MADISON, WISCONSIN

2018 & 2022 Inventory of Community-wide Greenhouse Gas Emissions

Prepared For:

Madison, Wisconsin

Produced By:

ICLEI – Local Governments for Sustainability USA
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Table of Contents

Tables and Figures

List of Tables

List of Figures

List of Abbreviations and Definitions

Abbreviations

AFOLU	Agriculture, Forestry, and Other Land Use
BAU	Business-as-usual
CO2	Carbon Dioxide
CO2e	Carbon Dioxide Equivalent
CH4	Methane
EIE	Environmental Insights Explorer
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
GWP	Global Warming Potential
ICLEI	International Council for Local Environmental Initiatives/Local Governments for Sustainability
IPCC	Intergovernmental Panel on Climate Change
kWh	Kilowatt-Hour
MT	Metric Tons
MMBtu	One Million British Thermal Units
N2O	Nitrous Oxide
SBT	Science-Based Target
scf	Standard Cubic Foot
VMT	Vehicle Miles Traveled
WICCI	Wisconsin Initiative on Climate Change Impacts

Definitions

Net-zero	Greenhouse gas emissions equal removals from the atmosphere

Letter from the Mayor

I am pleased to share the results of the latest greenhouse gas inventory for our community. The City of Madison is committed to doing our part to reduce greenhouse gas emissions and avoid the worst impacts of climate change.

This report not only marks a milestone in our commitment to sustainability but also provides a path to making our community more environmentally sustainable and resilient for current and future Madisonians. At the heart of this inventory lies a crucial understanding: to effectively address climate change, we must first measure our impact. By tracking our greenhouse gas emissions, we gain invaluable insights into the sources of our carbon footprint, allowing us to develop targeted strategies and policies to mitigate our environmental impact.

This inventory and the emissions reductions it shows are more than just a collection of numbers – they are a testament to the dedication and hard work of the City, community leaders, local businesses, and everyone who calls Madison home. It reflects the collective work of countless individuals who have embraced the challenge of building a more sustainable Madison. One of the key benefits of greenhouse gas inventories is their ability to hold us accountable. By documenting our emissions and progress towards reduction goals, we ensure that our actions are not just goals but tangible steps towards a cleaner, healthier environment.

As you review this greenhouse gas inventory, I ask that you remember that numbers from 2022 are likely influenced by the later effects of the COVID-19 pandemic. Nevertheless, we have achieved tangible, encouraging results. Let us use this inventory as a springboard for further action, inspiring us to continue our efforts to tackle climate change and build a more resilient community.

Sincerely,

Mayor Satya Rhodes-Conway

Executive Summary

The City of Madison is committed to doing our part to reduce greenhouse gas emissions and avoid the worst impacts of climate change. Madison has set the ambitious goal of reaching 100% renewable energy and net zero carbon emissions for city operations by 2030 and community-wide by 2050. Having already reduced community-wide emissions from 4,433,691 metric tons carbon dioxide equivalent (MT CO2e) in 2018 to 4,075,568 MT CO2e in 2022, we are making significant strides toward achieving that target. This is a reduction of 358,123 MT CO2e over four years (-8.1%).

In addition to establishing these goals, the City is also investing in a wide range of initiatives (air quality, extreme heat, flooding, and other impacts including climate-related hazards) to build our community's resilience to climate change:

- Installing a network air quality monitors across the city
- Collaborating with the University of Wisconsin-Madison to map extreme heat and urban heat islands
- Developing strategies to cool the city and keep residents safe during extreme heat
- Updating our stormwater ordinance, embarking on detailed watershed studies, and upgrading stormwater infrastructure

Despite our efforts to respond to the effects of climate change, these initiatives will not solve the main driver of it: greenhouse gas emissions. Maintaining an updated inventory of their sources and outputs is critical to developing effective strategies and tracking progress toward cutting greenhouse gas emissions across the various city sectors. This report provides estimates of greenhouse gas emissions resulting from activities in Madison as a whole in 2018 and 2022.

Three greenhouse gases are included in this inventory: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Many of the charts in this report represent emissions in "carbon dioxide equivalent" (CO_2e) values.

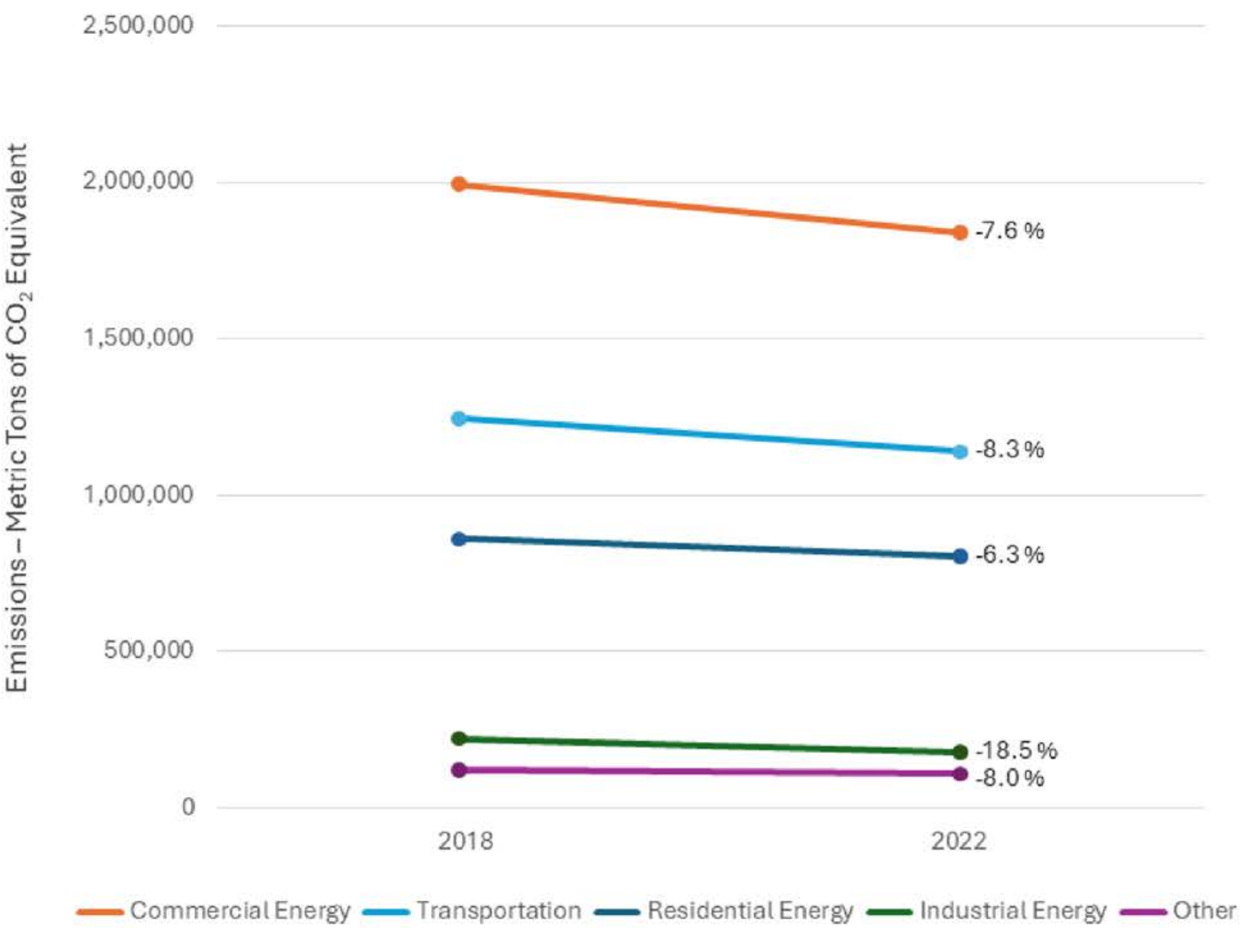
Wisconsin State Capitol from West Washington Avenue

