Ann Arbor 2019 Community-Wide Greenhouse Gas Inventory Guide

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Introduction

The City of Ann Arbor Community-Wide Greenhouse Gas Inventory is completed in accordance with the ICLEI – Local Governments for Sustainability US Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions (Community Protocol). The Community Protocol provides recommendations and data sources specifically relevant to the United States.

The inventory is completed on an annual basis and reported to the Carbon Disclosure Project (CDP) to benchmark our performance with cities around the world. The City of Ann Arbor was one of 150 global cities to a receive an "A" score from the CDP in 2019 for assessing climate risk, tracking emissions, working towards an ambitious reduction target through a robust adaptation and mitigation strategy, and for reporting this information publicly. The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories Accounting and Reporting Standard for Cities is used when reporting to the CDP, as required by the Global Covenant of Mayors (formerly the Compact of Mayors).[1]

The inventory accounts for three greenhouse gases: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These greenhouse gases represent 97% of emissions in the United States. Fluorinated gases are not estimated based on data availability but are synthetic and powerful greenhouse gases that are addressed in the A^{2}ZERO Carbon Neutrality Plan.

The community-wide greenhouse gas inventory was estimated for the year 2000 in 2007. Since then, more data associated with emission sources is available and inventory protocols have been updated. To maintain the ability to observe long term trends in emissions, a **Simple Inventory** is completed each year, which only includes emissions sources that can be estimated with historically available data. The **Expanded Inventory** is completed for 2015 and following years to provide a more comprehensive understanding of emissions associated with Ann Arbor, and to more accurately reflect how emissions inventories have expanded over time. **Table 1** summarizes the different emission sources included in each version of the inventory.

The **Expanded Inventory** includes additional emission sources and represents 17% more emissions than the **Simple Inventory.** The largest additional emissions source accounted for in the **Expanded Inventory** is commuting patterns, representing over 85% of the additional emissions.

Table 1: *Simple and Expanded Inventory Comparison*

Emission Source	**Simple Inventory**	**Expanded Inventory**
Electricity used in buildings	•	•
Transmission and distribution losses	•	•
Natural gas used in buildings	•	•
Local fugitive natural gas leaks		•
Additional stationary energy emission sources		•
Local passenger and commercial vehicles	•	•

[1] The GPC protocol is slightly different than the ICLEI protocol for estimating emissions for solid waste and waste water. The values for these emissions reported to the CDP are different than presented here. These emissions are collectively less than 3% of total emissions, and within the goal of 5% accuracy.

Commuting passenger vehicles		•
Rail and aviation		•
Generated solid waste	•	•
Additional solid waste emission sources		•
Wastewater processing		•

This guide explains how the annual inventory is estimated. For each emissions source, the specific ICLEI methodology, scope, GPC reference number, assumptions, and data source are provided. The ICLEI methodology number can be referenced for more information. The scope describes where emissions occur – physically within the city boundary (scope 1), emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam, and/or cooling within the city boundary (scope 2), and from all other emissions that occur outside the city boundary as a result of activities taking place within the city boundary (scope 3).

Overview

Table 2 summarizes the emission sources accounted for in the **Expanded Inventory** and provides the notation key for comparison with the GPC. The notation keys provide details on emission sources that are not currently included in the inventory:

- **IE – Included Elsewhere:** Emissions for this activity are estimated in another category of the inventory. The GPC reference number where these emissions are included is provided.
- **NE – Not Estimated:** Emissions occur but have not been estimated or reported.
  - ***:** Not estimated due to unavailable data; †: Not estimated due to small emission contribution
- **NA – Not Applicable:** The activity occurs but does not cause emissions.
- **NO – Not Occurring:** An activity or process that does not occur or exist within the community

