049	0.006
ERCT	ERCT (ERCOT All)	813.6	0.054	0.008	1,177.4	0.065	0.009
FRCC	FRCC (FRCC All)	832.9	0.053	0.007	1,016.5	0.054	0.007
HIMS	HIMS (HICC Miscellaneous)	1,134.4	0.135	0.021	1,649.4	0.176	0.027
HIOA	HIOA (HICC Oahu)	1,633.1	0.176	0.027	1,784.0	0.172	0.027
MROE	MROE (MRO East)	1,582.1	0.148	0.022	1,555.9	0.133	0.019
MROW	MROW (MRO West)	995.8	0.107	0.015	1,808.3	0.183	0.026
NEWE	NEWE (NPCC New England)	539.4	0.072	0.009	900.5	0.073	0.009
NWPP	NWPP (WECC Northwest)	634.6	0.058	0.008	1,545.7	0.139	0.020
NYCW	NYCW (NPCC NYC/Westchester)	816.8	0.019	0.002	930.8	0.020	0.002
NYLI	NYLI (NPCC Long Island)	1,210.9	0.126	0.016	1,317.3	0.040	0.005
NYUP	NYUP (NPCC Upstate NY)	233.1	0.015	0.002	880.7	0.047	0.006
PRMS	PRMS (Puerto Rico Miscellaneous)	1,558.0	0.081	0.013	1,618.1	0.060	0.011
RFCE	RFCE (RFC East)	672.8	0.049	0.007	1,357.3	0.106	0.015
RFCM	RFCM (RFC Michigan)	1,214.1	0.115	0.016	1,717.0	0.160	0.023
RFCW	RFCW (RFC West)	1,046.1	0.095	0.014	1,798.8	0.172	0.025
RMPA	RMPA (WECC Rockies)	1,158.9	0.109	0.016	1,614.2	0.128	0.018
SPNO	SPNO (SPP North)	991.7	0.108	0.016	1,926.2	0.204	0.029
SPSO	SPSO (SPP South)	1,031.6	0.080	0.012	1,584.6	0.116	0.017
SRMV	SRMV (SERC Mississippi Valley)	772.7	0.040	0.006	1,177.0	0.066	0.009
SRMW	SRMW (SERC Midwest)	1,543.0	0.171	0.025	1,763.2	0.179	0.026
SRSO	SRSO (SERC South)	891.9	0.067	0.010	1,384.6	0.101	0.015
SRTV	SRTV (SERC Tennessee Valley)	931.6	0.087	0.013	1,636.2	0.151	0.022
SRVC	SRVC (SERC Virginia/Carolina)	639.7	0.052	0.007	1,357.0	0.116	0.016
US Average	US Average	852.3	0.071	0.010	1,410.0	0.110	0.016

Source: EPA eGRID2021, February 2023 (Table 1. Subregion Output Emission Rates)
https://www.epa.gov/egrid/download-data

Notes:

Total output emission factors can be used as default factors for estimating GHG emissions from electricity use when developing a carbon footprint or emissions inventory. Annual non-baseload output emission factors should not be used when developing a carbon footprint or emissions inventory, but can be used to estimate GHG emissions reductions on the grid from changes in electricity use.
For technical information, reference the EPA's eGRID Technical Guide

https://www.epa.gov/system/files/documents/2023-01/eGRID2021_technical_guide.pdf

The factors represented in the table above represent combustion emissions only (tank-to-wheel) and do not represent upstream emissions or well-to-wheel emissions.

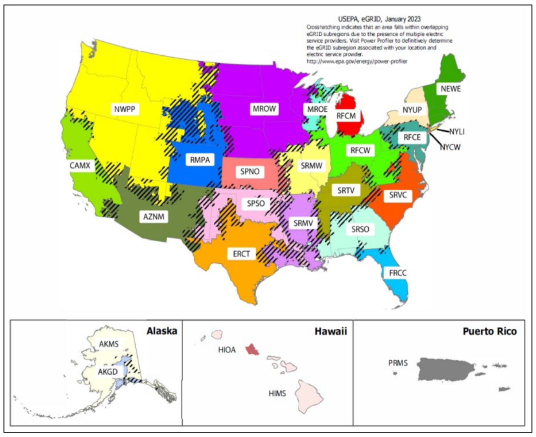

Table 7 Steam and Heat

	CO_2 Factor (kg / mmBtu)	CH_4 Factor (g / mmBtu)	N_2O Factor (g / mmBtu)
Steam and Heat	66.33	1.250	0.125

Notes:

Emission factors are per mmBtu of steam or heat purchased. These factors assume natural gas fuel is used to generate steam or heat at 80 percent thermal efficiency.