Key Findings

Figure 1 shows community-wide emissions by sector in 2018 and 2022. The largest contributor in 2022 is Commercial Energy (45%). The next largest contributors are Transportation & Mobile Sources (28%) and Residential Energy (19%). Actions to reduce emissions in all of these sectors will be a key part of a climate action plan. Industrial Energy (5%), Water & Wastewater (1%), Solid Waste (1%), Process & Fugitive Emissions (1%), and Agriculture, Forestry, and Other Land Use (<.1%) were responsible for the remaining emissions.

The Inventory Results section of this report provides a detailed profile of emissions sources within Madison; information that is key to guiding local reduction efforts. These data will also provide a baseline against which the city will be able to compare future performance and demonstrate progress in reducing emissions.

Figure 1: Community-wide Emissions Trends (2018 to 2022)



Other includes Wastewater, Solid Waste, Process & Fugitive Emissions, and Agriculture, Forestry, and Other Land Use

Introduction to Climate Change

Naturally occurring gases dispersed in the atmosphere determine the Earth's climate by trapping solar radiation. This phenomenon is known as the greenhouse effect. Overwhelming evidence shows that human activities are increasing the concentration of greenhouse gases (GHGs) and changing the global climate. The most significant contributor is burning fossil fuels for transportation, electricity generation and other purposes, which introduces large amounts of carbon dioxide and other greenhouse gases into the atmosphere.

Collectively, these gases intensify the natural greenhouse effect, causing global average surface and lower atmospheric temperatures to rise across the globe, threatening the safety, quality of life, and economic prosperity of communities. Although the natural greenhouse effect is needed to keep the earth warm, a human-enhanced greenhouse effect with the rapid accumulation of GHGs in the atmosphere leads to too much heat and radiation being trapped. The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report confirms that human activities have unequivocally caused an increase in carbon emissions and other GHGs in the atmosphere [1]. Many regions are already experiencing the consequences of global climate change, and Madison is no exception.

Martin Luther King Jr. Boulevard on June 28th, 2023 during the worst of the Canadian wildfire air-quality impacts

[1] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [MassonDelmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press.

We are already feeling the impacts of climate change in Madison, especially increased heat and rainfall. The climate of the Midwest has continuously warmed since the first half of the 20th century, and annual precipitation has increased alongside it. Recent decades were Wisconsin's warmest and wettest on record. Wisconsin's annual average temperature has risen by 3 degrees Fahrenheit since the 1950's and is likely to increase an additional 2 - 8 degrees Fahrenheit by 2050 according to climate projections from the Wisconsin Initiative on Climate Change Impacts (WICCI). By 2050, extreme heat days over 90 degrees Fahrenheit will likely triple, and the number of hot nights when the temperature does not drop below 70 degrees Fahrenheit will likely quadruple. With the higher temperatures comes a number of risks to the health of our residents, including heat waves, flooding, and poor air quality. Some populations are especially at risk, such as those with preexisting cardiovascular and respiratory conditions and the elderly.

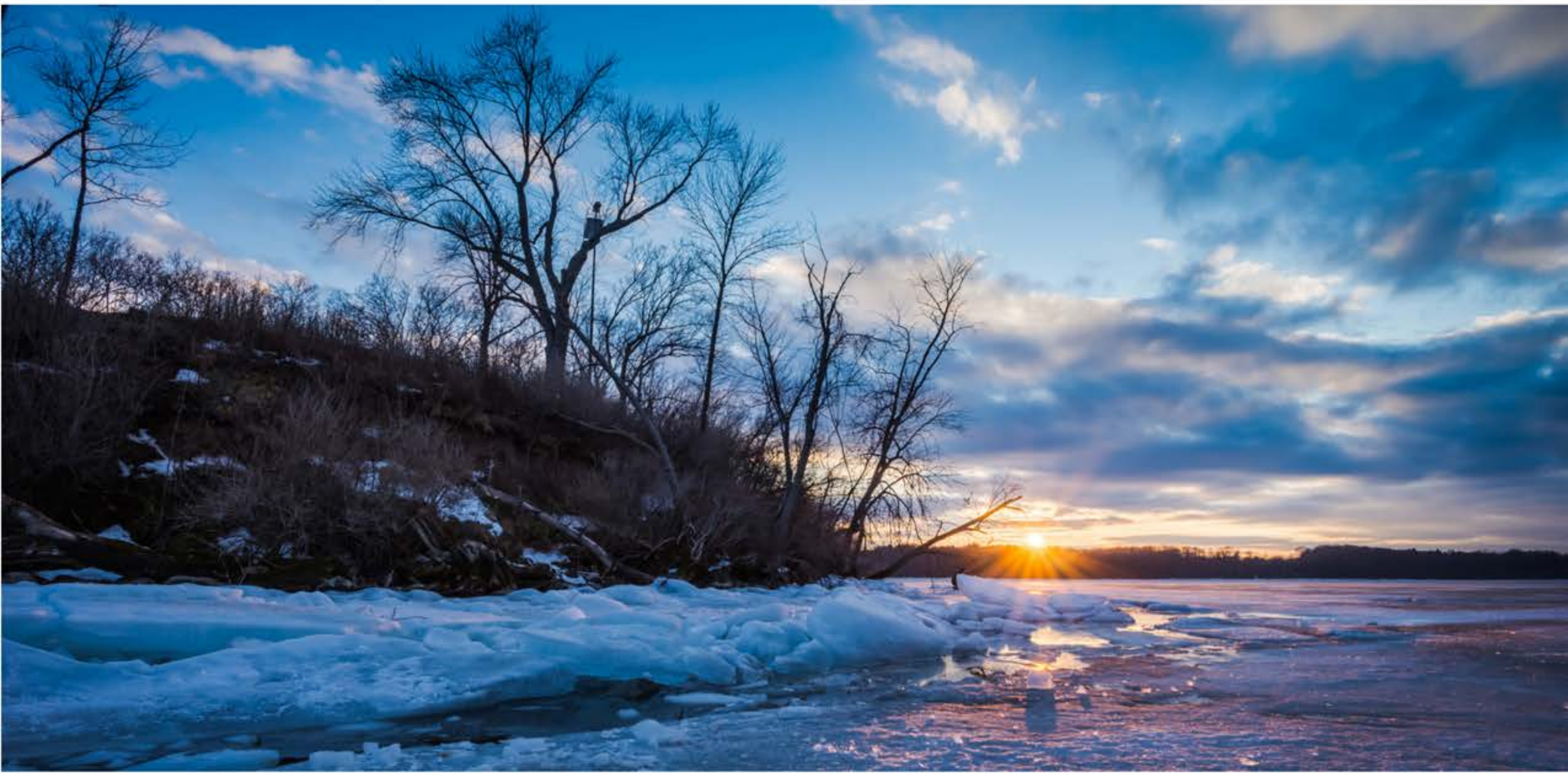
Our region has also seen frequent changes associated with the shifting temperature and climate patterns. Summer months with fewer warm days and extreme fluctuations in dry and wet periods have resulted in unpredictable weather patterns. This warming trend is bringing increases in the frequency of extreme storms and heavy rainfall events, leading to flooding and high winds that put our communities at risk. By the end of the century, these storms will probably be nearly twice as frequent throughout Wisconsin [2]. Throughout the Midwest, and in Madison, roads, wastewater facilities, bridges, and energy systems need upgrades to offset the increased risk of failure brought about by more frequent and intense storms. The existing quality of most Midwestern infrastructure currently ranges from C to D+, emphasizing their susceptibility to increased stressors associated with climate impacts [3]. The failure of these systems would not only be costly, but dangerous as well, cutting us from access to vital goods and services.