Table 2. *Emission sources included in the Expanded GHG Inventory.*

GPC ref.	Scope	GHG Emissions Source (by Sector and Sub-sector)	Notation Key
I		**Stationary Energy**	
I.1		**Residential Buildings**	
I.1.1	1	Emissions from natural gas combustion within the city boundary	
I.1.1	1	Emissions from propane combustion within the city boundary	
I.1.2	2	Emissions from grid-supplied electricity consumed within the city boundary	
I.1.3	3	Emissions from transmission and distribution losses from grid-supplied electricity consumption	
I.2		**Commercial and institutional buildings and facilities**	
I.2.1	1	Emissions from natural gas combustion within the city boundary in commercial buildings	
I.2.1	1	Emissions from propane combustion within the city boundary in commercial buildings	NE*
I.2.1	1	Emissions from fuel oil combustion within the city boundary in commercial buildings	NE*
I.2.1	1	Emissions from natural gas combustion within the city boundary in institutional buildings	
I.2.1	1	Emissions from propane combustion within the city boundary in institutional buildings	
I.2.1	1	Emissions from fuel oil combustion within the city boundary in institutional buildings	
I.2.2	2	Emissions from grid-supplied electricity consumed within the city boundary in commercial buildings	
I.2.2	2	Emissions from grid-supplied electricity consumed within the city boundary in institutional buildings	

I.2.3	3	Emissions from transmission and distribution losses from grid-supplied electricity consumption in commercial buildings	
I.2.3	3	Emissions from transmission and distribution losses from grid-supplied electricity consumption in institutional buildings	
I.3		**Manufacturing industries and construction**	
I.3.1	1	Emissions from fuel combustion within the city boundary	IE (I.2.1)
I.3.2	2	Emissions from grid-supplied energy consumed within the city boundary	IE (I.2.2)
I.3.3	3	Emissions from transmission and distribution losses from grid-supplied electricity consumption	IE (I.2.3)
I.4		**Energy industries**	
I.4.1	1	Emissions from energy used in power plant auxiliary operations within the city boundary	NE†
I.4.2	2	Emissions from grid-supplied energy consumed in power plant auxiliary operations within the city boundary	NE†
I.4.3	3	Emissions from transmission and distribution losses from grid-supplied electricity consumption	NE†
I.4.4	1	Emissions from energy generation supplied to the grid	IE (I.2.1)
I.5		**Agriculture, forestry and fishing activities**	
I.5.1	1	Emissions from fuel combustion within the city boundary	NE*
I.5.2	2	Emissions from grid-supplied energy consumed within the city boundary	NE*
I.5.3	3	Emissions from transmission and distribution losses from grid-supplied electricity consumption	NE*
I.6		**Non-specified sources**	
I.6.1	1	Emissions from fuel combustion within the city boundary	NO
I.6.2	2	Emissions from grid-supplied electricity consumed within the city boundary	NO
I.6.3	3	Emissions from transmission and distribution losses from grid-supplied energy consumption	NO
I.7		**Fugitive emissions from mining, processing, storage, and transportation of coal**	
I.7.1	1	Emissions from fugitive emissions within the city boundary	NO
I.8		**Fugitive emissions from mining, processing, storage, and transportation of natural gas**	
I.8.1	1	Emissions from fugitive emissions within the city boundary	
II		**Transportation**	
II.1		**On-road transportation**	
II.1.1	1	Emissions from fuel combustion from passenger on-road vehicles (gasoline and diesel)	
II.1.1	1	Emissions from fuel combustion from commercial on-road vehicles (gasoline and diesel)	
II.1.1	1	Emissions from fuel combustion from local bus transit	
II.1.1	2	Emissions from grid-supplied electricity used for on-road transportation	IE (I.1.2, I.2.2)
II.1.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary	