The factors represented in the table above represent combustion emissions only (tank-to-wheel) and do not represent upstream emissions or well-to-wheel emissions.

Scope 3 Emission Factors

Scope 3 emission factors provided below are aligned with the Greenhouse Gas Protocol Technical Guidance for Calculating Scope 3 Emissions, version 1.0 (Scope 3 Calculation Guidance). Where applicable, the specific calculation method is referenced. Refer to the Scope 3 Calculation Guidance for more information (http://www.ghgprotocol.org/scope-3-technical-calculation-guidance)

Table 8 Scope 3 Category 4: Upstream Transportation and Distribution and Category 9: Downstream Transportation and Distribution

These factors are intended for use in the distance-based method defined in the Scope 3 Calculation Guidance. If fuel data are available, then the fuel-based method should be used, with factors from Tables 2 through 5.

Vehicle Type	CO_2 Factor (kg / unit)	CH_4 Factor (g / unit)	N_2O Factor (g / unit)	Units
Medium- and Heavy-Duty Truck	1.387	0.013	0.038	vehicle-mile
Passenger Car [A]	0.313	0.008	0.007	vehicle-mile
Light-Duty Truck [B]	0.467	0.013	0.012	vehicle-mile
Medium- and Heavy-Duty Truck[C]	0.170	0.0016	0.0047	ton-mile
Rail	0.021	0.0016	0.0005	ton-mile
Waterborne Craft	0.044	0.0254	0.0011	ton-mile
Aircraft	0.698	0	0.0215	ton-mile

Source:
CO_2, CH_4, and N_2O emissions data for road vehicles are from Table 2-13 of the EPA (2022) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020.
Vehicle-miles and passenger-miles data for road vehicles are from Table VM-1 of the Federal Highway Administration Highway Statistics 2020.
CO_2e emissions data for non-road vehicles are based on Table A-107 of the EPA (2022) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020, which are distributed into CO_2, CH_4, and N_2O emissions based on fuel/vehicle emission factors.
Freight ton-mile data are from Table 1-50 of the Bureau of Transportation Statistics, National Transportation Statistics for 2021 (2020 data).

Notes:
Vehicle-mile factors are appropriate to use when the entire vehicle is dedicated to transporting the reporting company's product. Ton-mile factors are appropriate when the vehicle is shared with products from other companies.
The factors represented in the table above represent combustion emissions only (tank-to-wheel) and do not represent upstream emissions or well-to-wheel emissions.
[A] Passenger car: includes passenger cars, minivans, SUVs, and small pickup trucks (vehicles with wheelbase less than 121 inches).
[B] Light-duty truck: includes full-size pickup trucks, full-size vans, and extended-length SUVs (vehicles with wheelbase greater than 121 inches).
[C] Medium- and Heavy-Duty Truck: includes Combination Trucks and single frame trucks that have 2-Axles and at least 6 tires or a gross vehicle weight rating exceeding 10,000 lbs.

Table 9 Scope 3 Category 5: Waste Generated in Operations and Category 12: End-of-Life Treatment of Sold Products

These factors are intended for use in the waste-type-specific method or the average-data method defined in the Scope 3 Calculation Guidance for category 5 and category 12. Choose the appropriate material and disposal method from the table below. For the average-data method, use one of the mixed material types, such as mixed MSW.