Sailboats on Lake Mendota near the University of Wisconsin-Madison

[2] Wisconsin Initiative on Climate Change Impacts. 2021. Wisconsin's Changing Climate - Impacts and solutions for a warmer climate. Retrieved from https://wicci.wisc.edu/2021-assessment-report/.
[3] U.S. Global Change Research Program. 2023. National Climate Assessment – Ch 24: Midwest. Retrieved from https://nca2023.globalchange.gov/chapter/24/.

Alongside the threats to human health and our community as a whole, the environment in and around Madison also faces challenges brought about by a shifting climate. Precipitation increases are expected to bring about more runoff events, deteriorating the water quality of drinking water sources we depend on through flooding and sewage spills. Increased precipitation and heat will provide harmful algal blooms with a hospitable environment [4] in Lake Mendota and Lake Monona, minimizing fishing and posing safety risks to recreational activities that can be done on the lakes.

It's clear that climate change puts our health, infrastructure, environment, and our economy at risk. In response, many communities in the United States have assumed responsibility for addressing climate change at the local level. Madison has invested in several initiatives to build community resilience to the impacts of climate change. Reducing fossil fuel use in the community should accompany these efforts, and can have many benefits in addition to reducing greenhouse gas emissions. These include decreased utility and transportation costs for residents and businesses due to improved efficiency, additional local jobs through retrofitted homes and businesses, and energy cost savings. With these benefits, residents are more likely to spend at local businesses and add to the local economy.



Ice cover along Madison's lake. Overall, the average number of days of ice cover on the Madison lakes has decreased by around 29-35 days over the past 150 years.
https://climatewisconsin.org/story/ice-cover.html

[4] U.S. Global Change Research Program. National Climate Assessment – Ch 24: Midwest.

Greenhouse Gas Inventory as a Step Toward Carbon Neutrality

Facing the climate crisis requires the concerted efforts of local governments and everyone close to the communities directly dealing with the impacts of climate change.

Cities, towns and counties are well placed to define coherent and inclusive plans and strategies for adaptation, resilience and mitigation. Existing targets and plans need to be reviewed to bring in the necessary level of ambition and outline how to achieve net-zero emissions by 2050 at the latest. Creating a roadmap for climate neutrality requires Madison to identify priority sectors for action, while considering climate justice, inclusiveness, local job creation and other benefits of sustainable development.

To complete this inventory, Madison contracted ICLEI - Local Governments for Sustainability (ICLEI), which provides authoritative direction for greenhouse gas emissions accounting and defines climate neutrality as follows:

> The targeted reduction of greenhouse gas (GHG) emissions and GHG avoidance in government operations and across the community in all sectors to an absolute net-zero emission level at the latest by 2050. In parallel to this, it is critical to adapt to climate change and enhance climate resilience across all sectors, in all systems and processes.

To achieve ambitious emissions reduction and move toward climate neutrality, Madison has set a goal of net-zero community-wide emissions by 2050 and should act rapidly following a holistic and integrated approach. Climate action is an opportunity for our community to experience a wide range of co-benefits, such as creating societal and economic opportunities, reducing poverty and inequality, and improving the health of people and nature.

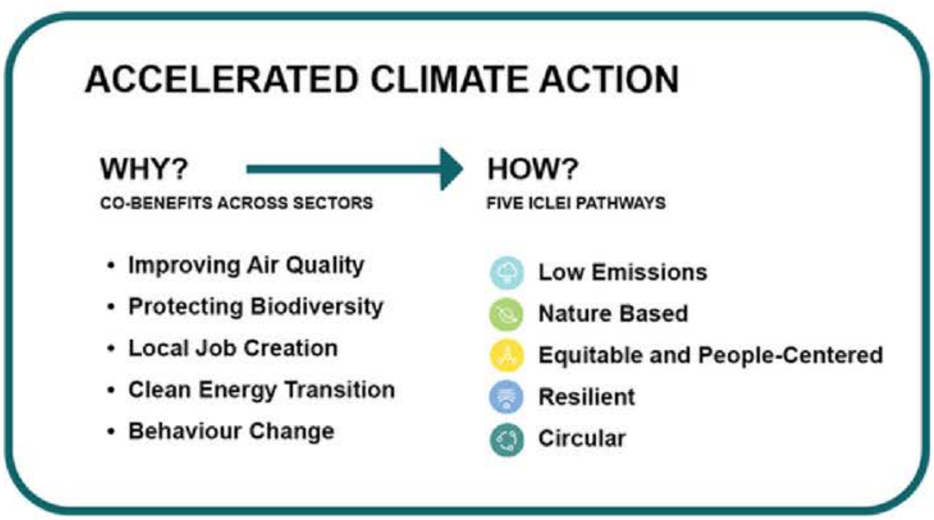


Figure 2: Co-benefits and ICLEI Pathways to Accelerated Climate Action

ICLEI Green Climate Cities Framework

For this inventory, ICLEI's process for quantifying Madison's emissions is informed by its Green Climate Cities Framework for integrated climate action. The City follows the stepwise approach shown below in Figure 3, which involves collecting and analyzing climate data, action, implementation, leadership, and collaboration—always with an equity lens.

The Framework is organized into Analyze, Act, and Accelerate phases for communities pursuing integrated climate action. The Framework incorporates greenhouse gas emissions reductions, climate adaptation actions, and equitable, inclusive decision-making. While Madison's inventory has Science-Based Targets [5] and falls under Step C- Analyze and set a baseline, the City has reached Step F - Implement and monitor through additional efforts beyond the scope of this project.

Over 600 U.S. communities have followed this basic Framework, previously known as ICLEI's Five Milestones for Emissions Management, and today, it is represented through the streamlined Analyze-Act-Accelerate model shown below.