II.2		**Railways**	
II.2.1	1	Passenger railway transportation occurring within the city boundary	
II.2.1	1	Freight railway transportation occurring within the city boundary	
II.2.2	2	Emissions from grid-supplied electricity consumed within the city boundary	IE (I.2.2)
II.2.3	3	Emissions from portion of transboundary journeys occurring the city boundary	NE*
II.3		**Waterborne navigation**	
II.3.1	1	Emissions from fuel combustion for waterborne navigation occurring within the city boundary	NO
II.3.2	2	Emissions from grid-supplied electricity consumed within the city boundary for waterborne navigation	NO
II.3.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary	NO
II.4		**Aviation**	
II.4.1	1	Emissions from fuel combustion for aviation occurring within the city boundary for aviation	
II.4.2	2	Emissions from grid-supplied energy consumed within the city boundary for aviation	IE
II.4.3	3	Emissions from portion of transboundary journeys occurring outside the city boundary	NE*
II.5		**Off-road transportation**	
II.5.1	1	Emissions from fuel combustion for off-road transportation occurring within the city boundary	NE
II.5.2	2	Emissions from grid-supplied electricity consumed within the city boundary for off-road transportation	NE
III		**Waste**	
III.1		**Solid waste disposal**	
III.1.1	1	Emissions from solid waste generated within the city boundary and disposed within city boundary	
III.1.2	3	Emissions from solid waste generated within the city boundary but disposed outside city boundary	
III.1.3	1	Emissions from waste generated outside the city boundary and disposed within city boundary	NO
III.2		**Biological treatment of waste**	
III.2.1	1	Emissions from solid waste generated within the city boundary and disposed within city boundary	
III.2.2	3	Emissions from solid waste generated within the city boundary but disposed outside city boundary	NO
III.2.3	1	Emissions from waste generated outside the city boundary and disposed within city boundary	NO
III.3		**Incineration and open burning**	
III.3.1	1	Emissions from solid waste generated and treated within the city boundary	NO
III.3.2	3	Emissions from solid waste generated within the city boundary but treated outside city boundary	NO
II.3.3	1	Emissions from waste generated outside the city boundary but treated within the city boundary	NO
III.4		**Wastewater treatment and discharge**	
III.4.1	1	Emissions from wastewater generated and treated within the city boundary	
III.4.2	3	Emissions from wastewater generated within city boundary but treated outside city boundary	NO
III.4.3	1	Emissions from wastewater generated outside the city boundary but treated within the city boundary	NE*

IV		**Industrial Process and Product Uses**	
IV.1	1	Emissions from industrial processes occurring within the city boundary	NE*****
IV.2	1	Emissions from product use occurring within the city boundary	NE*****
V		**Agriculture, Forestry, and Other Land Use**	
V.1		Emissions from livestock within the city boundary	NE†
V.2		Emissions from land within the city boundary	NE*****
V.3		Emissions from aggregate sources and non-CO2 emission sources on land within the city boundary	NE*****
VI		**Other Scope 3**	
VI.1	3	Other Scope 3	NE

General Information

General information about the City of Ann Arbor community frames the interpretation of the results of the greenhouse gas inventory.

The population and number of households of the City of Ann Arbor, Washtenaw County, and State of Michigan are collected from the US Census ACS 5-Year Estimate results.

The GDP of the City of Ann Arbor is collected from the Federal Reserve Bank of St. Louis.

The population of enrolled students, campus staff, and hospital staff at the University of Michigan Ann Arbor campus is collected from the University of Michigan's Office of Campus Sustainability.

Heating and cooling degree days are collected from the National Weather Service Forecast Office for the Ann Arbor University of Michigan location.

General Calculation

In general, greenhouse gas emissions are calculated with an emission factor and the global warming potential (GWP) of non-CO2 greenhouse gases. The total carbon dioxide-equivalent (CO_2e) emissions are reported in the inventory:

$$MT\ CO_2 = Activity\ Amount\ \times \frac{MT\ CO_2}{Activity\ Unit}$$

$$MT\ CH_4 = Activity\ Amount\ \times \frac{MT\ CH_4}{Activity\ Unit}$$

$$MT\ N_2O = Activity\ Amount\ \times \frac{MT\ N_2O}{Activity\ Unit}$$

$$MT\ CO_2e = MT\ CO_2 + (MT\ CH_4 \times GWP_{CH4}) + (MT\ N_2O \times GWP_{N2O})$$

The community-wide greenhouse has inventory uses the IPCC Fifth Assessment Report (AR5) values.

This guide was prepared in 2019. The emission factors provided are for the calendar year 2019 and may be a different value for other years. For more information, review the worksheets for each year of interest.

I Stationary Energy

The inventory estimates the emissions associated with the use of electricity and natural gas, propane, and fuel oil in buildings. The inventory estimates the emission associated with the residential, commercial, and institutional (University of Michigan) sectors. Commercial emissions represent a combined total of commercial and industrial emissions to maintain consistency between years.