	Metric Tons CO_2e / Short Ton Material					
Material	**Recycled[A]**	**Landfilled[B]**	**Combusted[C]**	**Composted[D]**	**Anaerobically Digested (Dry Digestate with Curing)**	**Anaerobically Digested (Wet Digestate with Curing)**
Aluminum Cans	0.06	0.02	0.01	NA	NA	NA
Aluminum Ingot	0.04	0.02	0.01	NA	NA	NA
Steel Cans	0.32	0.02	0.01	NA	NA	NA
Copper Wire	0.18	0.02	0.01	NA	NA	NA
Glass	0.05	0.02	0.01	NA	NA	NA
HDPE	0.21	0.02	2.80	NA	NA	NA
LDPE	NA	0.02	2.80	NA	NA	NA
PET	0.23	0.02	2.05	NA	NA	NA
LLDPE	NA	0.02	2.80	NA	NA	NA
PP	NA	0.02	2.80	NA	NA	NA
PS	NA	0.02	3.02	NA	NA	NA
PVC	NA	0.02	1.26	NA	NA	NA
PLA	NA	0.02	0.01	0.17	NA	NA
Corrugated Containers	0.11	0.90	0.05	NA	NA	NA
Magazines/Third-class mail	0.02	0.42	0.05	NA	NA	NA
Newspaper	0.02	0.35	0.05	NA	NA	NA
Office Paper	0.02	1.25	0.05	NA	NA	NA
Phonebooks	0.04	0.35	0.05	NA	NA	NA
Textbooks	0.04	1.25	0.05	NA	NA	NA
Dimensional Lumber	0.09	0.17	0.05	NA	NA	NA
Medium-density Fiberboard	0.15	0.07	0.05	NA	NA	NA
Food Waste (non-meat)	NA	0.58	0.05	0.15	0.14	0.11
Food Waste (meat only)	NA	0.58	0.05	NA	0.14	0.11
Beef	NA	0.58	0.05	0.15	0.14	0.11
Poultry	NA	0.58	0.05	0.15	0.14	0.11
Grains	NA	0.58	0.05	0.15	0.14	0.11
Bread	NA	0.58	0.05	0.15	0.14	0.11
Fruits and Vegetables	NA	0.58	0.05	0.15	0.14	0.11
Dairy Products	NA	0.58	0.05	0.15	0.14	0.11
Yard Trimmings	NA	0.33	0.05	0.19	0.11	NA
Grass	NA	0.26	0.05	0.19	0.09	NA
Leaves	NA	0.26	0.05	0.19	0.13	NA
Branches	NA	0.53	0.05	0.19	0.16	NA
Mixed Paper (general)	0.07	0.80	0.05	NA	NA	NA
Mixed Paper (primarily residential)	0.07	0.77	0.05	NA	NA	NA
Mixed Paper (primarily from offices)	0.03	0.75	0.05	NA	NA	NA
Mixed Metals	0.23	0.02	0.01	NA	NA	NA
Mixed Plastics	0.22	0.02	2.34	NA	NA	NA
Mixed Recyclables	0.09	0.68	0.11	NA	NA	NA
Food Waste	NA	0.58	0.05	0.15	NA	NA
Mixed Organics	NA	0.48	0.05	0.17	NA	NA
Mixed MSW	NA	0.52	0.43	NA	NA	NA
Carpet	NA	0.02	1.68	NA	NA	NA
Desktop CPUs	NA	0.02	0.40	NA	NA	NA
Portable Electronic Devices	NA	0.02	0.89	NA	NA	NA
Flat-panel Displays	NA	0.02	0.74	NA	NA	NA
CRT Displays	NA	0.02	0.64	NA	NA	NA
Electronic Peripherals	NA	0.02	2.23	NA	NA	NA
Hard-copy Devices	NA	0.02	1.92	NA	NA	NA
Mixed Electronics	NA	0.02	0.87	NA	NA	NA
Clay Bricks	NA	0.02	NA	NA	NA	NA
Concrete	0.01	0.02	NA	NA	NA	NA
Fly Ash	0.01	0.02	NA	NA	NA	NA
Tires	0.10	0.02	2.21	NA	NA	NA
Asphalt Concrete	0	0.02	NA	NA	NA	NA
Asphalt Shingles	0.03	0.02	0.70	NA	NA	NA
Drywall	NA	0.02	NA	NA	NA	NA
Fiberglass Insulation	0.05	0.02	NA	NA	NA	NA
Vinyl Flooring	NA	0.02	0.29	NA	NA	NA
Wood Flooring	NA	0.18	0.08	NA	NA	NA

Source: EPA, Office of Resource Conservation and Recovery (February 2016) Documentation for Greenhouse Gas Emission and Energy Factors used in the Waste Reduction Model (WARM). Factors from tables provided in the Management Practices Chapters and Background Chapters. WARM Version 15, November 2020 Update. Additional data provided by EPA, WARM-15 Background Data.

Notes: These factors do not include any avoided emissions impact from any of the disposal methods. All the factors presented here include transportation emissions, which are optional in the Scope 3 Calculation Guidance, with an assumed average distance traveled to the processing facility. AR4 GWPs are used to convert all waste emission factors into CO_2e.

[A] Recycling emissions include transport to recycling facility and sorting of recycled materials at material recovery facility.