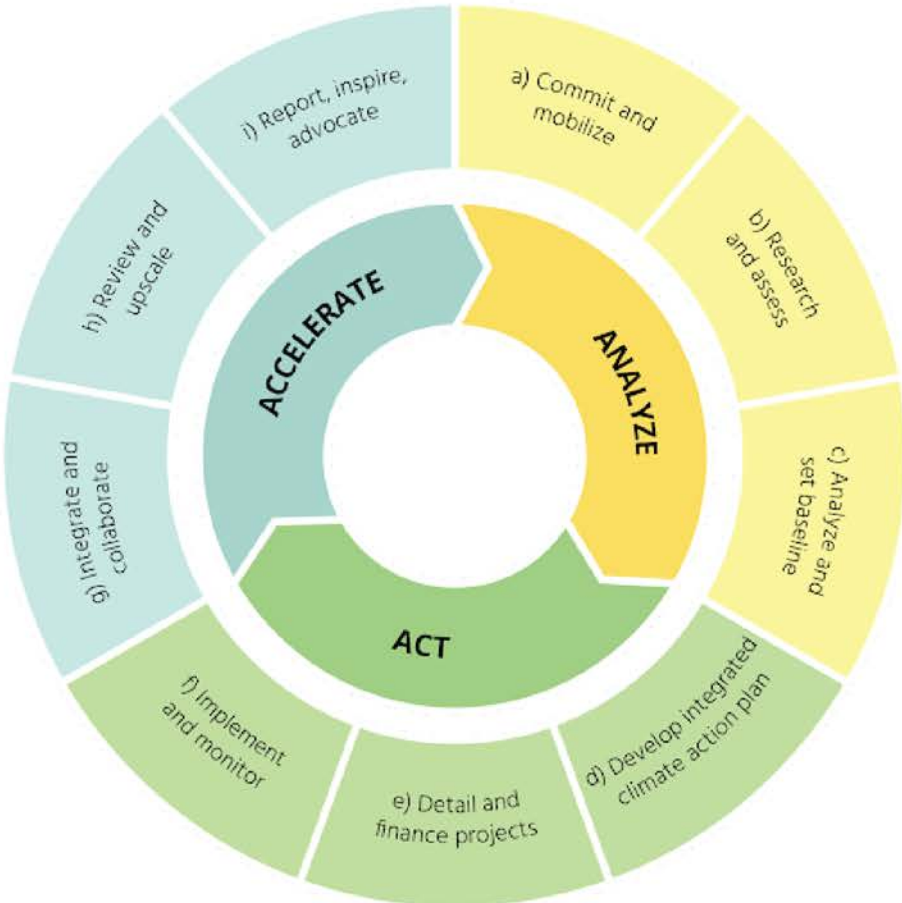


Figure 3: ICLEI Green Climate Cities Framework

[5] Science-Based Targets are calculated climate goals, in line with the latest climate science, that represent your community's fair share of the ambition necessary to meet the Paris Agreement commitment of keeping warming below 1.5°C. To achieve this goal, the Intergovernmental Panel on Climate Change (IPCC) states that we must reduce global emissions by 50% by 2030 and achieve climate neutrality by 2050. Equitably reducing global emissions by 50% requires that high-emitting, wealthy nations reduce their emissions by more than 50%.

Inventory Methodology

Understanding a Greenhouse Gas Emissions Inventory

The first step toward achieving tangible greenhouse gas (GHG) emission reductions requires identifying baseline emissions levels and sources and activities generating emissions in the community. This report presents emissions from the Madison community as a whole. The government operations inventory is mostly a subset of the community inventory, as shown in Figure 4. For example, data on commercial energy use by the community includes energy consumed by municipal buildings, and community vehicle-miles-traveled estimates include miles driven by municipal fleet vehicles.

Figure 4: Relationship of Community and Government Operations Inventories

As local governments continue to join the climate protection movement, the need for a standardized approach to quantify GHG emissions has proven essential. This inventory uses the approach and methods provided by the U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions (Community Protocol), discussed further on the following page.

See Table 1 for the carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) Global Warming Potentials (GWPs) from the IPCC 5th Assessment Report [6].

Table 1: Global Warming Potential Values (IPCC, 2014)

Greenhouse Gas	Global Warming Potential
Carbon Dioxide (CO2)	1
Methane (CH4)	28
Nitrous Oxide (N2O)	265

[6] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Community Emissions Protocol

Version 1.2 of the U.S. Community Protocol for Accounting and Reporting GHG Emissions [7] was released by ICLEI in 2019 and represents a national standard in guidance to help U.S. local governments develop effective community GHG emissions inventories. It establishes reporting requirements for all community GHG emissions inventories, provides detailed accounting guidance for quantifying GHG emissions associated with a range of emission sources and community activities, and provides a number of optional reporting frameworks to help local governments customize their community GHG emissions inventory reports based on their local goals and capacities.

The community inventory in this report includes emissions from the five Basic Emissions Generating Activities required by the Community Protocol. These activities are:

- Use of electricity by the community
- Use of fuel in residential and commercial stationary combustion equipment
- On-road passenger and freight motor vehicle travel
- Use of energy in potable water and wastewater treatment and distribution
- Generation of solid waste by the community

The community inventory also includes the following activities:

- Wastewater treatment processes
- Septic systems
- Use of fuel in industrial stationary combustion equipment
- Public transit, aviation, and rail travel
- Biologic treatment of solid waste
- Combustion and flaring of landfill gas

Quantifying Greenhouse Gas Emissions

Sources and Activities

Communities contribute to greenhouse gas emissions in many ways. Two central categorizations of emissions are used in the community inventory: 1) GHG emissions that are produced by "sources" located within the community boundary, and 2) GHG emissions produced as a consequence of community "activities."

Table 2: Source vs. Activity for Greenhouse Gas Emissions (GHG)

Source	Activity
Any physical process inside the jurisdictional boundary that releases GHG emissions into the atmosphere.	The use of energy, materials, and/or services by members of the community that result in the creation of GHG emissions.

[7] ICLEI. 2012. US Community Protocol for Accounting and Reporting Greenhouse Gas Emissions. Retrieved from http://www.icleiusa.org/tools/ghg-protocol/community-protocol

By reporting on both GHG emissions sources and activities, local governments can develop and promote a deeper understanding of GHG emissions in their communities. A purely source-based emissions inventory could be summed to estimate total emissions released within the community's jurisdictional boundary. In contrast, a purely activity-based emissions inventory could provide perspective on the efficiency of the community, even when the associated emissions occur outside the jurisdictional boundary. The division of emissions into sources and activities replaces the scopes framework that is used in government operations inventories, as the scopes framework does not have a clear definition for application to community inventories.

Base Year

The inventory process requires the selection of a base year with which to compare current emissions. Madison's community GHG emissions inventory utilizes 2018 as its baseline year, as it provides a recent year for which data is available and is the start year of the business-as-usual forecast.

Quantification Methods

GHG emissions can be quantified in two ways:

- Measurement-based methodologies refer to the direct measurement of GHG emissions (from a monitoring system) emitted from a flue of a power plant, wastewater treatment plant, landfill, or industrial facility.
- Calculation-based methodologies calculate emissions using activity data and emission factors. To calculate emissions accordingly, the basic equation below is used:

Activity Data x Emission Factor = Emissions

Most emissions sources in this inventory are quantified using calculation-based methodologies. Activity data refers to the relevant measurement of energy use or other GHG-generating processes such as fuel consumption by fuel type, metered annual electricity consumption, and annual vehicle miles traveled. Please see the appendices for a detailed listing of the activity data used in composing this inventory.

Known emission factors are used to convert energy usage or other activity data into associated quantities of emissions. Emissions factors are usually expressed in terms of emissions per unit of activity data (e.g. lbs CO_2/kWh of electricity). For this inventory, calculations were made using ICLEI's ClearPath Climate Planner tool [8].