Natural gas combustion

ICLEI Methodology: BE.1.1
Scope: 1
GPC Reference Number: I.1.1, I.2.1
Data Source: (1) DTE aggregated consumption for zip codes in Ann Arbor, (2) University of Michigan Office of Campus Sustainability

DTE provides aggregated consumption of natural gas data for all zip codes that are in the City of Ann Arbor for the residential, commercial, and industrial sectors. To account for areas of the zip codes that are not within the boundary, the aggregate total is scaled based on factors provided by the City of Ann Arbor's GIS department. To maintain consistency between years with differing definitions of sectors, the commercial and industrial sector is combined.

The University of Michigan's Office of Campus Sustainability Environmental Metrics does not distinguish between purchased natural gas used for power production or for direct use. Therefore, the full total is used to calculate emissions from natural gas combustion. Emissions associated with power production are provided for **Information Only** but are not included in total emissions to avoid double counting.

The total amount of natural gas consumed by each sector is multiplied by the natural gas emission factor provided by the EPA.

Zip Code Scaling Factor – Residential	73%
Zip Code Scaling Factor – Commercial and Industrial	76%
Emission Factor (MT CO_2e/CCF)	0.00545

Propane combustion

ICLEI Methodology: BE.1.2
Scope: 1
GPC Reference Number: I.1.1, I.2.1
Data Source: (1) EIA SEDS Michigan, Table CT4, (2) US Census ACS 5 Year Estimates, House Heating Fuel, (3) University of Michigan Office of Campus Sustainability

Residential propane combustion is estimated using data from the EIA and US Census ACS. The EIA provides the total amount of propane consumed by the residential sector in Michigan. The US Census ACS 5-year estimate provides the number of households in Ann Arbor and Michigan that use propane. The total amount of propane consumed is determined by the following equation:

$$\frac{Michigan\ total\ propane\ combustion}{No.\ of\ Michigan\ households\ using\ propane} \times No.\ of\ Ann\ Arbor\ households\ using\ propane$$

The University of Michigan also combusts propane. The amount is provided by their Office of Campus Sustainability.

The total amount of propane consumed by each sector is multiplied by the propane emission factor provided by the EPA.

Emission Factor (MT CO_2e/CCF)	0.01552

Fuel oil combustion

ICLEI Methodology: BE.1.1
Scope: 1
GPC Reference Number: I.1.1, I.2.1
Data Source: University of Michigan Office of Campus Sustainability

The University of Michigan combusts fuel oil. The amount is provided by their Office of Campus Sustainability.

The total amount of fuel oil consumed by each sector is multiplied by the fuel oil emission factor provided by the EPA.

Emission Factor (MT CO_2e/gal)	0.011

Electricity consumption

ICLEI Methodology: BE.2.1
Scope: 2
GPC Reference Number: I.1.2, I.2.2
Data Source: (1) DTE aggregated consumption for zip codes in Ann Arbor, (2) University of Michigan Office of Campus Sustainability

DTE provides aggregated consumption of electricity data for all zip codes that are in the City of Ann Arbor for the residential, commercial, and industrial. To account for areas of the zip codes that are not within the boundary, the aggregate total is scaled based on factors provided by the City of Ann Arbor's GIS department. To maintain consistency between years with differing definitions of sectors, the commercial and industrial sector is combined.

The fuel mix and associated greenhouse gas emissions factor is determined from DTE's reported values. The emissions factor for carbon dioxide is multiplied by the fraction of fossil fuel energy sources in DTE's fuel mix. A weighted average is determined using the regional grid and the amount purchased from the regional grid. The total electricity consumption is multiplied by the emission factor to determine the emissions.

Energy consumed onsite from distributed generation is not included in DTE's aggregated consumption data. The amount of electricity generated from onsite solar is not subtracted from this total due to this, but there is some portion of solar energy that is produced and sold to the grid that is not accounted for. This is therefore a conservative estimate of emissions. Because of the low penetration of onsite solar in Ann Arbor, this is a negligible impact.

Emission reduction from renewable energy credits are treated like an offset and will be presented as a metric in the future. Renewable energy credits do not reduce local emissions, so the full number is still reported.