[B] Landfilling emissions include transport to landfill, equipment use at landfill and fugitive landfill CH_4 emissions. Landfill CH_4 is based on typical landfill gas collection practices and average landfill moisture conditions.

[C] Combustion emissions include transport to combustion facility and combustion-related non-biogenic CO_2 and N_2O

[D] Composting emissions include transport to composting facility, equipment use at composting facility and CH_4 and N_2O emissions during composting.

Table 10 Scope 3 Category 6: Business Travel and Category 7: Employee Commuting

These factors are intended for use in the distance-based method defined in the Scope 3 Calculation Guidance. If fuel data are available, then the fuel-based method should be used, with factors from Tables 2 through 5.

Vehicle Type	CO_2 Factor (kg / unit)	CH_4 Factor (g / unit)	N_2O Factor (g / unit)	Units
Passenger Car [A]	0.313	0.008	0.007	vehicle-mile
Light-Duty Truck [B]	0.467	0.013	0.012	vehicle-mile
Motorcycle	0.178	0.111	0.019	vehicle-mile
Intercity Rail - Northeast Corridor [C]	0.058	0.0055	0.0007	passenger-mile
Intercity Rail - Other Routes [C]	0.150	0.0117	0.0038	passenger-mile
Intercity Rail - National Average [C]	0.113	0.0092	0.0026	passenger-mile
Commuter Rail [D]	0.135	0.0109	0.0027	passenger-mile
Transit Rail (i.e. Subway, Tram) [E]	0.096	0.0080	0.0011	passenger-mile
Bus	0.055	0.0063	0.0011	passenger-mile
Air Travel - Short Haul (< 300 miles)	0.207	0.0064	0.0066	passenger-mile
Air Travel - Medium Haul (>= 300 miles, < 2300 miles)	0.129	0.0006	0.0041	passenger-mile
Air Travel - Long Haul (>= 2300 miles)	0.163	0.0006	0.0052	passenger-mile

Source:
CO_2, CH_4, and N_2O emissions data for highway vehicles are from Table 2-13 of the EPA (2022) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020.
Vehicle-miles and passenger-miles data for highway vehicles are from Table VM-1 of the Federal Highway Administration Highway Statistics 2020.
Fuel consumption data and passenger-miles data for rail are from Tables A.14 to A.16 and C.9 to C.11 of the Transportation Energy Data Book: Edition 40. Fuel consumption was converted to emissions by using fuel and electricity emission factors presented in the tables above.
Intercity Rail factors from communication with Amtrak, March 2020. These are based on 2019 values.
Air Travel factors from 2022 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting. Version 2.0 June 2022.

Notes:
The factors represented in the table above represent combustion emissions only (tank-to-wheel) and do not represent upstream emissions or well-to-wheel emissions.
CH_4 and N_2O emission factor updates for motorcycle and bus due to a methodology change.

[A] Passenger car: includes passenger cars, minivans, SUVs, and small pickup trucks (vehicles with wheelbase less than 121 inches).

[B] Light-duty truck: includes full-size pickup trucks, full-size vans, and extended-length SUVs (vehicles with wheelbase greater than 121 inches).

[C] Intercity rail: Amtrak long-distance rail between major cities. Northeast Corridor extends from Boston to Washington D.C. Other Routes are all routes outside the Northeast Corridor.

[D] Commuter rail: rail service between a central city and adjacent suburbs (also called regional rail or suburban rail).

[E] Transit rail: rail typically within an urban center, such as subways, elevated railways, metropolitan railways (metro), streetcars, trolley cars, and tramways.

Global Warming Potentials

Table 11 Global Warming Potentials (GWPs)

Gas	100-Year GWP
CO_2	1
CH_4	25
N_2O	298
HFC-23	14,800
HFC-32	675
HFC-41	92
HFC-125	3,500
HFC-134	1,100
HFC-134a	1,430
HFC-143	353
HFC-143a	4,470
HFC-152	53
HFC-152a	124
HFC-161	12
HFC-227ea	3,220
HFC-236cb	1,340
HFC-236ea	1,370
HFC-236fa	9,810
HFC-245ca	693
HFC-245fa	1,030
HFC-365mfc	794
HFC-43-10mee	1,640
SF_6	22,800
NF_3	17,200
CF_4	7,390
C_2F_6	12,200
C_3F_8	8,830
c-C_4F_8	10,300
C_4F_{10}	8,860
C_5F_{12}	9,160
C_6F_{14}	9,300
$C_{10}F_{18}$	>7,500

Source:
100-year GWPs from IPCC Fourth Assessment Report (AR4), 2007. IPCC AR4 was published in 2007 and is among the most current and comprehensive peer-reviewed assessments of climate change. AR4 provides revised GWPs of several GHGs relative to the values provided in previous assessment reports, following advances in scientific knowledge on the radiative efficiencies and atmospheric lifetimes of these GHGs and of CO2.