[8] ICLEI's ClearPath Climate Planner tool is the leading online software for completing greenhouse gas inventories, forecasts, climate action plans, and monitoring at community-wide or government-operations scales. The software allows for local governments to track direct and indirect emissions from energy, transportation, waste, consumption, and forests and trees. Emissions are entered under the guidance of different protocol options, including the U.S. Community Protocol, Global Protocol for Community-scale Greenhouse Gas Inventories, or Local Government Operations Protocols.

Community Emissions Inventories Results

The total community-wide emissions for the 2018 and 2022 inventories are shown in Table 3 and Figures 5 and 6.

Table 3: 2018 and 2022 Community-wide Emissions Inventories

Sector	Fuel or Source	2018 Usage	2022 Usage	Usage Unit	2018 Emissions (MT CO2e)	2022 Emissions (MT CO2e)	% Change (MT CO2e)
Residential Energy	Electricity - MG&E	572,601,784	585,818,271	kWh	426,307	393,263	-7.75%
	Electricity - Alliant	155,322,170	167,678,343	kWh	111,768	88,416	-20.89%
	Natural Gas - MG&E	56,900,296	56,825,703	Therms	302,633	302,236	-0.13%
	Natural Gas - Alliant	90,933	86,515	Therms	484	460	-4.96%
	Distillate Fuel Oil No. 2	77,320	63,467	MMBtu	5,757	4,726	-17.91%
	Propane	181,973	259,769	MMBtu	11,293	16,121	42.75%
	Wood	166,824	46,322	MMBtu	1,662	461	-72.26%
Residential Energy Total					**859,904**	**805,683**	**-6.31%**
Commercial Energy	Electricity - MG&E	1,613,279,463	1,634,207,147	kWh	1,201,099	1,097,053	-8.66%
	Electricity - Alliant	176,883,048	161,944,318	kWh	127,283	85,393	-32.91%
	Natural Gas - MG&E	112,413,044	111,515,384	Therms	597,886	593,111	-0.80%
	Natural Gas - Alliant	279	254	Therms	1	1	-0.00%
	Distillate Fuel Oil No. 2	328,595	346,278	MMBtu	24,466	25,783	5.38%
	Propane	488,451	537,642	MMBtu	30,313	33,365	10.07%
	Wood	444,047	428,291	MMBtu	4,423	4,266	-3.55%

Table 3: 2018 and 2022 Community-wide Emissions Inventories (Continued)

Sector	Fuel or Source	2018 Usage	2022 Usage	Usage Unit	2018 Emissions (MT CO2e)	2022 Emissions (MT CO2e)	% Change (MT CO2e)
Commercial Energy	Coal	44,405		MMBtu	4,266		
Commercial Energy Total					**1,989,737**	**1,838,972**	**-7.58%**
Industrial Energy	Electricity - MG&E	151,265,613	133,393,672	kWh	112,618	89,548	-20.49%
	Electricity - Alliant	103,674,475	95,521,269	kWh	74,603	50,368	-32.49%
	Natural Gas - MG&E	6,034,324	6,471,869	Therms	32,027	34,349	7.25%
	Distillate Fuel Oil No. 1 - Blount Street	420	292	Gallons	4	3	-25.00%
	Distillate Fuel Oil No. 2 - Charter Street	96,675	522,964	Gallons	990	5,357	441.11%
	Distillate Fuel Oil No. 2 - Walnut Street	1,753	429	Gallons	18	4	-77.78%
Industrial Energy Total					**220,260**	**179,629**	**-18.45%**
Transportation & Mobile Sources	Gasoline - On Road	1,816,215,478	1,634,236,501	VMT	749,736	658,868	-12.12%
	Diesel - On Road	193,761,811	195,255,160	VMT	289,698	281,231	-2.92%
	Gasoline - Offroad	510,015	511,228	VMT	36,133	36,219	0.24%
	Diesel - Offroad	1,677,357	1,681,372	MMBtu	124,064	124,361	0.24%
	CNG - Offroad	21,900	21,953	MMBtu	1,162	1,165	0.26%
	LPG - Offroad	174,693	175,116	MMBtu	10,741	10,767	0.24%
	Gasoline - Union Cab	108,833	65,238	Gallons	964	577	-40.15%

Table 3: 2018 and 2022 Community-wide Emissions Inventories (Continued)

Sector	Fuel or Source	2018 Usage	2022 Usage	Usage Unit	2018 Emissions (MT CO2e)	2022 Emissions (MT CO2e)	% Change (MT CO2e)
Transportation & Mobile Sources	Diesel - Metro Transit	1,227,847	989,509	Gallons	12,539	10,105	-19.41%
	Diesel - Canadian Pacific	230	230	MMBtu	17	17	0.00%
	Diesel - Wisconsin & Southern	15,299	15,299	MMBtu	1,141	1,141	0.00%
	Jet Kerosene - Dane County Regional Airport	1,600,000	1,600,000	Gallons	15,652	15,652	0.00%
	Aviation Gasoline - Dane County Regional Airport	225,001	80,000	Gallons	1,876	667	-64.45%
Transportation & Mobile Sources Total					**1,243,723**	**1,140,770**	**-8.28%**
Solid Waste	Methane - Demetral Landfill (Closed)	7	7	Pounds	0.00000085960	0.00000085960	0.00%
	Methane - Sycamore Landfill (Closed)	0.0003	0.0003	Pounds	0.0000038612	0.0000038612	0.00%
	Methane - Olin Landfill (Closed)	0.0001	0.0001	Pounds	0.0000016856	0.0000016856	0.00%
	Methane - Mineral Point Landfill (Closed)	0.00008	0.00008	Pounds	0.000001036	0.000001036	0.00%
	Methane - Greentree Landfill (Closed)	0.0003	0.0003	Pounds	0.0000035084	0.0000035084	0.00%

Table 3: 2018 and 2022 Community-wide Emissions Inventories (Continued)

Sector	Fuel or Source	2018 Usage	2022 Usage	Usage Unit	2018 Emissions (MT CO2e)	2022 Emissions (MT CO2e)	% Change (MT CO2e)
Solid Waste	Combustion of Landfill Gas - Rodefeld Landfill	813,669,278	324,489,031	Cubic Feet / Year	109	12	-88.99%
	In-jurisdiction Landfills - Rodefeld Landfill	1,240	1,084	Metric Tons CH4	34,717	30,353	-12.57%
	In-jurisdiction Landfills - WM Madison Prairie Landfill	13	13	Metric Tons Ch4	370	370	0.00%
	Biowaste Composting - Earth Stew	30	23	Tons	5	4	-20.00%
	Biowaste Composting - Curbside Composter	4,339	4,339	Tons	767	767	0.00%
	Biowaste Composting - Streets Division		5	Tons		1	
	Green Waste Composting - Streets Division	18,472	18,422	Tons	2,604	2,597	-0.27%
Solid Waste Total					**38,572**	**34,104**	**-11.58%**

Table 3: 2018 and 2022 Community-wide Emissions Inventories (Continued)