Emission Factor (MT CO_2e/kWh)	0.000645

Transmission and Distribution Losses

ICLEI Methodology: BE.4.1
Scope: 3
GPC Reference Number: I.1.3, I.2.3
Data Source: EIA State Electricity Profiles, Michigan

Transmission and distribution losses represent the amount of energy lost to heat when electricity is transmitted through power lines. The rate of energy loss is determined for the state of Michigan from the EIA State Profile:

$$\%\ T\&D\ Loss = \frac{Estimated\ Losses}{Total\ Disposition - Direct\ Use}$$

The total electricity consumption is then multiplied by this factor to determine the quantity of transmission and distribution loss. This loss is multiplied by the grid emission factor to determine total emissions.

Emissions from Electric Power Production – Information Only

ICLEI Methodology: BE.6.1.A.1
Scope: 1
GPC Reference Number: I.4.1
Data Source: EPA eGRID

The EPA eGrid program provides facility level emissions reports, including the University of Michigan's Central Power Plant.[2] The "Plant CO2 equivalent emissions (tons)" value is recorded for each year. It is challenging to distinguish between University of Michigan purchased natural gas used in the Central Power Plant and that used directly. As a result, these emissions are provided for **Information Only.** The University of Michigan natural gas total represents *all* natural gas purchased by the University of Michigan.

Fugitive emissions from natural gas distribution

ICLEI Methodology: N/A
Scope: 1
GPC Reference Number: I.8.1
Data Source: DTE Methane Emissions Report

Some natural gas delivered within Ann Arbor leaks before it is combusted. Natural gas is primarily methane, a more potent greenhouse gas than the carbon dioxide generated when natural gas is combusted. The local leak rate is reported by DTE as 0.3%. The amount of fugitive methane is determined by a protocol provided in the ICLEI Clear Path Tool:

$$MT\ CH_4 = Volume\ of\ natural\ gas\ consumed \times Leakage\ rate \times Natural\ gas\ density \times Mass\ fraction\ CH_4\ in\ natural\ gas \times GWP_{CH4}$$

[2] Note that data used is available in downloadable spreadsheet for each year of interest.

$$MT\ CO_2 = Volume\ of\ natural\ gas\ consumed\ \times Leakage\ rate\ \times Natural\ gas\ density \times Mass\ fraction\ CO_2\ in\ natural\ gas$$

Emission Factor (MT CO_2e/CCF natural gas emitted)	0.059

II Transportation

The inventory estimates the emissions associated with the use of vehicles, rail, and aviation for transportation. The inventory estimates local passenger, commercial, transit, rail, and aviation emissions, and the full range of inbound and outbound passenger commutes.

In-boundary Passenger and Commercial Vehicle Emissions

ICLEI Methodology: TR.1.B, TR.2.B
Scope: 1
GPC Reference Number: II.1.1
Data Source: (1) WATS VMT Estimate, (2) SEMCOG Washtenaw County Vehicle Registration, (3) FHA Highway Statistics Table VM-1, (4) ORNL Transportation Energy Data Book, (5) BTS Average Age of Automobiles and Trucks in Operation in the United States, (6) EPA Greenhouse Gas Emission Factors

WATS provides a total estimate for vehicle miles traveled (VMT) within the City boundary that are associated with trips that begin, end, or are contained in Ann Arbor. Pass-through trips and buses are excluded from this total.

Emission factors are determined for various vehicle types for gasoline and diesel vehicles. Average miles per gallon and average age of vehicles are used to determine the appropriate CO_2, N_2O, and CH_4 emissions factors. The EPA provides carbon dioxide emission factors in units of gallons of fuel consumed, and methane and nitrous oxide emissions in units of miles for gasoline and diesel vehicles. Carbon dioxide emission factors are converted to units of miles using the calculated average miles per gallon. The fraction of gasoline and diesel vehicles are used to determine the total emissions.

Emission Factor (MT CO_2e/VMT)	0.00043

Out-of-boundary Passenger Commuting Patterns Emissions

ICLEI Methodology: TR.1.B
Scope: 3
GPC Reference Number: II.1.3
Data Source: (1) SEMCOG Commuting Behaviors, (2) EPA Greenhouse Gas Emission Factors