Factors in the 2023 Emission Factors update are based on AR4 GWPs, but EPA recognizes that Fifth Assessment Report (AR5) GWPs have been published and used in the Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021 report (published February 2023). However, this 2023 Emission Factors Hub and the GHG Reporting Program continue to use AR4 GWPs. EPA plans to incorporate AR5 GWPs into the 2024 Emission Factors Hub update.

Table 12 Global Warming Potentials (GWPs) for Blended Refrigerants

ASHRAE #	100-year GWP	Blend Composition
R-401A	16	53% HCFC-22 , 34% HCFC-124 , 13% HFC-152a
R-401B	14	61% HCFC-22 , 28% HCFC-124 , 11% HFC-152a
R-401C	19	33% HCFC-22 , 52% HCFC-124 , 15% HFC-152a
R-402A	2,100	38% HCFC-22 , 6% HFC-125 , 2% propane
R-402B	1,330	60% HCFC-22 , 38% HFC-125 , 2% propane
R-403B	3,444	56% HCFC-22 , 39% PFC-218 , 5% propane
R-404A	3,922	44% HFC-125 , 4% HFC-134a , 52% HFC 143a
R-406A	0	55% HCFC-22 , 41% HCFC-142b , 4% isobutane
R-407A	2,107	20% HFC-32 , 40% HFC-125 , 40% HFC-134a
R-407B	2,804	10% HFC-32 , 70% HFC-125 , 20% HFC-134a
R-407C	1,774	23% HFC-32 , 25% HFC-125 , 52% HFC-134a
R-407D	1,627	15% HFC-32 , 15% HFC-125 , 70% HFC-134a
R-407E	1,552	25% HFC-32 , 15% HFC-125 , 60% HFC-134a
R-408A	2,301	47% HCFC-22 , 7% HFC-125 , 46% HFC 143a
R-409A	0	60% HCFC-22 , 25% HCFC-124 , 15% HCFC-142b
R-410A	2,088	50% HFC-32 , 50% HFC-125
R-410B	2,229	45% HFC-32 , 55% HFC-125
R-411A	14	87.5% HCFC-22 , 11 HFC-152a , 1.5% propylene
R-411B	4	94% HCFC-22 , 3% HFC-152a , 3% propylene
R-413A	2,053	88% HFC-134a , 9% PFC-218 , 3% isobutane
R-414A	0	51% HCFC-22 , 28.5% HCFC-124 , 16.5% HCFC-142b
R-414B	0	5% HCFC-22 , 39% HCFC-124 , 9.5% HCFC-142b
R-417A	2,346	46.6% HFC-125 , 5% HFC-134a , 3.4% butane
R-422A	3,143	85.1% HFC-125 , 11.5% HFC-134a , 3.4% isobutane
R-422D	2,729	65.1% HFC-125 , 31.5% HFC-134a , 3.4% isobutane
R-423A	2,280	47.5% HFC-227ea , 52.5% HFC-134a
R-424A	2,440	50.5% HFC-125 , 47% HFC-134a , 2.5% butane/pentane
R-426A	1,508	5.1% HFC-125 , 93% HFC-134a , 1.9% butane/pentane
R-428A	3,607	77.5% HFC-125 , 2% HFC-143a , 1.9% isobutane
R-434A	3,245	63.2% HFC-125 , 16% HFC-134a , 18% HFC-143a , 2.8% isobutane
R-500	32	73.8% CFC-12 , 26.2% HFC-152a , 48.8% HCFC-22
R-502	0	48.8% HCFC-22 , 51.2% CFC-115
R-504	325	48.2% HFC-32 , 51.8% CFC-115
R-507	3,985	5% HFC-125 , 5% HFC143a
R-508A	13,214	39% HFC-23 , 61% PFC-116
R-508B	13,396	46% HFC-23 , 54% PFC-116

Source:
100-year GWPs from IPCC Fourth Assessment Report (AR4), 2007. See the source note to Table 11 for further explanation. GWPs of blended refrigerants are based on their HFC and PFC constituents, which are based on data from http://www.epa.gov/ozone/snap/refrigerants/refblend.html.