Sector	Fuel or Source	2018 Usage	2022 Usage	Usage Unit	2018 Emissions (MT CO2e)	2022 Emissions (MT CO2e)	% Change (MT CO2e)
Water & Wastewater	Supply of Potable Water - Madison Water Utility (MG&E)	17,655,672 / 70,152	17,762,259 / 80,427	kWh / Therms	13,518	12,352	-8.63%
	Supply of Potable Water - Madison Water Utility (Alliant)	3,458,685	3,438,199	kWh	2,489	1,813	-27.16%
	Wastewater Treatment Energy Use - Madison Metropolitan Sewerage District	33,860,320 / 789,495	32,535,735 / 888,410	kWh / Therms	29,408	26,567	-9.66%
	In-boundary Process N2O from Wastewater Treatment - Madison Metropolitan Sewerage District	261,600	261,600	People Served	607	607	0.00%
	Imported Process N2O from Wastewater Treatment - Madison Metropolitan Sewerage District	162,400	162,400	People Served	377	377	0.00%

Table 3: 2018 and 2022 Community-wide Emissions Inventories (Continued)

Sector	Fuel or Source	2018 Usage	2022 Usage	Usage Unit	2018 Emissions (MT CO2e)	2022 Emissions (MT CO2e)	% Change (MT CO2e)
Water & Wastewater	In-boundary Process N2O from Effluent Discharge - Madison Metropolitan Sewerage District	261,600	261,600	People Served	1,904	1,904	0.00%
	Imported Process N2O from Effluent Discharge - Madison Metropolitan Sewerage District	162,400	162,400	People Served	1,182	1,182	0.00%
	In-boundary Combustion of Digester Gas - Madison Metropolitan Sewerage District	534,923	534,923	scf / Day	0.30917	0.30917	0.00%
	Imported Combustion of Digester Gas - Madison Metropolitan Sewerage District	332,077	332,077	scf / Day	0.19193	0.19193	0.00%
	In-boundary Flaring of Digester Gas - Madison Metropolitan Sewerage District	43,065	43,065	Cubic Feet / Day	0	0	0.00%

Table 3: 2018 and 2022 Community-wide Emissions Inventories (Continued)

Sector	Fuel or Source	2018 Usage	2022 Usage	Usage Unit	2018 Emissions (MT CO2e)	2022 Emissions (MT CO2e)	% Change (MT CO2e)
Water & Wastewater	Imported Flaring of Digester Gas - Madison Metropolitan Sewerage District	26,735	26,735	Cubic Feet / Day	0	0	0.00%
	Septic Systems	130	130	People Served	16	16	0.00%
Water & Wastewater Total					**49,501**	**44,818**	**-9.46%**
Agriculture, Forestry, and Other Land Use (AFOLU)	Electricity - Alliant	959,443	806,472	kWh	690	425	-38.41%
Agriculture, Forestry, and Other Land Use Total					**690**	**425**	**-38.41%**
Process & Fugitive Emissions	Fugitive Emissions from Natural Gas Distribution - MG&E	175,417,816	174,893,383	Therms	30,434	30,343	0.00%
	Fugitive Emissions from Natural Gas Distribution - Alliant	86,769	86,769	Therms	15	15	0.00%
	Hydrofluroca rbon & Refrigerant Emissions - R-410a	0.4120603186 2	0.401347601	Metric Tons	711	692	-2.67%
	Hydrofluroca rbon & Refrigerant Emissions - R-134a	0.0281227	0.0281227	Metric Tons	37	37	0.00%

Table 3: 2018 and 2022 Community-wide Emissions Inventories (Continued)

Sector	Fuel or Source	2018 Usage	2022 Usage	Usage Unit	2018 Emissions (MT CO2e)	2022 Emissions (MT CO2e)	% Change (MT CO2e)
Process & Fugitive Emissions	Hydrofluroc arbon & Refrigerant Emissions - R-22	0.0606594746306	0.0456909264206	Metric Tons	107	80	-25.23%
Process & Fugitive Emissions Total					**31,304**	**31,167**	**-0.44%**
Total Gross Emissions					**4,433,691**	**4,075,568**	**-8.08%**

*Blank cells are a result of variability in the format of available data by sector and fuel or source type.

Figure 5 and 6 show the distribution of community-wide emissions by sector. Commercial Energy is the largest contributor, followed by Transportation & Residential Energy.

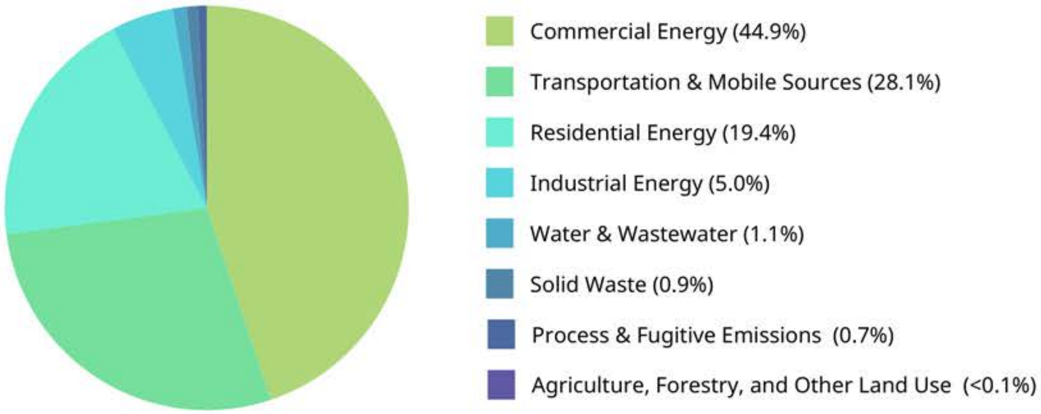


Figure 5: 2018 Community-wide Emissions by Sector

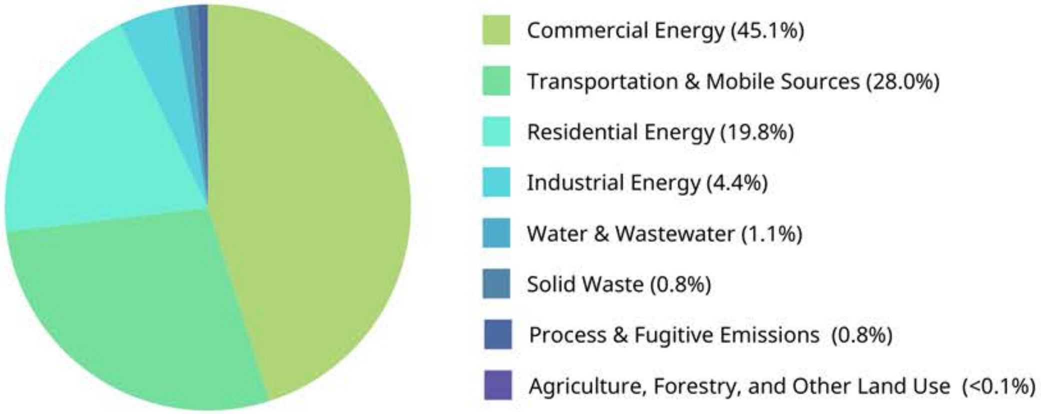


Figure 6: 2022 Community-wide Emissions by Sector

Next Steps

The inventory should be used to focus and prioritize actions to reduce emissions. Based on the inventory results, the following areas have the greatest potential for emissions reduction:

- Energy
  - Electrification of residential and commercial non-electricity fuels
  - Improved efficiency of residential and commercial buildings and appliances
- Transportation
  - General vehicle miles traveled reduction of gasoline and diesel on-road transportation (additional public transit infrastructure, more bike paths, etc.)
  - Increased electric vehicle adoption for gasoline and diesel travel

Completion of another GHG inventory in two to five years is recommended to assess progress resulting from any actions implemented, and Madison plans to do so every four. The detailed methodology section of this report, as well as notes and attached data files in the ClearPath Climate Planner tool provided to the Madison, will be helpful to complete a future inventory consistent with this one.