SEMCOG summarizes Census data on the number of inbound and outbound Ann Arbor commuters for all locations in Southeast Michigan. This data is updated every 6 years. An estimated distance between locations and Ann Arbor is determined using Google Maps. Locations of commuters working or living outside of Southeast Michigan and outside of Michigan are not provided – it is assumed that these distances are 65 and 60 miles, respectively. To avoid double counting the in-boundary portion of the

commute captured in the In-boundary Passenger and Commercial Vehicles Emissions, an average radius of Ann Arbor is subtracted from the total commuted distance. It is assumed that all commuters return to their place of origin, and commute 5 days a week for 48 weeks out of the year. The share of workers who carpool or work from home are determined from the US Census ACS 5-year estimates for Means of Transportation within Washtenaw County. This portion of commuters is subtracted from the total number of commuters. A summary of this calculation is provided below:

$$
\begin{aligned}
&Commuting\ VMT \\
&\quad = 2 \times 5 \times 48 \times (1 - fraction\ of\ alternative\ commutes) \\
&\quad \times \left(\sum_{n=1}^{n} No.\ of\ Commuters\ \times (Distance\ to\ Ann\ Arbor - Ann\ Arbor\ Radius) \right. \\
&\quad \left. + \sum_{m=1}^{m} No.\ of\ Commuters\ \times (Distance\ from\ Ann\ Arbor - Ann\ Arbor\ Radius) \right)
\end{aligned}
$$

Where n is the count of all locations inbound commuters reside, and m is the count of all locations where outbound commuters work.

The total VMT is multiplied by an emission factor for employee commuting provided by the EPA.

Emission Factor (MT CO_2e/VMT)	0.00041

A Note on Electric Vehicles

Electric vehicles are charged from electricity provided from buildings, and emissions from this electricity is included within the Stationary Energy estimate. The number of electric vehicles in Ann Arbor is provided by the Atlas EV Hub State Profile. As of 2019, electric vehicles represent less than 0.5% of all passenger vehicles. If electric vehicles become a more substantial portion of vehicles, a proportionate amount of emissions will be subtracted from vehicle emission estimates to avoid double counting.

Community-Wide Bus Emissions

ICLEI Methodology: TR.4.A and TR.4.B
Scope: 1
GPC Reference Number: II.1.1
Data Source: (1) Ann Arbor Area Transit Authority, (2) University of Michigan Office of Campus Sustainability Environmental Metrics, (3) EPA Greenhouse Gas Emission Factors

Buses are not included in the VMT estimate totals provided by WATS and are calculated separately. Annual vehicle consumption is provided by the AAATA and collected from the University of Michigan's Office of Campus Sustainability Environmental Metrics. Gallons of fuel consumed are multiplied by emission factors to estimate total emissions.

Emission Factor (MT CO_2e/gal)	0.0097

Passenger Rail Emissions

ICLEI Methodology: TR.5
Scope: 1
GPC Reference Number: II.2.1
Data Source: (1) Amtrak, (2) EPA Greenhouse Gas Emission Factor

Passenger rail emissions are estimated for Amtrak operations within Ann Arbor. Emissions associated with the full range of these trips are not estimated.

The annual average passengers using the Ann Arbor Amtrak station is provided by Amtrak. The length of railway within Ann Arbor is determined using Google Maps. Annual passenger-miles are determined by:

$$Annual\ Passenger\ Miles = Annual\ Passengers \times Inboundary\ Railway\ Miles$$

Annual passenger miles are multiplied by an emission factor to determine total emissions.

Emission Factor (MT CO_2e/passenger mile)	0.000141

Freight Rail Emissions

ICLEI Methodology: TR.3
Scope: 1
GPC Reference Number: II.2.1
Data Source: (1) MDOT, (2) EPA Greenhouse Gas Emission Factor

Annual ton-miles for inbound, intra, and outbound freight rail trips for Ann Arbor are provided by MDOT. Annual ton-miles are multiplied by an emission factor to determine total emissions.

Emission Factor (MT CO_2e/ton mile)	0.000023

Municipal Aviation Emissions

ICLEI Methodology: TR.6.A
Scope: 1
GPC Reference Number: II.4.1
Data Source: (1) City of Ann Arbor, (2) EPA Greenhouse Gas Emission Factor

Annual aviation fuel consumption at the Ann Arbor Municipal Airport is used to estimate local aviation activity. Gallons of fuel are multiplied by an emission factor to determine total emissions.

Emission Factor (MT CO_2e/gal)	0.01

III Waste

Emissions associated with solid waste and wastewater generated within the City of Ann Arbor are estimated, along with emissions associated with the closed City landfill.