Students board Madison Metro along University Avenue

Greenhouse Gas Emissions Forecasts

Madison's most recent community-wide greenhouse gas (GHG) inventory includes emissions from activities and sources that took place within the city during the 2018 and 2022 calendar years. Using the 2018 GHG inventory as a baseline, ICLEI prepared a basic "business-as-usual" forecast for 2030.

Business-As-Usual (BAU) Forecast

The BAU forecast (Figure 7) is a projection of emissions through the year 2030. The projected emissions estimated population growth [9], changes in automotive fuel efficiency standards [10], and changes to the carbon intensity of grid electricity [11].

Madison's 2018 emissions were 4,433,691 metric tons carbon dioxide equivalent (MT CO2e). Based on population growth, increasing on-road vehicle fuel efficiency, and utility decarbonization plans, Madison's 2030 emissions will be 3,008,971 MT CO2e. This is a 32.1% reduction in emissions.

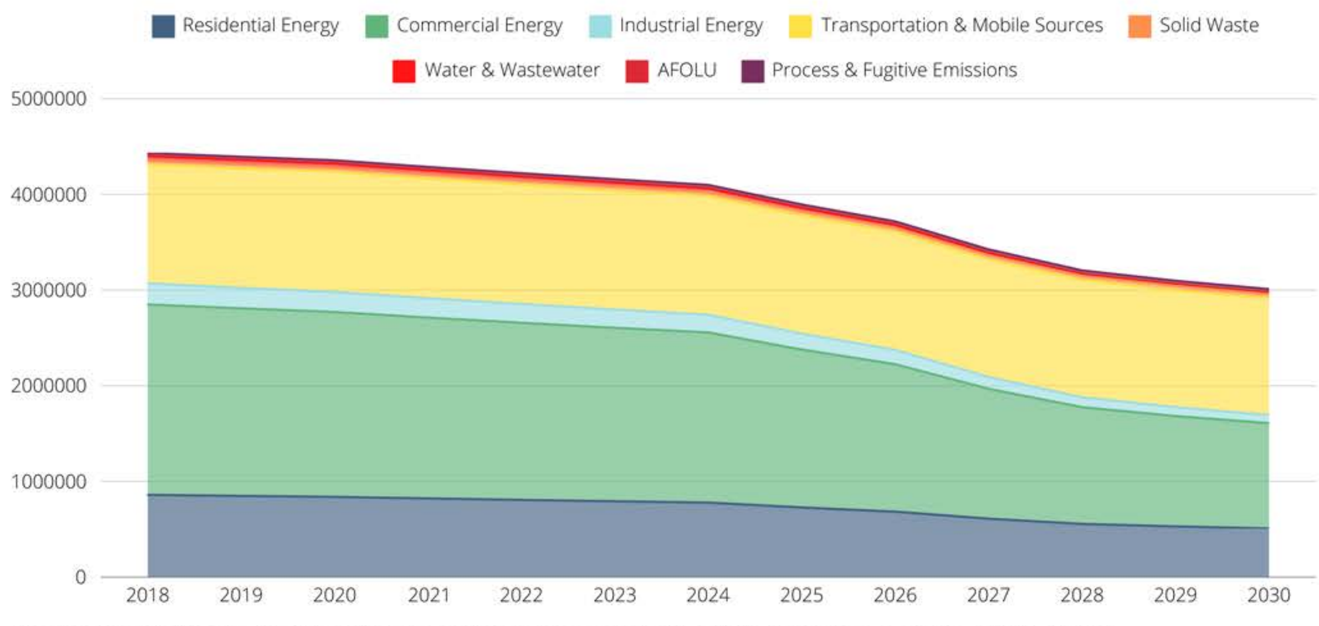


Figure 7: Business-As-Usual Forecast for Community-wide Emissions from 2018-2030

[9] Imagine Madison. 2023. City of Madison Comprehensive Plan. Retrieved from https://www.cityofmadison.com/dpced/planning/documents/2023_Comprehensive_Plan_Part1.pdf

[10] ICLEI's Carbon Intensity Reference Sheet

[11] Gagnon, Pieter, Brady Cowiestoll, and Marty Schwarz. 2023. Cambium 2022 Scenario Descriptions and Documentation. Retrieved from https://www.nrel.gov/docs/fy23osti/84916.pdf

Conclusion

This inventory marks the completion of Step C of the ICLEI GreenClimateCities Framework, though additional steps by the City of Madison place its progress at Step F - Implement and monitor. The next step is to build upon the existing Madison initiatives with a more robust climate action plan that identifies specific quantified strategies that can cumulatively meet that target.

The Intergovernmental Panel on Climate Change (IPCC) states that to meet the Paris Agreement commitment of keeping warming below 1.5°C we must reduce global emissions by 50% by 2030 and reach climate neutrality by 2050. Equitably reducing global emissions by 50% requires that high-emitting, wealthy nations reduce their emissions by more than 50%. More than ever, it is imperative that countries, regions, and local governments set targets that are ambitious enough to slash carbon emissions between now and mid-century. In line with global efforts, the City of Madison's 2050 Science-Based Targets are 100% renewable energy and net-zero carbon emissions for community-wide operations [12].

Science-Based Targets (SBTs) are calculated climate goals, in line with the latest climate science, that represent a community's fair share of the global ambition necessary to meet the Paris Agreement commitment [13]. Community education, involvement, and partnerships will be instrumental to achieve a science-based target. Using its 2005 baseline, the City of Madison calculated its 2050 community-wide emissions goal, and is maintaining that same target with addition of the newer inventories. ICLEI generally encourages cities to adopt 2030 SBTs. However these are often very ambitious given the short time frame, and is why Madison has decided to continue using its 2050 target.

Science-Based Targets are climate goals in line with the latest climate science. They represent the city's fair share of the ambition necessary to meet the Paris Agreement commitment to keep warming below 1.5°C.

In addition, Madison will continue to track key energy use and emissions indicators on an on-going basis. It is recommended that communities update their inventories regularly, especially as plans are implemented to ensure measurement and verification of impacts. Regular inventories also allow for "rolling averages" to provide insight into sustained changes and can help reduce the change of an anomalous year being incorrectly interpreted. This inventory shows that commercial energy, as well as transportation patterns and residential energy will be particularly important to focus on. Through these efforts and others, Madison can achieve environmental, economic, and social benefits beyond reducing emissions.

Solar lighting along the Campus Drive bicycle path

[12] City of Madison Sustainability & Resilience. 2024. Climate. Retrieved from https://www.cityofmadison.com/sustainability/climate
[13] "Science Based Climate Targets: A Guide for Cities." Science Based Targets Network, November 4, 2021. https://sciencebasedtargetsnetwork.org/.

Appendix: Methodology Details

Energy

Table 4: Energy Data Sources

Activity	Data Source	Data Gaps/Assumptions
Residential Electricity	Madison Gas & Electric; Alliant Energy	N/A
Commercial Electricity	Madison Gas & Electric; Alliant Energy	N/A
Industrial Electricity	Madison Gas & Electric; Alliant Energy	N/A
Residential Natural Gas	Madison Gas & Electric; Alliant Energy	N/A
Commercial Natural Gas	Madison Gas & Electric; Alliant Energy	N/A
Industrial Natural Gas	Madison Gas & Electric	N/A

Table 5: MG&E + MROE (2018 + 2022) Emissions Factors for Electricity Consumption

Emissions Factor/ Year	CO2 (lbs./MWh)	CH4 (lbs./GWh)	N2O (lbs./GWh)	Data Gaps and Assumptions
Madison Gas and Electric + eGrid 2018	1630	169	25	MG&E only provided CO2 factors - eGrid used for CH4 and N2O
Madison Gas & Electric + eGrid 2021 (Proxy for 2022)	1470	148		MG&E only provided CO2 factors - eGrid used for CH4 and N2O

Table 6: Alliant Energy (2018 + 2022) Emissions Factors for Electricity Consumption

Emissions Factor/ Year	CO2 (lbs./MWh)	CH4 (lbs./GWh)	N2O (lbs./GWh)	Data Gaps and Assumptions
Alliant Energy (Wisconsin Power & Light) 2018	1580	40	20	From Wisconsin Power and Light Electric Utility Supplier-Specific Customer Data
Alliant Energy (Wisconsin Power & Light) 2022	1159	30	10	From Wisconsin Power and Light Electric Utility Supplier-Specific Customer Data

Transportation

Table 7: Transportation Data Sources

Activity	Data Source	Data Gaps/Assumptions
On-Road Transportation	Google Environmental Insights Explorer (EIE)	N/A
Off-Road Transportation	Environmental Protection Agency National Emissions Inventory (EPA NEI)	Other used as a default for all sectors; Small utility used as a default for all equipment; Fuel use estimated by dividing total CO2e by emissions factors to ouput actvity data for ClearPath
Public Transit	Union Cab; Metro Transit	Union Cab exclusively uses priuses and vans - assume all passenger vehicles and gasoline for fuel type; Metro Transit only runs 40' diesel buses for these years - assume all transit buses
Rail	Environmental Protection Agency National Emissions Inventory (EPA NEI); Google Maps; Wisconsin & Southern Railroad	2020 NEI data instead of 2017 NEI data used for 2018 as rail emissions were not quantified; Track lengths estimated based on track ownership information; Track length ratio of Madison to Dane County used for local attribution; Fuel use estimated by dividing total CO2e by emissions factors to ouput actvity data for ClearPath
Aviation	Dane County Regional Airport	2022 data used for 2018 per City of Madison's request due to a lack of specificity with fuel data provided

For vehicle transportation, it is necessary to apply average miles per gallon and emissions factors for CH4 and N2O to each vehicle type. The factors used are shown in Table 9.

Table 8: MPG and Emissions Factors by Vehicle Type

Fuel	Vehicle Type	MPG	CH4 (g/mile)	N2O (g/mile)
		2018		
Gasoline	Passenger car	24.37713	0.0186	0.0093
	Light truck	17.86788	0.0201	0.0167
	Heavy truck	5.365653	0.086	0.0664
	Motorcycle	24.37713	0.0186	0.0093
Diesel	Passenger car	24.37713	0.0005	0.001
	Light truck	17.86788	0.001	0.0015
	Heavy truck	6.307708	0.0051	0.0048

Table 8: MPG and Emissions Factors by Vehicle Type (Continued)

Fuel	Vehicle Type	MPG	CH4 (g/mile)	N2O (g/mile)
2021 (Proxy for 2022)				
Gasoline	Passenger car	25.3	0.0084	0.0069
	Light truck	18.2	0.0117	0.0087
	Heavy truck	5.383557	0.0719	0.0611
	Motorcycle	44	0.0084	0.0069
Diesel	Passenger car	25.3	0.0005	0.001
	Light truck	18.2	0.001	0.0015
	Heavy truck	6.561615	0.0051	0.0048

Wastewater

Table 9: Wastewater Data Sources

Activity	Data Source	Data Gaps/Assumptions
Wastewater Treatment Energy Use	Madison Metropolitan Sewerage District	Includes natural gas purchased from MGE (23,493,225 kWh) as well as recovered/generated onsite
Process N2O from Wastewater Treatment	Madison Metropolitan Sewerage District	Madison Metropolitan Sewerage District crosses Madison and Monona - data divided between in-boundary and imported populations served accordingly
Process N2O from Effluent Discharge	Madison Metropolitan Sewerage District	Serve 25 owner communities - data divided between in-boundary and imported populations served accordingly
Combustion of Digester Gas	Madison Metropolitan Sewerage District	Data divided between in-boundary and imported populations served
Flaring of Digester Gas	Madison Metropolitan Sewerage District	Data divided between in-boundary and imported populations served
Septic Systems	City of Madison	Number of accounts used for population served

Potable Water

Table 10: Potable Water Data Sources

Activity	Data Source	Data Gaps/Assumptions
Supply of Potable Water	Madison Gas & Electric; Alliant Energy	N/A

Solid Waste

Table 11: Solid Waste Data Sources

Activity	Data Source	Data Gaps/Assumptions
Landfilled Waste	City of Madison Streets Division; WM Waste Management; Environmental Protection Agency Facility Level GHG Emissions Data (EPA FLIGHT)	WM Waste Management landfill does not accept municipal solid waste, so assume emissions are entirely lumber associated with construction & demolition
Biologic Treatment of Waste	City of Madison Streets Division; Curbside Composter; Earth Stew	City of Madison Streets Division unsure of how many tons it collects from backyard composters;
In-jurisdiction Landfills	City of Madison Engineering Division	All city-owned landfills are closed
Combustion of Landfill Gas	EPA FLIGHT	Average of high heat value across 12 months used to determine heat content

Agriculture, Forestry and Other Land Use (AFOLU)

Table 12: Agriculture, Forestry, and Other Land Use Data Sources

Activity	Data Source	Data Gaps/Assumptions
Community-wide		
Agricultural Electricity	Alliant Energy	N/A

Fugitive Emissions

Table 13: Fugitive Emissions Data Sources

Activity	Data Source	Data Gaps/Assumptions
Fugitive Emissions from Natural Gas DIstribution	Madison Gas & Electric; Alliant Energy	N/A
Hydrofluorocarbon & Refrigerant Emissions	City of Madion	N/A

Inventory Calculations

The 2018 and 2022 inventory was calculated following the US Community Protocol and ICLEI's ClearPath Climate Planner Climate Planner software. As discussed in Inventory Methodology, the IPCC 5th Assessment was used for global warming potential (GWP) values to convert methane and nitrous oxide to CO2 equivalent units. ClearPath Climate Planner's inventory calculators allow for input of the sector activity (i.e. kWh or VMT) and emission factor to calculate the final carbon dioxide equivalent (CO2e) emissions.

Madison residents relaxing along Lake Mendota