Emissions from Community's Materials Disposal

ICLEI Methodology: SW.4.1
Scope: 3
GPC Reference Number: III.1.2
Data Source: (1) City of Ann Arbor, (2) Michigan Economic Impact Potential and Characterization of Municipal Solid Waste in Michigan, (3) ICLEI Emissions Factors

Municipal solid waste generated in Ann Arbor is treated outside of the city. Total tonnage of municipal solid waste generated by the residential and commercial sectors are used to estimate community materials disposal. The waste characterization estimate for the state is used as a proxy for the waste characterization in Ann Arbor. This data was last estimated in 2016. An aggregate emission factor is calculated by:

$$Aggregate\ Emission\ Factor = \sum_{k=1}^{k} Material\ Emission\ Factor\ \times Material\ Mass\ Fraction$$

Where *k* is the count of materials in the municipal solid waste.

Landfilled waste emissions are estimated using the methane commitment method, were the lifecycle emissions of waste are assigned to the year they are landfilled. You can learn more about methane commitment in ICLEI's US Community Protocol Solid Waste Appendix. Landfilled waste emissions depend on characteristics of the landfill's gas collection system and climate. A collection efficiency value of 0.75 is used.

Emission Factor (MT CO_2e/ton)	0.32

Emissions from In-boundary Landfills

ICLEI Methodology: SW.1
Scope: 1
GPC Reference Number: III.1.1
Data Source: EPA Flight Program

Landfills are required to report annual emissions to the EPA FLIGHT Program. Annual emissions associated with the closed City of Ann Arbor landfill are determined from this reporting.

Process Emissions

ICLEI Methodology: SW.5
Scope: 3
GPC Reference Number: N/A

Data Source: (1) City of Ann Arbor, (2) ICLEI US Community Protocol

The emissions associated with processing landfilled waste are estimated based on the total weight of municipal solid waste landfilled and the emission factor for diesel process equipment provided by ICLEI.

Emission Factor (MT CO_2e/ton)	0.0164

Biological Treatment of Waste

ICLEI Methodology: N/A
Scope: 1
GPC Reference Number: III.2.1
Data Source: (1) City of Ann Arbor, (2) ICLEI Clear Path

ICLEI Clear Path provides emission factors for estimating emissions associated with biological treatment of waste, or composting. To provide context, the inventory also estimates the avoided emissions of composting this waste rather than disposing organic waste in landfills. This estimate is for **information only.**

Emission Factor (MT CO_2e/ton)	0.0696

Process Emissions from Wastewater Treatment Plants that Use Nitrification or Denitrification

ICLEI Methodology: WW.7
Scope: 1
GPC Reference Number: III.4.1
Data Source: City of Ann Arbor

Process emissions associated with wastewater generated and treated in Ann Arbor are estimated. The emissions are calculated based on the population of Ann Arbor. The following factors are used:

Description	**Value**	**Units**	**Notes**
Factor for high nitrogen loading of industrial or commercial discharge	1.25	N/A	Default high value used based on input from City of Ann Arbor WWTP
Emission factor for a wastewater treatment plant with nitrification or denitrification	7	g N_2O/person/year	Default value

Emission Factor (MT CO_2e/capita)	0.0023

Fugitive Nitrous Oxide Emissions from Effluent Discharge

ICLEI Methodology: WW.12
Scope: 1
GPC Reference Number: III.4.1
Data Source: City of Ann Arbor

Fugitive emissions associated with wastewater generated and treated in Ann Arbor are estimated. The emissions are calculated based on the population of Ann Arbor. The following factors are used:

Description	Value	Units	Notes
Factor for industrial or commercial discharge	1.25	N/A	Default high value used based on input from City of Ann Arbor WWTP
Average total nitrogen per day	0.026	kg N/person/day	Default value
Nitrogen uptake for cell growth in aerobic systems	0.05	kg N/kg BOD	Default value for aerobic systems
Amount of BOD5 produced per person per day	0.09	Kg BOD/person/day	Default value
Emission Factor	0.005	Kg N_2O-N/kg sewage-N discharged	Default value for river or stream discharge

Emission Factor (MT CO_2e/capita)	0.0061